TOTAL MAXIMUM DAILY LOADS (TMDLs)

FOR THE

LOWER RIO CHAMA WATERSHED
(BELOW EL VADO RESERVOIR TO THE CONFLUENCE WITH THE RIO GRANDE)

June 2004

Table of Contents

List of Figures

List of Tables

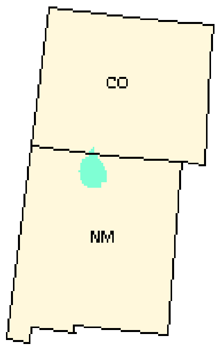
ABBREVIATIONS

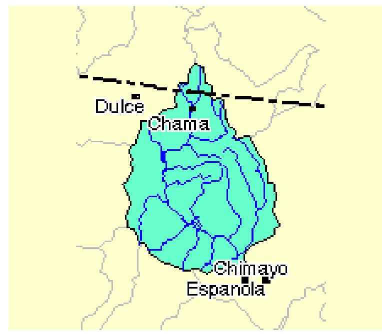
20.6.4 NMAC	New Mexico Water Quality Standards (as amended through October 11, 2002)
4Q3	4-day, 3-year low flow frequency
BMP	Best Management Practice
cfs	cubic feet per second
cfu	colony forming units
CBODu	carbonaceous biochemical oxygen demand
CWA	Clean Water Act
CWAP	Clean Water Action Plan
CWF	coldwater fishery
FC	Fecal Coliform
HQCWF	high quality coldwater fishery
$J/m^2/s$	joules/meters squared/second
LA	load allocation
LCD	Local Climatological Data
MGD	million gallons per day
mg/L	milligrams per liter
MOS	margin of safety
MOU	memorandum of understanding
NMAC	New Mexico Administrative Code
NMED	New Mexico Environment Department
NMDGF	New Mexico Department of Game and Fish
NMSU	New Mexico State University
NPDES	National Pollutant Discharge Elimination System
NPS	nonpoint source
NTU	nephelometric turbidity units
QAPP	quality assurance project plan
SSTEMP	Stream Segment Temperature Model
SWQB	Surface Water Quality Bureau
TMDL	total maximum daily load
TSS	total suspended solids
TBODu	total ultimate biochemical oxygen demand
USDA	U.S. Department of Agriculture
USDI	U.S. Department of Interior
USEPA	U. S. Environmental Protection Agency
USFS	United States Forest Service
USGS	U.S. Geological Survey
UWA	Unified Watershed Assessment
WLA	waste load allocation
WMP	watershed management plan
WQLS	water quality limited segment
WQCC	New Mexico Water Quality Control Commission
WQS	water quality standards (NMAC 20.6.4 as amended through October 11, 2002)

WWTP	wastewater treatment plant

TOTAL MAXIMUM DAILY LOAD SUMMARY TABLES

TOTAL MAXIMUM DAILY LOAD FOR TURBIDITY, CHRONIC ALUMINUM, AND FECAL COLIFORM IN CAÑONES CREEK

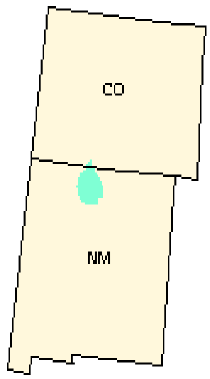




Summary Table

New Mexico Standards Segment	Rio Grande, 20.6.4.119 (formerly 2116)
Waterbody Identifier	Cañones Creek (Abiquiu Reservoir to headwaters), NM-2116.A_010, 17.44 mi.
Parameters of Concern	Turbidity Chronic aluminum Fecal Coliform
Use Affected	High quality coldwater fishery
Geographic Location	Rio Chama USGS Hydrologic Unit Code 13020102
Scope/Size of Watershed	TMDL area: 84 square mile
Land Type	Ecoregions: Southern Rockies and Arizona/New Mexico Plateau
Land Use/Cover	Forest (67 percent) and Rangeland (33 percent)
Identified Sources	Turbidity: Rangeland, Silviculture, Removal of Riparian Vegetation, Streambank Modification/Destabilization Chronic aluminum: Natural and Unknown Fecal Coliform: Rangeland and Land Disposal (on-site wastewater systems)
Watershed Ownership	Forest Service (94 percent) and Private (6 percent)
Priority Ranking	3
Threatened and Endangered Species	None
TMDL for: Turbidity (as TSS) Chronic aluminum Fecal Coliform	 WLA (0) + LA (1,618) + MOS (540)= **2,158 lbs/day** WLA (0) + LA (4) + MOS (1)= **5 lbs/day** WLA (0) + LA (2.5 x 10^{10}) + MOS (1.3 x 10^{9})= **2.629 x 10^{10} cfu/day**

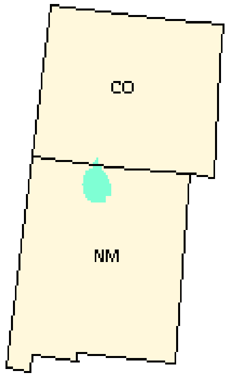
TOTAL MAXIMUM DAILY LOAD FOR TURBIDITY IN THE RIO NUTRIAS



Summary Table

New Mexico Standards Segment	Rio Grande, 20.6.4.119 (formerly 2116)
Waterbody Identifier	Rio Nutrias (Rio Chama to headwaters), NM-2116.A_060, 34.63 mi.
Parameters of Concern	Turbidity
Use Affected	High quality coldwater fishery
Geographic Location	Rio Chama USGS Hydrologic Unit Code 13020102
Scope/Size of Watershed	TMDL area: 106 square mile
Land Type	Ecoregions: Southern Rockies and Arizona/New Mexico Plateau
Land Use/Cover	Forest (66 percent) and Rangeland (34 percent)
Identified Sources	Agriculture (irrigated crop production), Rangeland, Removal of Riparian Vegetation, Streambank Modification/Destabilization
Watershed Ownership	Private (74 percent), Forest Service (12 percent), Bureau of Land Management (10 percent), State (2 percent), and State Game and Fish (2 percent)
Priority Ranking	4
Threatened and Endangered Species	None
TMDL for: Turbidity (as TSS)	WLA (0) + LA (6,125) + MOS (2,042)= **8,167 lbs/day**

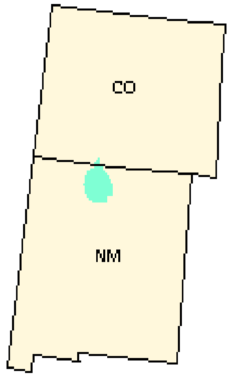
TOTAL MAXIMUM DAILY LOAD FOR
TURBIDITY IN POLEO CREEK



Summary Table

New Mexico Standards Segment	Rio Grande, 20.6.4.119 (formerly 2116)
Waterbody Identifier	Poleo Creek (Rio Puerco de Chama to headwaters), NM-2116.A_023, 12.16 mi.
Parameters of Concern	Turbidity
Use Affected	High quality coldwater fishery
Geographic Location	Rio Chama USGS Hydrologic Unit Code 13020102
Scope/Size of Watershed	TMDL area: 47 square mile
Land Type	Ecoregion: Southern Rockies
Land Use/Cover	Forest (71 percent) and Rangeland (29 percent)
Identified Sources	Agriculture, Removal of Riparian Vegetation, Streambank Modification/Destabilization
Watershed Ownership	Forest Service (80 percent) and Private (20 percent)
Priority Ranking	4
Threatened and Endangered Species	None
TMDL for: Turbidity (as TSS)	WLA (0) + LA (124) + MOS (41)= **165 lbs/day**

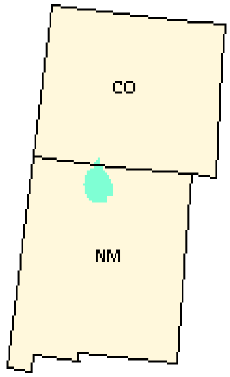
TOTAL MAXIMUM DAILY LOAD FOR TEMPERATURE IN POLVADERA CREEK

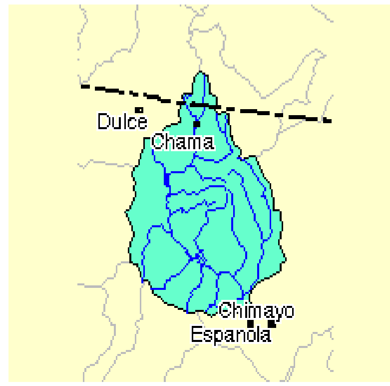


Summary Table

New Mexico Standards Segment	Rio Grande, 20.6.4.119 (formerly 2116)
Waterbody Identifier	Polvadera Creek (Cañones Creek to headwaters), NM-2166.A011, 13.94 mi.
Parameters of Concern	Temperature
Use Affected	High quality coldwater fishery
Geographic Location	Rio Chama USGS Hydrologic Unit Code 13020102
Scope/Size of Watershed	TMDL area: 33 square mile
Land Type	Ecoregions: Southern Rockies and Arizona/New Mexico Plateau
Land Use/Cover	Forest (71 percent) and Rangeland (29 percent)
Identified Sources	Removal of Riparian Vegetation
Watershed Ownership	Forest Service (98 percent) and Private (2 percent)
Priority Ranking	4
Threatened and Endangered Species	None
TMDL for: Temperature	WLA (0) + LA (208.96) + MOS (23.3)= **233.46 joules/m^2/s/d**

TOTAL MAXIMUM DAILY LOAD FOR TURBIDITY, CHRONIC ALUMINUM, AND TEMPERATURE IN THE RIO VALLECITOS

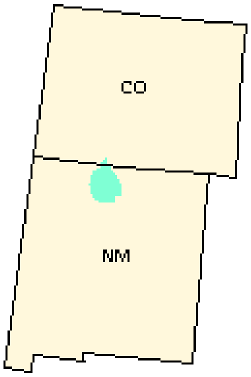


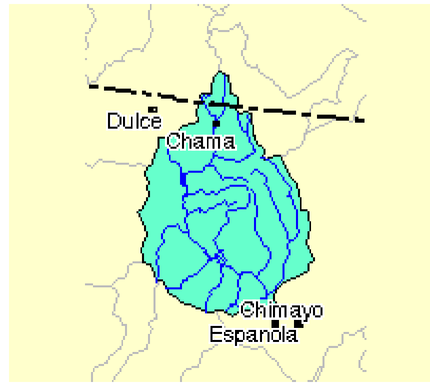


Summary Table

New Mexico Standards Segment	Rio Grande, 20.6.4.115 (formerly 2112)
Waterbody Identifier	Rio Vallecitos (Rio Tusas to headwaters), NM-2112.A_00, 36.31 mi.
Parameters of Concern	Turbidity Chronic aluminum Temperature
Use Affected	High quality coldwater fishery
Geographic Location	Rio Chama USGS Hydrologic Unit Code 13020102
Scope/Size of Watershed	TMDL area: 183 square mile
Land Type	Ecoregion: Southern Rockies
Land Use/Cover	Forest (82 percent) and Rangeland (18 percent)
Identified Sources	Turbidity: Agriculture, Resource Extraction, Hydromodification, Road Maintenance or Runoff, Removal of Riparian Vegetation, Streambank Modification/Destabilization Chronic aluminum: Resource Extraction and Hydromodification Temperature: Removal of Riparian Vegetation, Streambank Modification/Destabilization, Recreational Activities, Rangeland
Watershed Ownership	Forest Service (80 percent) and Private (20 percent)
Priority Ranking	4
Threatened and Endangered Species	None
TMDL for: Turbidity (as TSS) Chronic aluminum Temperature	 WLA (0) + LA (310) + MOS (104)= **414 lbs/day** WLA (0) + LA (4.16) + MOS (1.04)= **5.2 lbs/day** WLA (0) + LA (201.19) + MOS (22.4)= **223.37 joules/m^2/s**

TOTAL MAXIMUM DAILY LOAD
FOR DISSOLVED OXYGEN ON ABIQUIU CREEK





Summary Table

New Mexico Standards Segment	Rio Grande, 20.6.4.116 (formerly 2113)
Waterbody Identifier	Abiquiu Creek (Rio Chama to headwaters), NM-2113_50, 12.93 mi.
Parameters of Concern	Dissolved Oxygen
Use Affected	Coldwater fishery
Geographic Location	Rio Chama USGS Hydrologic Unit Code 13020102
Scope/Size of Watershed	45 square mile
Land Type	Ecoregions: Southern Rockies and Arizona/New Mexico Plateau
Land Use/Cover	Rangeland (54 percent) and Forest (45 percent)
Identified Sources	Rangeland, Hydromodification, Removal of Riparian Vegetation, and Streambank Modification/Destabilization
Watershed Ownership	Forest Service (59 percent) and Private (41 percent)
Priority Ranking	4
Threatened and Endangered Species	None
TMDL for: Dissolved Oxygen As SOD As TBOD	 WLA (0) + LA(0.015 g/ft^{2}day) + MOS (0) = **0.015 g/ft^{2}day** WLA (0) + LA(0.012 g/ft^{2}day) + MOS (0) = **0.012 g/ft^{2}day**

1.0 BACKGROUND INFORMATION

1.1 Location Description and History

The Rio Chama watershed (USGS Hydrologic Unit Code 13020102) is a subbasin of the Rio Grande Basin, in north-central New Mexico. The entire Rio Chama watershed encompasses 3,150 square miles. For practical purposes, the Rio Chama watershed was divided into upper and lower sampling units in 1999. The Surface Water Quality Bureau of the New Mexico Environment Department (SWQB/NMED) defines the Lower Rio Chama watershed (approximately 1725 square miles) as the Rio Chama watershed below El Vado Reservoir to the Rio Grande. Tributaries in the Lower Rio Chama watershed include Abiquiu Creek, El Rito Creek, Vallecitos Creek, Rio Tusas, Rio Nutrias, Canjilon Creek, Rio Ojo Caliente, Rio del Oso, Cañones Creek, Chihuahuenos Creek, Polvadera Creek, Rio Gallina, Clear Creek, Cecilia Canyon Creek, Rito Resumidero, Rio Puerco de Chama, Poleo Creek, Rito Encinco, Coyote Creek, and Rito Redondo.

1.2 Water Quality Standards

Water quality standards for all assessment units in this document are set forth in sections 20.6.4.115, 20.6.4.116, 20.6.4.119 and 20.6.4.900 of the 2001 New Mexico Standards for Interstate and Intrastate Surface Waters (20.6.4 NMAC).

20.6.4.115 NMAC reads as follows:

> **RIO GRANDE BASIN—**All perennial reaches of Rio Vallecitos and its tributaries, and Rio del Oso, and El Rito creek above the town of El Rito.
> **A. Designated Uses**: domestic water supply, irrigation, high quality coldwater fishery, livestock watering, wildlife habitat, and secondary contact.
> **B. Standards**:
> (1) In any single sample: conductivity shall not exceed 300 µmhos, pH shall be within the range of 6.6 to 8.8, temperature shall not exceed 20 ºC (68 ºF), and turbidity shall not exceed 10 NTU. The use-specific numeric standards set forth in 20.6.4.900 NMAC are applicable to 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).

In addition, according to the New Mexico water quality standards (20.6.4.900.M NMAC), the dissolved aluminum chronic criterion is 87 µg/L and the dissolved aluminum acute criterion is 750 µg/L for aquatic life uses.

20.6.4.116 NMAC reads as follows:

RIO GRANDE BASIN—The Rio Chama from its mouth on the Rio Grande upstream to Abiquiu reservoir, the Rio Tusas, the Rio Ojo Caliente, Abiquiu creek, and El Rito creek below the town of El Rito.

A. **Designated Uses**: irrigation, livestock watering, wildlife habitat, coldwater fishery, warmwater fishery, and secondary contact.

B. **Standards**:

(1) In any single sample: pH shall be within the range of 6.6 to 8.8 and temperature shall not exceed 31 ºC (87.8 ºF). The use-specific numeric standards set forth in 20.6.4.900 NMAC are applicable to designated uses listed above in Subsection A of this section.

(2) The monthly geometric mean of fecal coliform bacteria shall not exceed 1,000/100 mL; no single sample shall exceed 2,000/100 mL (see Subsection B of 20.6.4.13 NMAC).

20.6.4.119 NMAC reads as follows:

RIO GRANDE BASIN—All perennial reaches of tributaries to the Rio Chama above Abiquiu dam except the Rio Gallina and Rio Puerco de Chama north of state highway 96 and the main stem of the Rio Chama from the headwaters of El Vado reservoir upstream to the New Mexico-Colorado line.

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 500 µmhos (1,000 µmhos for Coyote Creek), pH shall be within the range of 6.6 to 8.8, temperature shall not exceed 20 ºC (68 ºF), and turbidity shall not exceed 25 NTU. The use-specific numeric standards set forth in 20.6.4.900 NMAC are applicable to 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).

In addition, according to the New Mexico water quality standards (20.6.4.900.M NMAC), the dissolved aluminum chronic criterion is 87 µg/L and the dissolved aluminum acute criterion is 750 µg/L for aquatic life uses.

1.3 Intensive Water Quality Sampling

The Lower Rio Chama watershed was intensively sampled by SWQB/NMED in 1999. Water quality samples were collected during spring (April 19–22), summer (July 27–28), and fall (October 5–6). Select follow-up monitoring was completed in October 2001 and June–September 2002. Surface water quality monitoring stations were selected in this watershed to characterize water quality of the stream reaches (Table 1.1, Figure 1.1). Stations were positioned to evaluate the impact of tributary streams and to establish

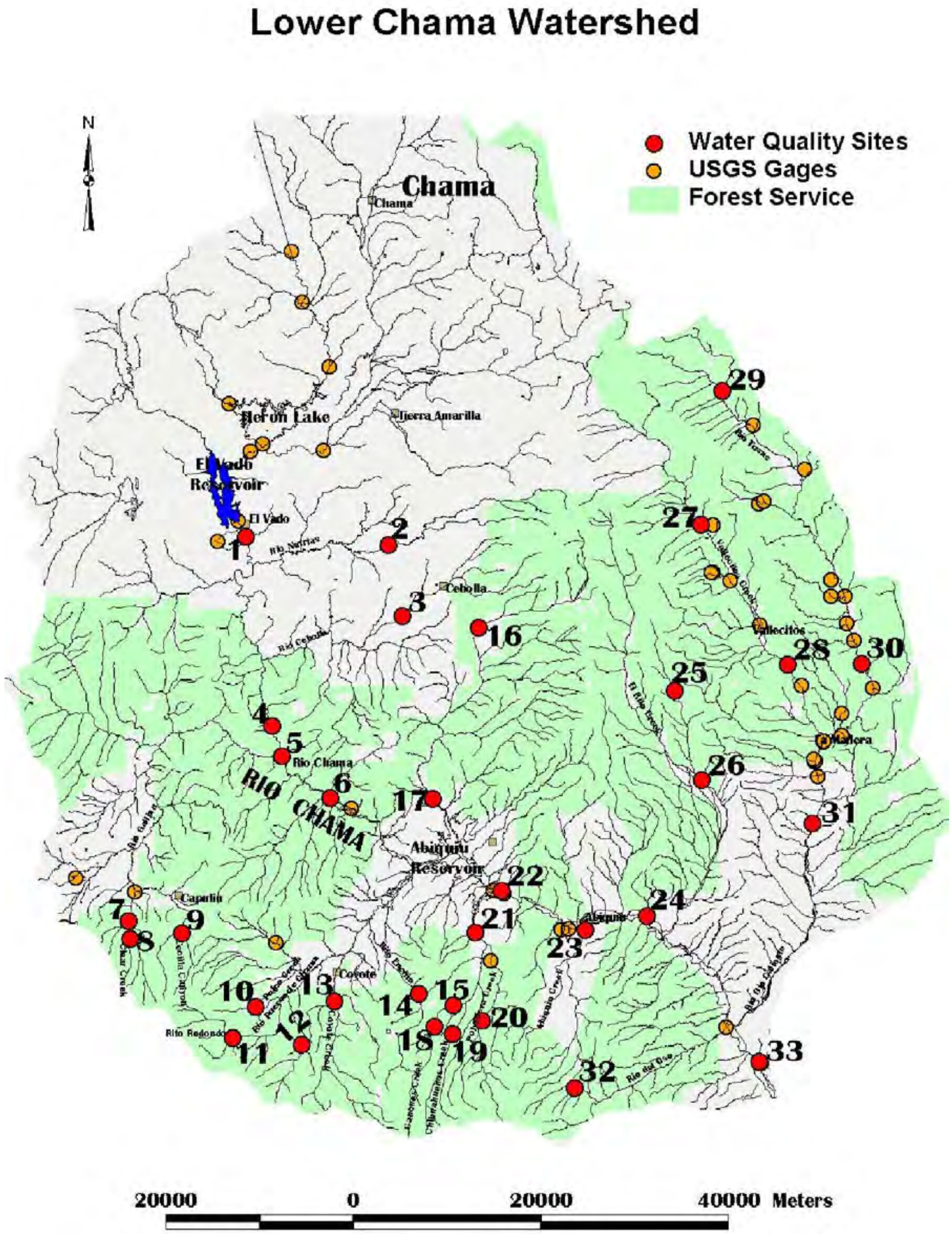


Figure 1.1. Water Quality Monitoring Sites for Lower Chama Watershed (1999)

background conditions. Because of the large percentage of private land in the Lower Rio Chama watershed, selection of sampling stations was often limited to road/bridge right-of-way locations, while some stations were situated with permission on private lands. The results of the survey were summarized in a water quality survey report (SWQB/NMED 2001a).

Table 1.1 SWQB/NMED 1999 Lower Rio Chama Watershed Sampling Stations

SWQB Station	STORET Reference	Station Location
1	29RChama120.6	Rio Chama @ USGS gage below El Vado dam
2	29RNutri028.4	Rio Nutrias @ Hwy 84
3	29RCebol027.0	Rio Cebolla @ Hwy 84
4	29RChama089.7	Rio Chama @ monastery
5	29RGalli000.5	Rio Gallina @ confluence with Rio Chama (QA)
6	29RChama079.5	Rio Chama above Abiquiu Reservoir, 1 mile above USGS station (QA)
7	29RGalli045.1	Rio Gallina @ Forest Road 76
8	29ClearC000.1	Clear Creek at Forest Road 76
9	29CeciliC000.1	Cecilia Canyon Creek @ Forest Road 171
10	29PoleoC009.5	Poleo Creek @ Forest Road 103
11	29RRedon000.2	Rito Redondo @ Forest Road 93
12	29RResum001.7	Rito Resumidero @ Forest Road 93
13	29Coyote005.6	Coyote Creek @ Forest Road 316
14	29REncin009.7	Rito Encino @ Forest Road 100Z
15	29RPuerc037.5	Rio Puerco de Chama @ Forest Road 103 (upper station)
15a	29RPuerc011.0	Rio Puerco de Chama @ County Road 211 in Youngsville
16	29Canjil035.0	Canjilon Creek @ bridge below Canjilon
17	29Canjil006.2	Canjilon Creek @ US 84 above Abiquiu Reservoir

SWQB Station	STORET Reference	Station Location
18	29Canone007.0	Cañones Creek above confluence with Chihuahuenos Creek
19	29Chihua000.1	Chihuahuenos Creek above confluence with Cañones Creek
20	29Polvad008.8	Polvadera Creek @ Forest Road 27 (County Road 95)
21	29Canone004.6	Cañones Creek @ Forest Road 167 below Canones
22	29RChama050.4	Rio Chama below Abiquiu Dam @ USGS gage
23	29Abique001.8	Abiquiu Creek @ US 84 bridge
24	29RChama038.3	Rio Chama @ Hwy 554
25	29ElRito044.0	El Rito above inholding 1.3 miles above Forest Road 106
26	29ElRito021.0	El Rito @ bridge in El Rito 400 feet from Hwy 554
27	29RValle030.5	Rio Vallecitos 8.4 miles above Vallecitos where road crosses river (USFS boundary)
28	29RValle007.9	Rio Vallecitos 3.9 miles above town of La Madera @ bridge
29	29RTusas000.2	Rio Tusas @ Forest Road 712
30	29RTusas000.1	Rio Tusas above confluence with Rio Vallecitos
31	29RojoCa026.1	Rio Ojo Caliente @ Hwy 414 @ Hot Springs bridge (QA)
31a	29RojoCa005.1	Rio Ojo Caliente 3.4 miles above confluence with Rio Chama
32	29RioOso001.9	Rio del Oso upstream from Canoncito
33	29RChama004.8	Rio Chama @ Hwy 74 bridge on San Juan Pueblo (QA)

QA – Stations were replicate samples were collected for quality assurance purposes.

In addition to the water quality survey, more detailed physical, biological, and chemical data were collected for this site using methods from the Regional Environmental Monitoring and Assistant Program (REMAP) study. These data were collected in conjunction with the water quality survey, and were used in the physical and biological assessment of this stream segment.

There are several USGS gaging stations in the Lower Rio Chama watershed (Table 1.2).

Table 1.2. USGS Gages in the Lower Chama Watershed

Site Number	Site Name	From (yyyy-mm-dd)	To (yyyy-mm-dd)
08288000	EL RITO NEAR EL RITO, NM	1931-10-01	1950-09-30
08286500	RIO CHAMA ABOVE ABIQUIU RESERVOIR, NM	1961-08-01	2001-09-30
08287000	RIO CHAMA BELOW ABIQUIU DAM, NM	1961-11-01	2001-09-30
08285500	RIO CHAMA BELOW EL VADO DAM, NM	1935-10-30	2001-09-30
08287500	RIO CHAMA NEAR ABIQUIU, NM	1941-10-01	1967-09-30
08289000	RIO OJO CALIENTE AT LA MADERA, NM	1932-10-01	2001-09-30

All temperature, chemical/physical, and stream bottom deposits sampling and assessment techniques are detailed in the Quality Assurance Project Plan (SWQB/NMED 2001b). As a result of the 1999 monitoring effort and subsequent assessment of results, several exceedances of New Mexico water quality standards for several streams were documented. Accordingly, these impairments were added to New Mexico's CWA Integrated §303(d)/§305(b) list. This TMDL document addresses each assessment unit by constituent (or pollutant) the standard(s) for which have been exceeded.

2.0 INDIVIDUAL WATERSHED DESCRIPTIONS

Table 2.1. Summary of Lower Chama Watershed Impairments to Be Addressed in This TMDL Document

Waterbody	Impairments	Delistings*
Cañones Creek	Turbidity Chronic aluminum Fecal Coliform	Temperature
Rio Nutrias	Turbidity	
Poleo Creek	Turbidity	
Polvadera Creek	Temperature	Stream Bottom Deposits
Rio Vallecitos	Turbidity Chronic aluminum Temperature	
Abiquiu Creek	Dissolved Oxygen	Stream Bottom Deposits Plant Nutrients

*A summary of delisting letters for these reaches and other reaches in the Lower Chama watershed can be found in Appendix A. The actual letters are in the SWQB Administrative file, available upon request.

2.1 Cañones Creek

The Cañones Creek watershed is approximately 84 square miles. The U.S. Forest Service (USFS) has jurisdiction over 94 percent of the watershed, while the other 6 percent is privately owned. Land cover consists of 67 percent forest and 33 percent rangeland. Cañones Creek (Abiquiu Reservoir to headwaters) (20.6.4.119 NMAC), is listed on the 2002–2004 CWA Integrated §303(d)/§305(b) list for turbidity, chronic aluminum, and fecal coliform. The probable sources of turbidity are rangeland, silviculture, removal of riparian vegetation, and streambank destabilization/modification. The probable sources of chronic aluminum include unknown and natural sources. The probable sources of fecal coliform are rangeland and on-site wastewater systems. A listing for temperature was subsequently removed from the list upon analysis of existing data.

Photo 2.1. Cañones Creek at Forest Road 167
(Photo taken in 1999)

2.2 Rio Nutrias

The Rio Nutrias watershed is approximately 106 square miles. Most of the watershed (74 percent) is privately owned, the USFS has jurisdiction over 12 percent of the watershed, the Bureau of Land Management (BLM) manages 10 percent, the State of New Mexico owns 2 percent, while the other 2 percent is owned by the New Mexico Department of Game and Fish. Land cover consists of 67 percent forest and 33 percent rangeland. Rio Nutrias (Rio Chama to headwaters) (20.6.4.119 NMAC), is listed on the 2002–2004 CWA Integrated §303(d)/§305(b) list for turbidity. The probable sources of turbidity are agriculture, removal of riparian vegetation, and streambank destabilization/modification.

Photo 2.2. Rio Nutrias
(Photo taken in 1999)

2.3 Poleo Creek

The Poleo Creek watershed is approximately 47 square miles. The USFS has jurisdiction over 80 percent of the watershed, while the other 20 percent is privately owned. Land cover consists of 71 percent forest and 29 percent rangeland. Poleo Creek (Rio Puerco de Chama to headwaters) (20.6.4.119 NMAC), is listed on the 2002–2004 CWA Integrated §303(d)/§305(b) list for turbidity. The probable sources of turbidity are silviculture, rangeland, removal of riparian vegetation, and streambank destabilization/modification.

2.4 Polvadera Creek

The Polvadera Creek watershed is approximately 33 square miles. The USFS has jurisdiction over 98 percent of the watershed, while the other 2 percent is privately owned. Land cover consists of 71 percent forest and 29 percent rangeland. Polvadera Creek (Cañones Creek to headwaters) (20.6.4.119 NMAC), is listed on the 2002–2004 CWA Integrated §303(d)/§305(b) list for temperature. The probable source of elevated temperature is removal of riparian vegetation. A listing for stream bottom deposits was subsequently removed from the list upon analysis of existing data.

Photo 2.3. Polvadera Creek
(Photo taken on June 11, 2002)

2.5 Rio Vallecitos

The Rio Vallecitos watershed is approximately 183 square miles. The USFS has jurisdiction over 80 percent of the watershed, while the other 20 percent is privately owned. Land cover consists of 82 percent forest and 18 percent rangeland. Rio Vallecitos (Rio Tusas to headwaters) (20.6.4.115 NMAC), is listed on the 2002–2004 CWA Integrated §303(d)/§305(b) list for turbidity, chronic aluminum, and temperature. The probable sources of turbidity are agriculture, resource extraction, hydromodification, road maintenance or runoff, recreation, removal of riparian vegetation, and streambank destabilization/modification. The probable sources of chronic aluminum are resource extraction and hydromodification. The probable source of elevated temperature is removal of riparian vegetation.

Photo 2.4. Rio Vallecitos 8.4 Miles Above Vallecitos Where Road Crosses River (USFS boundary) (Photo taken April 29, 2002)

2.6 Abiquiu Creek

The Abiquiu Creek watershed is approximately 45 square miles. The USFS has jurisdiction over 59 percent of the watershed, while the other 41 percent is privately owned. Land cover consists of 45 percent forest, 54 percent rangeland, and 1 percent urban. Abiquiu Creek (Rio Chama to headwaters) (20.6.4.116 NMAC), is listed on the 2002–2004 CWA Integrated §303(d)/§305(b) list for stream bottom deposits. The probable sources of the impairment to dissolved oxygen were identified as rangeland, hydromodification, and road maintenance/runoff. Data collected in 1999 were used to list Abiquiu Creek for dissolved oxygen. Listing for stream bottom deposits and plant nutrients were subsequently removed from the list upon analysis of existing data.

Photo 2.5. Abiquiu Creek at US Highway 84 Bridge (Photo taken on June 10, 2002)

3.0 TURBIDITY

3.1 Summary

During the SWQB 1999 intensive water quality survey in the Lower Rio Chama watershed, several exceedances of the New Mexico water quality standard for turbidity were documented at sampling stations on Cañones Creek, Rio Nutrias, Rio Vallecitos, and Poleo Creek (see Table 3.1). Consequently, these reaches were listed on the 2000–2002 CWA Integrated §303(d)/§305(b) list for turbidity.

Table 3.1. Turbidity Exceedances in the Lower Rio Chama Watershed

Site	Date (YYMMDD)	Turbidity Standard (NTU)	Field Turbidity Measures (NTU)*	Field Total Suspended Solids (TSS) Measures (mg/L)+
Cañones Creek at Forest Road 167 below Canones	990422	25	44.3	83
Cañones Creek at Forest Road 167 below Canones	990727	25	81.8	45
Cañones Creek at Forest Road 167 below Canones	990428	25	33.7	38
Cañones Creek at Forest Road 167 below Canones	991006	25	207.0	121
Rio Nutrias at US 84	990419	25	156.0	110
Rio Nutrias at US 84	990727	25	87.3	188
Rio Nutrias at US 84	991006	25	68.1	46
Rio Nutrias at US 84	991013**	25	60.6	49
Rio Nutrias at US 84	020610	25	233	157
Rio Nutrias at US 84	020611	25	378	250
Rio Vallecitos 3.9 miles above La Madera at bridge	990419	10	13.7	8
Rio Vallecitos 3.9 miles above La Madera at bridge	990420	10	10.8	3k
Rio Vallecitos 3.9 miles above La Madera at bridge	990421	10	17.6	14
Rio Vallecitos 3.9 miles above La Madera at bridge	990422	10	14.3	4
Rio Vallecitos 8.4 miles above Vallecitos at river crossing	990419	10	25.4	21
Rio Vallecitos 8.4 miles above Vallecitos at river crossing	990420	10	19.9	13
Rio Vallecitos 8.4 miles above Vallecitos at river crossing	990421	10	16.8	9
Rio Vallecitos 8.4 miles above	990422	10	14.9	9

Site	Date (YYMMDD)	Turbidity Standard (NTU)	Field Turbidity Measures (NTU)*	Field Total Suspended Solids (TSS) Measures (mg/L)+
Vallecitos at river crossing				
Poleo Creek at Forest Road 103	990419	25	34.6	28
Poleo Creek at Forest Road 103	990420	25	69.2	35
Poleo Creek at Forest Road 103	990421	25	143.0	93
Poleo Creek at Forest Road 103	990422	25	119.0	74
Poleo Creek at Forest Road 103	990727	25	71.4	74

*Each value represents one field measurement.
+Each value represents one laboratory measurement. Arithmetic means of the TSS values when measured turbidity exceeded the standard are the following (in mg/L): Cañones Creek (71.8), Rio Nutrias (133.3), Poleo Creek (60.8), and Rio Vallecitos (10.1).
**REMAP data.
k indicates sample holding time was exceeded.

3.2 Endpoint Identification

Target Loading Capacity

Target values for these turbidity 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 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 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 state's standard leading to an assessment of use impairment is the numeric criteria for turbidity of 25 nephelometric turbidity units (NTU) (Cañones Creek, Rio Nutrias, and Poleo Creek) and 10 NTU (Rio Vallecitos) for the designated use of a high quality coldwater fishery (HQCWF).

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. Since there are no wastewater treatment plants discharging into any of these streams listed for turbidity impairment, 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 wastewater treatment plant effluent.

Turbidity levels can be inferred from studies that monitor total suspended sediment (TSS) 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 1991a). 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 1991a). This impact is largely a mechanical action that severely reduces the available habitat for macroinvertebrates and fish species that use the streambed in various life stages. An increase in suspended sediment concentration reduces the penetration of light, decreases the ability of fish or fingerlings to capture prey, and reduces primary production (USEPA 1991a). Specifically, increased turbidity by sediments can reduce stream primary production by reducing photosynthesis, physically abrading algae and other plants, and preventing attachment of autotrophs to substrate surfaces (Van Nieuwenhuyse and LaPierre 1986, Brookes 1986).

TSS and turbidity were measured during the 1999 survey (for standards exceedances, see Table 3.1). A correlation (R2) was found between turbidity and TSS for each reach (see Table 3.2 and Appendix B).

Table 3.2. Relationships Between Turbidity and TSS for Turbidity Impaired Reaches in the Lower Chama Watershed

Reach	Correlation (R^2)	Regression Equation
Cañones Creek	.69	y= 0.4543x + 26.185
Rio Nutrias	.64	y = 0.5195x + 48.215
Poleo Creek	.90	y = 0.6443x + 2.9653
Rio Vallecitos	.63	y = 0.5869x + 1.0263

Flow

Sediment transport in a stream varies as a function of flow. As flow increases, the amount of sediment being transported increases. This TMDL is calculated for each reach at a specific flow. When available, U.S. Geologic Survey (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 any of the reaches with turbidity impairments. For these reaches, flow was measured by SWQB during the spring sampling run using standard USGS procedures (SWQB/NMED 2001b). The measured flow values are found in Table 3.3.

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 should be a goal to be attained. Meeting the calculated target load may be a difficult objective.

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 milligrams per liter to pounds per day (see Appendix C for the conversion factor derivation). The target loading capacity is calculated using Equation 1. The results are shown in Table 3.3.

Equation 1. critical flow (MGD) x standard (mg/L) x 8.34 (conversion factor) = target loading capacity

Table 3.3. Calculation of Target Loads for Turbidity (Expressed as TSS)

Location	Flow+ (MGD)	TSS* (mg/L)	Conversion Factor	Target Load Capacity (lbs/day)
Cañones Creek	6.9	37.5	8.34	2,158
Rio Nutrias	16.0	61.2	8.34	8,167
Poleo Creek	1.03++	19.1	8.34	165
Rio Vallecitos	7.2	6.9	8.34	414

+ Since USGS gages were unavailable, flow was measured during the 1999 spring, or highest flowing, sampling run (SWQB/NMED 2001a) Canones on 4/20/99, Rio Nutrias on 4/20/99, and Rio Vallecitos on 7/28/99.

++ Flow for Poleo Creek was not taken directly. This value is a percentage (based on watershed land area) of the flow measured at the Rio Puerco de Chama at Forest Road 103 gage station (SWQB/NMED 2001a).

*The TSS value was calculated using the relationship established between TSS and turbidity in Table 3.2 using the turbidity standard of 25 NTU for the X variable for Cañones Creek, Rio Nutrias, and Poleo Creek, and 10 NTU for Rio Vallecitos.

The measured loads for turbidity (expressed as TSS) were similarly calculated. To achieve comparability between the target and measured loads, the same flows were used for both calculations. The geometric mean of corresponding TSS values when turbidity exceeded the standard was substituted for the standard in Equation 1. The same conversion factor of 8.34 was used. The results are presented in Table 3.4.

Table 3.4 Calculation of Measured Loads for Turbidity (expressed as TSS)

Location	Flow+ (MGD)	TSS Arithmetic Mean * (mg/L)	Conversion Factor	Measured Load Capacity (lbs/day)
Cañones Creek	6.9	71.8	8.34	4,132
Rio Nutrias	16.0	133.3	8.34	17,788
Poleo Creek	1.03++	60.8	8.34	522
Rio Vallecitos	7.2	10.1	8.34	606

+ Since USGS gages were unavailable, flow was measured during the 1999 spring, or highest flowing, sampling run (SWQB/NMED 2001a) Canones on 4/20/99, Rio Nutrias on 4/20/99, and Rio Vallecitos on 7/28/99.

++ Flow for Poleo Creek was not taken directly. This value is a percentage (based on watershed land area) of the flow measured at the Rio Puerco de Chama at Forest Road 103 station. (SWQB/NMED 2001a).

* Arithmetic mean of TSS values when measured turbidity exceeded the standard (see Table 3.1).

Waste Load Allocations and Load Allocations

• <u>Waste Load Allocation</u>

There are no point source contributions associated with this TMDL. The waste load allocation (WLA) is zero.

• <u>Load Allocation</u>

To calculate the load allocation (LA), the waste load allocation and margin of safety (MOS) were subtracted from the target capacity (TMDL) following Equation 2.

Equation 2. WLA + LA + MOS = TMDL

The margin of safety is estimated to be 25 percent of the target load calculated in Table 3.3. Results are presented in Table 3.5. Additional details on the margin of safety chosen are presented later in this document.

Table 3.5. Calculation of the TMDL for Turbidity

Location	WLA (lbs/day)	LA (lbs/day)	MOS (25 percent) (lbs/day)	TMDL (lbs/day)
Cañones Creek	0	1,618	540	2,158
Rio Nutrias	0	6,125	2,042	8,167
Poleo Creek	0	124	41	165
Rio Vallecitos	0	310	104	414

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

The load reductions that would be necessary to meet the target loads were calculated to be the difference between the target load allocation (Table 3.3) and the measured load (Table 3.4), and are shown in Table 3.6.

Table 3.6. Calculation of Load Reduction for Turbidity (Expressed as TSS)

Location	Target Load Allocation (lbs/day)	Measured Load (lbs/day)	Load Reduction (lbs/day)
Cañones Creek	2,158	4,132	1,974
Rio Nutrias	8,167	17,788	9,621
Poleo Creek	165	522	357
Rio Vallecitos	414	606	192

Identification and Description of Pollutant Sources

Potential Sources of pollutants are listed for each segment in Table 3.7.

Table 3.7. Pollutant Source Summary for Turbidity

Pollutant Sources (percent from each)	**Magnitude** (WLA + LA + MOS)	**Location**	**Potential Sources**
Point: None (0 percent)	0		
Nonpoint: (100 percent) Turbidity (expressed as TSS in lbs/day)		Cañones Creek	Rangeland, Silviculture, Removal of Riparian Vegetation, Streambank Modification/Destabilization
		Rio Nutrias	Agriculture, Removal of Riparian Vegetation, Streambank Modification/Destabilization
		Poleo Creek	Agriculture, Removal of Riparian Vegetation, Streambank Modification/Destabilization
		Rio Vallecitos	Agriculture, Resource Extraction, Hydromodification, Road Maintenance or Runoff, Removal of Riparian Vegetation, Streambank Modification/Destabilization

Linkage Between 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. Turbidity 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 exceedances, 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 exceeding the state standards for the protection of aquatic habitat, namely the high quality coldwater fishery designated use. Through monitoring, and pollutant source documentation, it has been observed that the most probable causes for these exceedances are the alteration of the stream's hydrograph, grazing impacts, silviculture, resource extraction, removal of riparian vegetation, streambank modification/destabilization, and road maintenance and runoff. 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 the turbidity of the water
    - reduce transmission of sunlight needed for photosynthesis
    - interfere with animal behaviors dependent on sight (foraging, mating, and escaping 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; prevent fry from emerging from the buried gravel bed

2. Clearing of trees and shrubs from riparian areas, 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, construction of drainage ditches, and straightening of 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 through subsequent low flows
    - reduce baseflows

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

SWQB fieldwork includes an assessment of the potential sources of impairment (SWQB/NMED 1999). The Pollutant Source(s) Documentation Protocol form and Potential Sources Summary Table in Appendix D 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 3.7 (Pollutant Source Summary) 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, which is predominantly privately held, but also the upland and upstream areas in a more holistic watershed approach to implementing this TMDL.

The primary sources of impairment for the reaches identified in the state 303 (d) list are the following:

Cañones Creek: Rangeland, Silviculture, Removal of Riparian Vegetation, and Streambank Modification/Destabilization

Rio Nutrias: Agriculture, Removal of Riparian Vegetation, and Streambank Modification/Destabilization

Poleo Creek: Agriculture, Removal of Riparian Vegetation, and Streambank Modification/Destabilization

Rio Vallecitos: Agriculture, Resource Extraction, Hydromodification, Road Maintenance or Runoff, Removal of Riparian Vegetation, and Streambank

Modification/Destabilization

Cañones Creek
No turbidity exceedances were found at the upper station on Cañones Creek (Cañones Creek above Chihuahuenos Creek). Field notes from 2002 indicate that at this upper station there was a healthy riparian area with boulders, cobble, and little embeddedness. Field notes indicate that at the lower station, Cañones Creek at Forest Road 167 below Canones, the channel was incising, there was bank erosion, cows were grazing in the riparian area, and a large amount of sand was found on the stream bottom.

According to the Water Quality Survey of this watershed (SWQB/NMED 1991), activities that may contribute to water quality impairments include riparian quality degradation due to livestock grazing, recreation, and silviculture. In addition, the lower Cañones Creek sampling station was located below the town of Cañones and below the irrigation return flows of this community.

Rio Nutrias
Samples were taken at one site along this reach. Field notes indicate that turbidity impairments were likely because of a poorly installed and maintained box culvert and over-grazing in the riparian area along the reach.

Poleo Creek
Samples were taken at one site on this reach. There are no field notes available for this reach.

Rio Vallecitos
The Rio Vallecitos was sampled at two stations along the reach. Exceedances of turbidity were found at both stations. Field notes indicate that the upstream site (Rio Vallecitos 8.4 miles above Vallecitos at river crossing) is in good condition, although there is some channelization and berms alongside the stream. The stream passes through irrigated pasture, some rural development, and historic placer and gypsum mining sites. At the lower station the stream widens, although the riparian vegetation is abundant and the stream substrate consists of boulders with little embeddedness.

3.3 Margin of Safety (MOS)

TMDLs should reflect a margin of safety based on the uncertainty or variability in the data, the point and nonpoint source load estimates, and the modeling analysis. For this TMDL, there will be no margin of safety for point sources since none are found on any of the reaches. However, for the nonpoint sources, the margin of safety is **25 percent** of the sum of the WLA and LA. This margin of safety is the sum of the following two elements:

- *Errors in calculating nonpoint source loads*
  A level of uncertainty exists 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 margin of safety 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 for error in measurements of nonpoint source loads due to equipment accuracy, time of sampling, and other factors. Accordingly, a conservative MOS for this element is **15 percent**.

- *Errors in calculating flow*

  Flow estimates were based on estimated mean average annual discharge using cross-sectional field data (Appendix B) and USGS Technical Paper 2193 (USGS 1982). A conservative MOS for this element is **10 percent.**

3.4 Consideration of Seasonal Variation

Data used in the calculation of this TMDL were collected during spring, summer, and fall to ensure coverage of any potential seasonal variation in the system. Since the critical condition is set to estimate average stream discharge, all data collected throughout the seasons were used in determining the target capacities. Therefore, it is assumed that if critical conditions are met, any potential seasonal variation will therefore be covered.

3.5 Future Growth

Estimates of future growth do not indicate a significant increase in turbidity that cannot be controlled with the implementation of best management practices in this watershed.

4.0 TEMPERATURE

4.1 Summary

During the 1999 SWQB sampling monitoring effort in the Lower Rio Chama watershed, thermograph data recorded several exceedances of the New Mexico water quality standard for temperature in two stream reaches in the watershed. Thermographs were set to record every 15 minutes for several weeks to months during the warmest time of the year (generally June through September). Thermograph data are assessed using the SWQB/NMED temperature protocol (SWQB/NMED 2001c). Polvadera Creek and the Rio Vallecitos were listed on the 2002-2004 CWA Integrated §303(d)/§305(b) list for temperature.

4.2 Endpoint Identification

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 New Mexico Water Quality Control Commission (WQCC) has adopted numeric water quality criteria for temperature to protect the designated use of HQCWF (20.6.4.900.C NMAC). These water quality standards have been set at a level to protect cold-water aquatic life such as trout. The use designation of high quality coldwater fishery (HQCWF) 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 temperature criterion of 20 °C (68 °F). On the following reaches, temperatures exceeded the criterion (see Appendix E for a graphical representation of thermograph data):

> RIO VALLECITOS—Two thermographs were deployed on this reach in 1999. The upper thermograph was deployed under the bridge at the Forest Service boundary (SWQB station 27, see Table 1.1). Recorded temperatures exceeded the HQCWF criterion 80 of 3,030 times with a maximum temperature of 22.46 °C. The lower thermograph was deployed at the Rio Vallecitos 3.9 miles above town of La Madera at the bridge (SWQB station 28, see Table 1.1). Recorded temperatures exceeded the HQCWF criterion 413 of 3,031 times with a maximum temperature of 24.53 °C.
>
> POLVADERA CREEK—In 1999, three water temperature samples (July 27, July 28, and September 8) demonstrated an exceedance of the HQCWF criterion. In

2002, a thermograph was deployed on Polvadera Creek at Forest Road 27 (County Road 95) at the County road 512 bridge (SWQB station 20, see Table 1.1). Recorded temperatures exceeded the HQCWF criterion 302 of 2,718 times with a maximum temperature of 24.13 °C.

Calculations
The model Stream Segment Temperature (SSTEMP) version 1.2.2 was used to predict stream temperatures based on watershed geometry, hydrology, and meteorology. This model was developed by the USGS Biological Resource Division (USGS 1999). The model predicts minimum 24-hour stream temperatures, mean 24-hour stream temperatures, and maximum 24-hour stream temperatures for a given day, as well as a variety of intermediate values. The predicted temperature values are compared with 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 loss of riparian vegetation, 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.

Waste Load Allocations and Load Allocations

• *Waste Load Allocation*
There are no point source contributions associated with this TMDL. The waste load allocation (WLA) is therefore zero.

• *Load Allocation*
Water temperature can be expressed as heat energy per unit volume. SSTEMP provides an estimate of heat energy per unit volume expressed in joules (the absolute meter kilogram-second unit of work or energy equal to 10^7 ergs or approximately 0.7375 foot pounds) per meter squared per second ($j/m^2/s$) and Langley's (a unit of solar radiation equivalent to one gram calorie per square centimeter of irradiated surface) per day. The following information, relevant to the model runs that were used to determine temperature TMDLs, was copied from the user's manual (USGS 1999). Various notes have been added in brackets to clarify local sources of input data.

DESCRIPTION OF LOGIC

SSTEMP version 1.2.2 integrates SSSOLAR version 1.6 and SSSHADE version 1.4 into one simple-to-use program. 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 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 the local topography is factored in by computing the sunrise and sunset times based on the 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 from 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 PARAMETERS

1. **Segment Inflow (cfs or cms)—**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; all accumulated flow will accrue from lateral inflow, both surface 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.

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 upstream segment.
[NOTE: Thermograph data from the top of the modeled reach are used to determine the inflow temperature.]

3. **Segment Outflow (cfs or cms)—**The program calculates the lateral discharge 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 probably should divide the segment into two or more subsections. "Major" is defined as any stream contributing more than 10 percent of the mainstem flow.
[NOTE: To be conservative, 4Q3 low flow values were used as the segment outflow. These critical low flows were used to decrease the assimilative capacity of the stream to adsorb and disperse solar energy. See Appendix F for calculations.]

4. **Accretion Temperature (°F or °C)—**The temperature of the lateral inflow, barring tributaries, generally should be the same as ground water temperature. In turn, ground water temperature may be approximated by the mean annual air temperature. You can verify this by checking 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 using equilibrium temperatures. [NOTE: Mean annual air temperature data are found at the Western Regional Climate Centers web site (www.wrcc.dri.edu).]

GEOMETRY PARAMETERS

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 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 column from solar noon to the end of the segment, allowing it to heat up toward 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.

3. **Segment Length (miles or kilometers)—**Enter the length of the segment for which you want to predict the outflowing temperature. Remember that all parameters 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 GIS tool.]

4. **Upstream Elevation (feet or meters)—**Enter elevation as taken from a 7½ minute quadrangle map.
[NOTE: Upstream elevation is generally determined in the field with a GPS unit.]

5. **Downstream Elevation (feet or meters)—**Enter elevation as taken from a 7½ 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.]

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 parameter). Theoretically, the A term is the 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.

8. **Manning's n (essentially dimensionless)—**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 01, 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. 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 be measured (in the shade), and should be for truly accurate results; however, this and the other 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.

Use the adiabatic lapse rate to correct for elevational differences from the meteorological 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 water temperature.
[NOTE: Mean daily air temperature data are found at the Western Regional Climate Center's Web site (www.wrcc.dri.edu) or determined from air thermographs deployed in the shade near the in-stream thermograph locations. 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 of an override condition. Unlike the other parameters where simply typing a value influences which parameters "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. Note: maximum air temperature appears in the Intermediate Values portion of the screen, not with the other mean daily meteorology values.

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 * [1.0640 ^ (To-Ta)] * [(Ta+273.16)/(To+273.16)]
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)
^ = exponentiation

[NOTE: Relative humidity data are found at the Western Regional Climate Center's Web site (www.wrcc.dri.edu) or National Renewable Energy Laboratory (NREL) Solar Radiation Data Base Web site (rredc.nrel.gov/solar/pubs/NSRDB). 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 LCD reports. 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, SSTEMP would like wind speed to be right above the water's surface.
[NOTE: Wind speed data are found at the Western Regional Climate Center's Web site (www.wrcc.dri.edu) or NREL Solar Radiation Data Base Web site (rredc.nrel.gov/solar/pubs/NSRDB).]

5. **Ground Temperature (°F or °C)—**Use mean annual air temperature from LCD reports.
[NOTE: Mean annual air temperature is found at the Western Regional Climate Center's Web site (www.wrcc.dri.edu).]

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 parameter 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 measure of cloud cover. Measure with a pyrometer or use LCD Reports.
[NOTE: Percentage possible sun is found at the Western Regional Climate Center's Web site (www.wrcc.dri.edu).]

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 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, 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 percent 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 on the NREL Solar Radiation Data Base Web site (rredc.nrel.gov/solar/pubs/NSRDB).]

SHADE PARAMETER

Total Shade (percent)—This parameter refers to how much of the segment is shaded by vegetation, cliffs, etc. If 10 percent of the water surface is shaded through the day, enter 10. As a shortcut, you may think of the shade factor as

being the percentage of water surface shaded at noon on a sunny day. In actuality, however, shade represents the percentage of the incoming solar radiation that does not reach the water. If you enter a value for total shade, the optional shading parameters are ignored.
[NOTE: There is a set of optional shading parameters that can also be used to calculate total shade in SSTEMP. In 2002, optional shading parameters and concurrent densiometer readings were measured at seventeen Upper Chama watershed stations in order to compare modeling results from the use of these more extensive data sets with modeling results using densiometer readings as an estimate of total shade. The estimated value for total shade was within 15 percent of the calculated value in all cases. Estimated values for maximum temperatures differed by less than 0.5 percent in all cases. The optional shading parameters depend 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. Therefore, densiometer readings are used to determine total shade for each modeled reach. Aerial photos are also examined and considered whenever available.]

OUTPUT

The program will predict the minimum, mean, and maximum daily water temperature for the set of parameters you provide (Figure 4.1). 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. Other output includes the intermediate parameters average width, average depth and slope, maximum daily air temperature (all calculated from the input parameters), and the mean daily heat flux components.

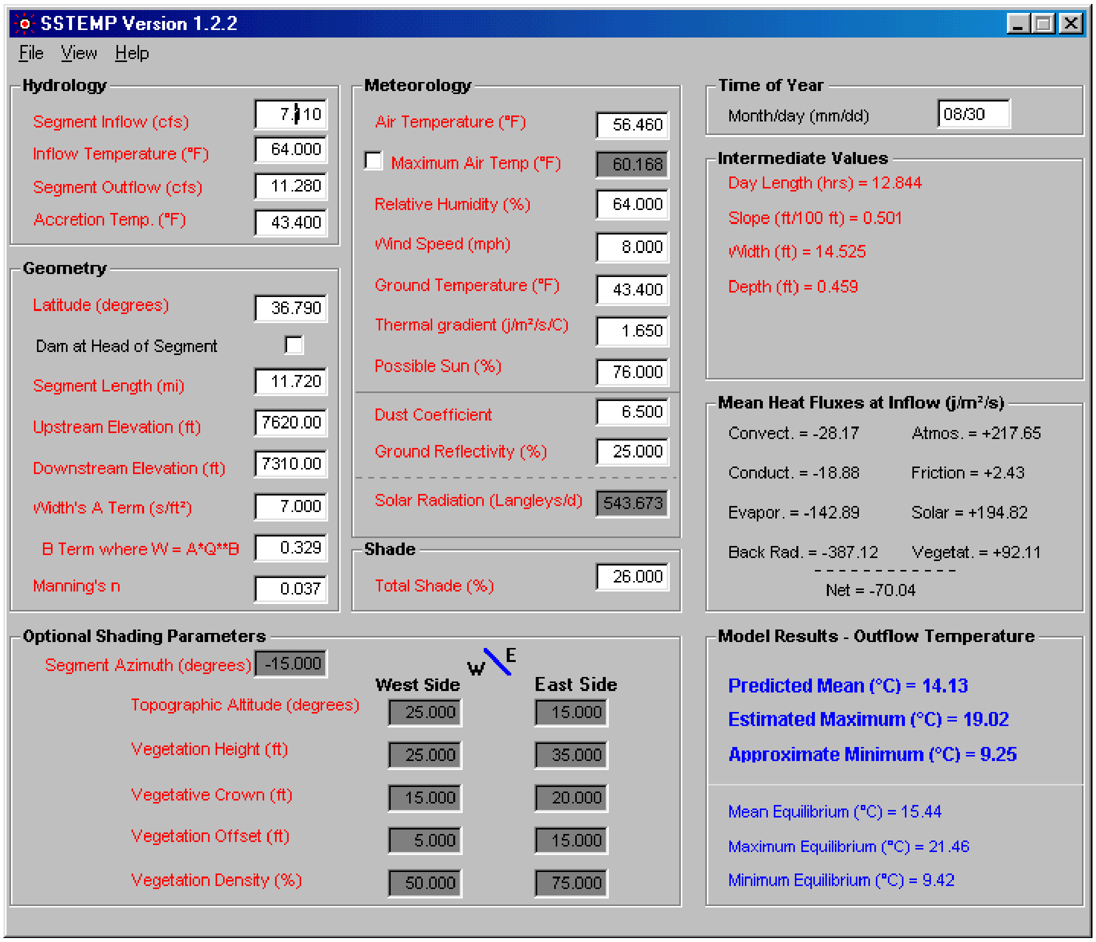


Figure 4.1. Example of SSTEMP Input and Output

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. The user 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).

SENSITIVITY ANALYSIS

SSTEMP may be used to compute a one-at-a-time sensitivity of a set of input values (Figure 4.2). 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 percent 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.

```
          Sensitivity for mean temperature values (10 percent variation) SSTEMP
(2.0.8)
Original mean temperature = 57.23°F
                              Temperature change (°F)
                                  if variable is:
Variable                        Decreased Increased   Relative Sensitivity
--------------------------------------------------------------------------------
Segment Inflow (cfs)              -0.03     +0.09 *
Inflow Temperature (°F)            0.00     +0.00
Segment Outflow (cfs)             +0.07     -0.01 *
Accretion Temp. (°F)              +0.00     +0.00
Width's A Term (s/ft²)            +0.02     -0.02
  B Term where W = A*Q**B         +0.00      0.00
Manning's n                       +0.00     +0.00
Air Temperature (°F)              -3.16     +3.11 ******************************
Relative Humidity (percent)             -0.77     +0.79 ********
Wind Speed (mph)                  +0.59     -0.64 ******
Ground Temperature (°F)           -0.29     +0.29 ***
Thermal gradient (j/m²/s/C)       +0.04     -0.04
Possible Sun (percent)                  -0.72     +0.74 *******
Dust Coefficient                  +0.05     -0.05
Ground Reflectivity (percent)           -0.04     +0.04
Total Shade (percent)                   +0.14     -0.14 *
```

Figure 4.2. Example of SSTEMP Sensitivity Analyses for Polvadera Creek

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 parameter 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, however, 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 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.

For example, suppose your stream has an average velocity of 0.5 meters per second and you want to simulate a 10 kilometer 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 kilometer segment length, you can simulate a single day if you wish. But if your stream’s velocity were only 0.05 miles per second, the water would only travel 4.3 kilometer, 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. An example would be testing alternative cases 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.

<u>Temperature Allocations as Determined by Percentage of Total Shade and Width-to-Depth Ratios</u>

Tables 4.1 and 4.2 detail model run outputs for Polvadera Creek and the Rio Vallecitos, respectively (see Appendix G for model runs). SSTEMP is first calibrated against thermograph data to determine the standard error of the model. Initial conditions are determined. As the percentage of total shade is increased and the width's A term is decreased, the maximum 24-hour temperature decreases until the segment specific standard of 20 ºC is achieved. The calculated 24-hour Solar Radiation Component is the maximum solar load that can occur in order to meet the water quality standard (i.e., the target capacity). In order to calculate the actual load allocation (LA), the waste load allocation (WLA) and margin of safety (MOS) were subtracted from the target capacity (TMDL) following Equation 2.

Equation 2. $WLA + LA + MOS = TMDL$

For Polvadera Creek, the water quality standard for temperature is achieved when the percentage total shade is 19 percent, and the width's A term is reduced to 6 (Table 4.1). Any reductions to the Width's A term simulate a decrease in the width-to-depth ratio of the channel, but this does not significantly impact the temperature of the stream. According to the model runs, the actual load allocation (LA) of 208.96 joules/meter^2/second/day is achieved when the shade is further increased to 27.5 percent (Table 4.1). This load allocation includes a margin of safety.

For the Rio Vallecitos, the water quality standard for temperature is achieved when the percentage total shade is 22.5 percent and the width's A term is reduced to 7.0 (Table 4.2). Any reductions to the width's A term simulate a decrease in the width-to-depth ratio of the channel, but this does not significantly impact the temperature of the stream. According to the model runs, the actual load allocation (LA) of 201.19 joules/meter^2/second/day is achieved when the shade is further increased to 30.3 percent (Table 4.2). This load allocation includes a margin of safety.

Target loads determined by the modeling runs are summarized in Tables 4.1 and 4.2. The margin of safety is estimated to be 10 percent of the target load calculated by the modeling runs. Results are presented in Table 4.3. Additional details on the margin of safety are presented in Section 4.3.

Table 4.1. SSTEMP Model Results for Polvadera Creek

<table>
<tr><th>Rosgen Channel Type</th><th>WQS (HQCWF)</th><th>Model Run Dates</th><th>Segment Length (mi)</th><th>Solar Radiation Component per 24 Hours (+/-)</th><th>Percent Total Shade</th><th>Width's A Term</th><th>Modeled Temperature °C (24 hour)</th></tr>
<tr><td>E</td><td>20 °C
(68 °F)</td><td>August 16</td><td>12.2</td><td>Current Field Condition
+259.4
joules/meter^2/
second</td><td>10</td><td>8</td><td>Minimum 6.96
Mean 14.01
Maximum 21.07</td></tr>
<tr><td colspan="4" rowspan="3">Stream Segment Temperature Model (SSTEMP) Results

TEMPERATURE ALLOCATIONS
FOR
Polvadera Creek

* DENOTES 24-HOUR ACHIEVEMENT OF SURFACE WQS FOR TEMPERATURE

♦ DENOTES 24-HOUR LOAD ALLOCATION (LA) NEEDED TO ACHIEVE SURFACE WQS WITH A 10 PERCENT MARGIN OF SAFETY

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

259.4 joules/meter^2/second (current condition) –
208.96 joules/meter^2/second (LA) =

50.44 joules/meter^2/second</td><td>*+230.58
joules/meter^2/second</td><td>20</td><td>8</td><td>Minimum 6.63
Mean 13.22
Maximum 19.82</td></tr>
<tr><td>*+233.46
joules/meter^2/second</td><td>19</td><td>6</td><td>Minimum 6.74
Mean 13.34
Maximum 19.94</td></tr>
<tr><td>Actual Load Allocation
♦+208.96
joules/meter^2/second</td><td>27.5</td><td>8</td><td>Minimum 6.39
Mean 12.61
Maximum 18.83</td></tr>
</table>

Table 4.2. SSTEMP Model Results for the Rio Vallecitos

<table>
<tr><th>Rosgen Channel Type</th><th>WQS (HQCWF)</th><th>Model Run Dates</th><th>Segment Length (mi)</th><th>Solar Radiation Component per 24 Hours (+/-)</th><th>Percent Total Shade</th><th>Width’s A Term</th><th>Modeled Temperature °C (24 hour)</th></tr>
<tr><td>B</td><td>20 °C
(68 °F)</td><td>August 16</td><td>36.31</td><td>Current Field Condition
+259.78 joules/meter^2/second</td><td>10.0</td><td>7.8</td><td>Minimum 7.49
Mean 14.50
Maximum 21.50</td></tr>
<tr><td colspan="4" rowspan="3">Stream Segment Temperature Model (SSTEMP) Results

TEMPERATURE ALLOCATIONS
FOR
Rio Vallecitos

* DENOTES 24-HOUR ACHIEVEMENT OF SURFACE WQS FOR TEMPERATURE

♦ DENOTES 24-HOUR LOAD ALLOCATION (LA) NEEDED TO ACHIEVE SURFACE WQS WITH A 10 PERCENT MARGIN OF SAFETY

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

259.78 joules/meter^2/second (current condition) –
201.19 joules/meter^2/second (LA) =

58.59 joules/meter^2/second</td><td>+230.92 joules/meter^2/second</td><td>20</td><td>7.8</td><td>Minimum 7.17
Mean 13.72
Maximum 20.27</td></tr>
<tr><td>*+223.7 joules/meter^2/second</td><td>22.5</td><td>7.0</td><td>Minimum 7.09
Mean 13.53
Maximum 19.96</td></tr>
<tr><td>Actual Load Allocation
♦+201.19 joules/meter^2/second</td><td>30.3</td><td>7.8</td><td>Minimum 6.85
Mean 12.89
Maximum 18.94</td></tr>
</table>

Table 4.3. Calculation of TMDL for Temperature

Location	WLA ($j/m^2/s$)	LA ($j/m^2/s$)	MOS (10 percent)* ($j/m^2/s$)	TMDL ($j/m^2/s$)
Polvadera Creek	0	208.96	23.3	233.46
Rio Vallecitos	0	201.19	22.4	223.7

* Actual MOS values may be slightly greater than 10 percent 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 percent.

The load reductions that would be necessary to meet the target loads were calculated to be the difference between the calculated target load allocation and the measured load (i.e., current field condition in Tables 4.1 and 4.2), and are shown in Table 4.4.

Table 4.4. Calculation of Load Reduction for Temperature

Location	Load Allocation ($j/m^2/s$)	Measured Load ($j/m^2/s$)	Load Reduction ($j/m^2/s$)
Polvadera Creek	208.96	259.4	50.44
Rio Vallecitos	201.19	259.78	58.59

Identification and Description of Pollutant Sources

Potential pollutant sources are listed for each segment in Table 4.5.

Table 4.5. Pollutant Source Summary for Temperature

Pollutant Sources	**Magnitude** (Load Allocation + MOS)	**Location**	**Potential Sources** (percent from each)
Point: None (0 percent)	0	--------	
Nonpoint: (100 percent) Temperature (expressed as solar radiation)		Polvadera Creek Rio Vallecitos	Removal of Riparian Vegetation Removal of Riparian Vegetation Streambank Modification/Destabilization Recreational Activities Rangeland

Linkage Between Water Quality and Pollutant Sources

Temperature is always a factor affecting aquatic organism. 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 the 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). In a discussion of temperature requirements for endangered western native trout, Behnke and Zarn (1976) 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 resulting in 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. 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 from 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 along this reach that exceed the state standards for the protection of aquatic habitat, namely the HQCWF designed use. Through monitoring, and pollutant source documentation, it has been observed that the most probable causes of these temperature exceedances are the alteration of the stream’s hydrograph, removal of riparian vegetation, and livestock grazing. Alterations can be historical or current in nature.

A variety of factors impact stream temperature (Figure 4.3). 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 caused stream channels to widen. 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 a 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.

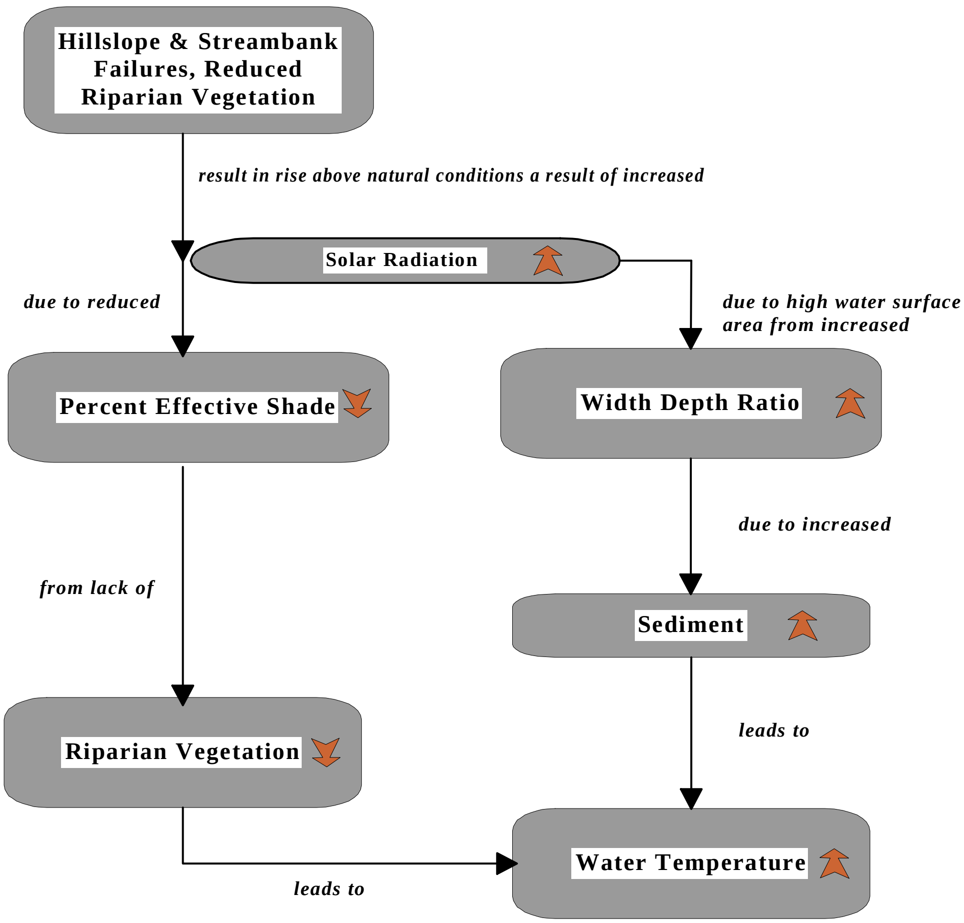


Figure 4.3. Factors That Impact Water Temperature

Riparian vegetation, stream morphology, hydrology, climate, geographic location, and aspect (exposure) 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 Lower Chama watershed result from the following conditions:

1. Channel widening (i.e., increased width-to-depth ratios), which has increased the stream surface area exposed to incident solar radiation
2. Riparian vegetation disturbance, which has reduced stream surface shading and riparian vegetation height and density
3. Reduced summertime base flows, which result from in-stream 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 base flows. 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 New Mexico water quality standards. 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 using the best available information.

SWQB fieldwork includes an assessment of the potential sources of impairment (SWQB/NMED 1999). The Pollutant Source(s) Documentation Protocol form and Potential Sources Summary Table in Appendix D 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 4.5 (Pollutant Source Summary) 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, which is predominantly privately held, but also the upland and upstream areas in a more holistic watershed approach to implementing this TMDL.

The primary sources of impairment for the reaches identified in the state CWA Integrated §303(d)/§305(b) list are the following:

Polvadera Creek: Removal of Riparian Vegetation

Rio Vallecitos*:* Agriculture, Resource Extraction, Hydromodification, Road Maintenance or Runoff, Removal of Riparian Vegetation, and Streambank Modification/Destabilization

Polvadera Creek
There was one sampling station along this reach. Field notes indicate that at this sampling station the reach had no vegetative overstory, had trash (cars) in the creek, and was overgrazed by many cows. Notes also indicate natural springs are feeding the reach throughout the system (see Photo 2.3).

Rio Vallecitos
The Rio Vallecitos was sampled at two stations along the reach. Exceedances of temperature were found at both stations, although a greater number were found at the lower station. Field notes indicate that the upstream site (Rio Vallecitos 8.4 miles above Vallecitos at river crossing) is in good condition, although there is some channelization

and berms alongside the stream. The stream passes through irrigated pasture, some rural development, and historic placer and gypsum mining sites. At the lower station the stream widens, although the riparian vegetation is abundant and the stream substrate consists of boulders with little embeddedness.

4.3 Margin of Safety (MOS)

The Federal Clean Water Act (CWA) requires that each TMDL be calculated with a margin of safety. This statutory requirement that TMDLs incorporate a margin of safety 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 margin of safety 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 margin of safety may be implicit, using conservative assumptions for calculation of the loading capacity, waste load allocations and load allocations. The margin of safety may also be explicitly stated as an added separate quantity in the TMDL calculation.

For this TMDL, there will be no margin of safety 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 to capture the seasonality of temperature exceedances.
- 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 two formulas developed by the USGS. One formula (USGS 1993) 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 this range, a different regression formula is used (Borland 1970). See Appendix F for details.

As detailed in section 4.2, 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 percent** is assigned to this TMDL.

4.4 Consideration of Seasonal Variation

Section 303(d)(1) of the CWA requires TMDLs to be “established at a level necessary to implement the applicable water quality standard 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 New Mexico water quality standards in summer and early fall. Warmest stream temperatures correspond 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 in-stream temperatures. It is assumed that if critical conditions are met, any potential seasonal variation will therefore be covered.

4.5 Future Growth

Estimates of future growth do not indicate a significant increase in stream temperature that cannot be controlled with the implementation of BMPs implementation in this watershed.

5.0 ALUMINUM

5.1 Summary

During the 1999 SWQB intensive water quality survey in the Lower Rio Chama watershed, exceedances of the New Mexico water quality standard for chronic aluminum were documented at two sampling stations, one on Cañones Creek and one on the Rio Vallecitos (SWQB Stations 21 and 28, see Table 1.1). Consequently, these reaches were listed on the 2000–2002 CWA Integrated §303(d)/§305(b) list for chronic aluminum.

5.2 Endpoint Identification

Target Loading Capacity

Target values for this chronic aluminum 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 dissolved aluminum are based on numeric criteria. This TMDL is also consistent with New Mexico's antidegradation policy.

According to the New Mexico water quality standards (20.6.4.900.M NMAC), the dissolved aluminum chronic criterion is 87 µg/L (0.087 mg/L) and the dissolved aluminum acute criterion is 750 µg/L (0.75 mg/L) for aquatic life uses.

High chronic levels of dissolved aluminum can be toxic to fish, benthic invertebrates, and some single-celled plants. Aluminum concentrations from 100 to 300 µg/L increase mortality, and retard the growth, gonadal development, and egg production of fish (http://h2osparc.wq.ncsu.edu). To be conservative, these TMDLs were written for chronic aluminum and, therefore, should also protect against any acute exceedances of the aluminum standard.

Data were collected from both Cañones Creek and the Rio Vallecitos at two stations, with only the lower stations on both creeks showing any exceedances of the aluminum criteria (see Table 5.1). These stations were sampled eight times over varying flow regimes between April 19 and October 6, 1999. Dissolved aluminum concentrations exceeded the chronic criterion for aluminum during spring sampling (high flows), and once on Cañones Creek in October (low flows). The calculated dissolved aluminum 4-day average during the spring sampling run was 0.2 mg /L on Cañones Creek and 0.6 mg /L on Rio Vallecitos. Two exceedances of the acute standard were found at the station Rio Vallecitos 3.9 miles above La Madera at bridge on April 19 and 20, 1999. Aluminum exceedances were not detected at these two stations during the summer and only once on Cañones Creek during fall (low flows) of 1999. Total suspended solids (TSS) data were collected at that time and are given in Table 5.1. These data will be discussed in the Linkage section below.

Table 5.1 Dissolved Aluminum (Al) and Total Suspended Solids (TSS) Concentrations for Cañones Creek and the Rio Vallecitos

Site	Date (YYMMDD)	Chronic aluminum Standard (mg/L)	Field Dissolved Aluminum Measures (mg/L)*	Field Total Suspended Solids (TSS) Measures (mg/L)
Cañones Creek at Forest Road 167 below Canones	990419	.087	.22	14
Cañones Creek at Forest Road 167 below Canones	990421	.087	.09	58
Cañones Creek at Forest Road 167 below Canones	990422	.087	.28	83
Cañones Creek at Forest Road 167 below Canones	991006	.087	.3	121
Rio Vallecitos 3.9 miles above La Madera at bridge	990419	.087	.9	8
Rio Vallecitos 3.9 miles above La Madera at bridge	990420	.087	.8	14
Rio Vallecitos 3.9 miles above La Madera at bridge	990421	.087	.6	21
Rio Vallecitos 3.9 miles above La Madera at bridge	990422	.087	.31	9

*The arithmetic means of the dissolved aluminum values that exceeded the standard are 0.22 mg/L for Cañones Creek and 0.65 mg/L for Rio Vallecitos.

Flow

TMDLs are calculated for Cañones Creek and the Rio Vallecitos at a specific flow. Metal concentrations in a stream vary as a function of flow. As flow increases, the concentration of metals can increase. When available, USGS gages are used to estimate flow. Where gages are absent, geomorphologic cross-sectional field data are collected at each site and flows are modeled or actual flow measurements are taken. In this case, flows were measured on both reaches during the spring sampling run using standard USGS procedures (SWQB/NMED 2001b). The measured flow values are found in Tables 5.2 and 5.3.

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 should be a goal to be attained. Meeting the calculated target load may be a difficult objective.

Calculations

A target load for chronic aluminum is calculated based on a flow, the current water quality criterion, and a conversion factor (8.34) that is used to convert mg/L units to pounds per/day (see Appendix C for the conversion factor derivation). The target loading capacity is calculated using Equation 1. The results are shown in Table 5.2.

Equation 1. critical flow (mgd) x standard (mg/L) x 8.34 (conversion factor) = target loading capacity

Table 5.2. Calculation of Target Loads for Chronic Dissolved Aluminum

Location	Flow+ (MGD)	Dissolved Al chronic criterion (mg/L)	Conversion Factor	Target Load Capacity (lbs/day)
Cañones Creek	6.9	0.087	8.34	5.0
Rio Vallecitos	7.2	0.087	8.34	5.2

+ Since USGS gages were unavailable, flow was measured during the 1999 spring, or highest flowing, sampling run (SWQB/NMED 2001a) Canones on 4/20/99 and Rio Vallecitos on 7/28/99 and used in the TMDL calculations.

The measured loads for dissolved aluminum were similarly calculated. In order to achieve comparability between the target and measured loads, the same flow value was used for both calculations. The geometric mean of the collected data that exceeded the standards was substituted for the standard in Equation 1. The same conversion factor of 8.34 was used. The results are presented in Table 5.3.

Table 5.3. Calculation of Measured Loads for Chronic Dissolved Aluminum

Location	Flow+ (MGD)	Dissolved Al Arithmetic Mean* (mg/L)	Conversion Factor	Measured Load Capacity (lbs/day)
Cañones Creek	6.9	0.22	8.34	12.7
Rio Vallecitos	7.2	0.65	8.34	39.0

+ Since USGS gages were unavailable, flow was measured during the 1999 spring, or highest flowing, sampling run (SWQB/NMED 2001a) Canones on 4/20/99 and Rio Vallecitos on 7/28/99.
* Arithmetic mean of dissolved aluminum exceedances (see the note in Table 5.1).

Waste Load Allocations and Load Allocations

• *Waste Load Allocation*
There are no point source contributions associated with this TMDL. The waste load allocation (WLA) is therefore zero.

• *Load Allocation*

To calculate the load allocation (LA), the waste load allocation (WLA) and margin of safety (MOS) were subtracted from the target capacity (TMDL) following Equation 2.

Equation 2. $WLA + LA + MOS = TMDL$

The margin of safety is estimated to be 20 percent of the target load calculated in Table 5.2. The results are presented in Table 5.4. Additional details on the margin of safety chosen are presented in Section 5.3.

Table 5.4. Calculation of TMDL for Chronic Dissolved Aluminum

Location	WLA (lbs/day)	LA (lbs/day)	MOS (20 percent) (lbs/day)	TMDL (lbs/day)
Cañones Creek	0	4	1	5.0
Rio Vallecitos	0	4.16	1.04	5.2

The extensive data collection and analyses necessary to determine background dissolved aluminum loads for Cañones Creek and the Rio Vallecitos watersheds were beyond the resources available for this study. It is therefore assumed that a portion of the load allocation is made up of natural background loads.

The load reductions that would be necessary to meet the target loads were calculated to be the difference between the calculated target load allocation (Tables 5.2 and 5.4) and the measured load (Table 5.3), and are shown in Table 5.5.

Table 5.5 Calculation of Load Reduction for Chronic Dissolved Aluminum

Location	Target Load Allocation (lbs/day)	Measured Load (lbs/day)	Load Reduction (lb/day)
Cañones Creek	5.0	12.7	7.7
Rio Vallecitos	5.2	39.0	33.8

Identification and Description of Pollutant Sources

Potential sources of pollutant are listed for each segment in Table 5.6.

Table 5.6. Pollutant Source Summary for Chronic Dissolved Aluminum

Pollutant Sources (percent from each)	**Magnitude** (Load Allocation + MOS)	**Location**	**Potential Sources**
Point: None (0 percent)			None

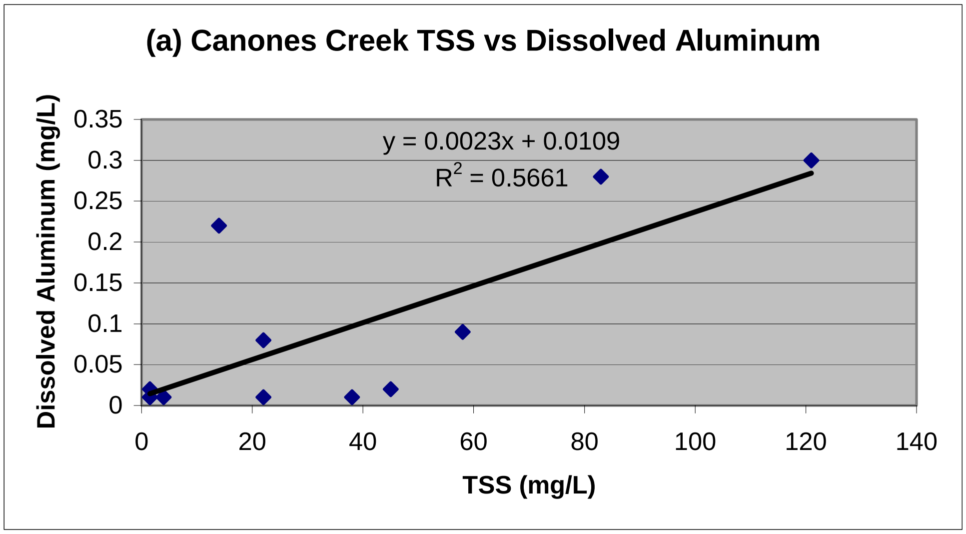
Nonpoint: (100 percent) Chronic dissolved aluminum	5.0 5.2	Cañones Creek Rio Vallecitos	Natural and Unknown Resource Extraction and Hydromodification

Linkage Between Water Quality and Pollutant Sources

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

SWQB fieldwork includes an assessment of the potential sources of impairment (SWQB/NMED 1999). The Pollutant Source(s) Documentation Protocol form and Potential Sources Summary Table in Appendix D 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 5.6 (Pollutant Source Summary) 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, which is predominantly state and privately managed land, but also on the upland and upstream areas in a more holistic watershed approach to implementing this TMDL.

Aluminum is the most common metal in the Earth's crust and the third most common element. Aluminum comprises, on average, about 8 percent of the Earth's crust. In general, increased aluminum in the water column can commonly be linked to sediment transport and accumulation, where the aluminum is a constituent part of the sediment. This appears to be somewhat the case in Cañones Creek and the Rio Vallecitos as evidenced by the fact that there is a relationship between dissolved aluminum and total suspended sediment concentrations (TSS) according to the 1999 sampling data (see Figure 5.1 a and b).



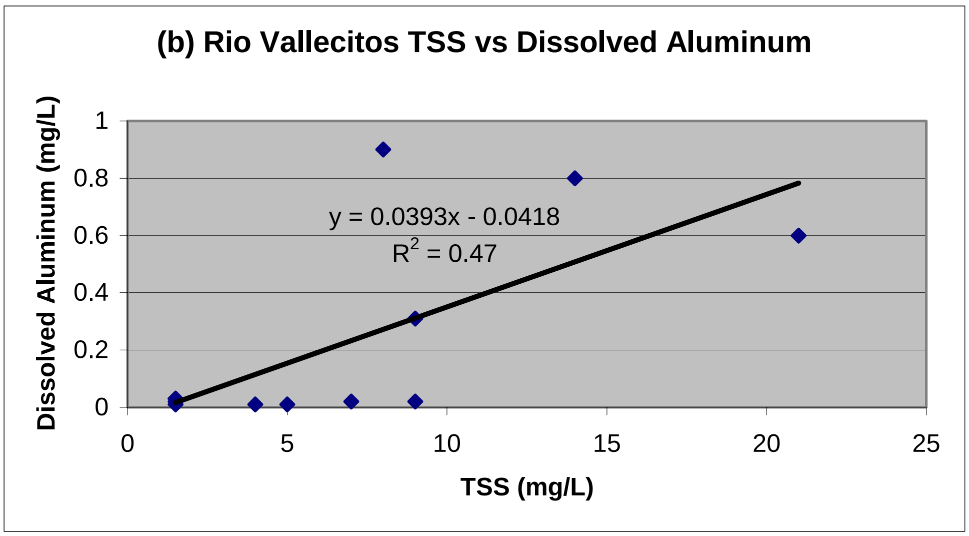


Figure 5.1(a) and (b.) Relationship Between TSS and Dissolved Aluminum in Cañones Creek (a) and the Rio Vallecitos (b).

High aluminum is characteristic of the spring snowmelt/runoff period and is not pronounced during base flow conditions in both Cañones Creek and the Rio Vallecitos. Normal aqueous chemical processes, enhanced by the slight natural acidity of snow and rain, are capable of making some of this abundant, naturally-occurring aluminum available to the stream system. The fact that high dissolved aluminum concentrations were found during the spring sampling run as opposed to generally below detection limit concentrations during summer and fall sampling runs, is indicative of a landscape source. Acidic anions as well as carbonic acid carried in snow are released into the soil as the snow melts and bring aluminum species into solution. Thus, aluminum concentrations are often high during spring runoff in many areas in New Mexico despite the expected diluting effects of high flow. The exceedance during fall on Cañones Creek is most likely associated with high suspended sediment levels in that sample.

5.3 Margin of Safety (MOS)

TMDLs should reflect a margin of safety based on the uncertainty or variability in the data, the point and nonpoint source load estimates, and the modeling analysis. For this TMDL, there is no margin of safety for point sources, since there are none. However, for nonpoint sources the margin of safety is **20 percent** of the sum of the WLA and LA. This margin of safety is the sum of the following two elements:

- *Errors in calculating nonpoint source loads*
  A level of uncertainty exists in sampling nonpoint sources of pollution. Techniques used for measuring chronic aluminum concentrations in stream water are ±15 percent accurate according to the Quality Assurance Project Plan (SWQB/NMED 2001b). Accordingly, a conservative MOS for this element is **15 percent.**

- *Errors in calculating flow*
  Flow estimates were based on one measurement during the spring sampling run. Instrument and operator error can lead to inaccuracy in flow measurements. Accordingly, a conservative MOS for this element is **5 percent.**

5.4 Consideration of Seasonal Variation

Data used in the calculation of this TMDL were collected during the spring, summer, and fall of 1999 in order to ensure coverage of any potential seasonal variation in the system. Critical condition is set to high flow for dissolved aluminum because most data exceedances were measured during high spring flows. A flow measurement taken during the spring sampling run was used in the calculations.

5.5 Future Growth

Estimate of future growth do not indicate a significant increase of chronic aluminum that cannot be controlled with BMP implementation in this watershed.

6.0 Fecal Coliform

6.1 Summary

During the 1999 SWQB sampling monitoring effort in the Lower Rio Chama watershed, fecal coliform data showed several exceedances of the New Mexico water quality standard in Cañones Creek (see Table 6.1). Presence of fecal coliform bacteria is an indicator of the possible presence of other bacteria that may limit beneficial uses and present human health concerns. There are nonpoint sources of fecal coliform bacteria throughout the watershed that could be contributing to the fecal coliform levels. Two potential sources of fecal coliform bacteria have been identified in the Cañones Creek watershed. These sources include rangeland and onsite wastewater systems. Cañones Creek is listed on the 2002-2004 CWA Integrated §303(d)/§305(b) list with fecal coliform as a pollutant of concern.

Table 6.1. Results of Fecal Coliform Monitoring on Cañones Creek from 1991 Through 1999

Date	Cfu/100mL	Flow (cfs)
4/25/91	60	-----
4/22/99	**2,400**	10.74
7/28/99	**440**	3.34
10/6/99	73J	4.84

Bolded values indicate an exceedance of the standard.
J indicates that the value was estimated.

6.2 Endpoint Identification

Target Loading Capacity

Overall, the target values for fecal coliform 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 fecal coliform are based on numeric criteria.

Fecal Coliform

Cañones Creek is in the standard segment defined in 20.6.4.119 NMAC (formerly 2116), which reads:

> All perennial reaches of tributaries to the Rio Chama above Abiquiu dam except the Rio Gallina and Rio Puerco de Chama north of state highway 96 and the main stem of the Rio Chama from the headwaters of El Vado reservoir upstream to the New Mexico-Colorado line.

The state's standard leading to an assessment of use impairment is the numeric criteria stating that "The monthly geometric mean of fecal coliform bacteria shall not exceed

100/100 mL; no single sample shall exceed 200/100 mL" for the appropriate designated use of a high quality coldwater fishery (HQCWF).

Flow

Fecal coliform numbers can vary as a function of flow. As seen in the 1999 data, exceedances of the criterion occurred at both high and low flows. However, since the exceedance was much greater at the higher flow and TMDLs are calculated for each reach at a specific flow. Accordingly, the target flow was set to high flow.

When available, USGS gages are used to estimate flow. Where gages are absent or poorly located along a reach, either actual flow (measured as water quality samples are taken) is used as target flows or geomorphologic cross-sectional information is taken to model the flows. Because there was no USGS gage station on Cañones Creek, the flow used for this TMDL was the highest flow taken during the field-sampling season (6.94 MGD, taken April 20, 1999) on this reach. 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 at water quality standards the target load will vary based on the changing flow (see Figure 6.1). Management of the load should set a goal attainment, not meeting the calculated target load.

Calculations

Fecal coliform standards are expressed as colonies per unit volume. Using the 30-day geometric mean criterion of 100 cfu/100 mL stream load can be calculated. The geometric mean criterion is utilized in these calculations because it is conservative. In addition, if the 200 cfu/100 mL standard was used as a target, the geometric mean criterion of 100 cfu/100 mL may not be reached. This is accomplished through application of the following conversion calculations.

Equation 1

C as cfu/100 mL * 1,000 mL/1 L * 1 L/ 0.264 gallons * Q in gallons/day = cfu/day

Where C = state water quality standard criterion,
Q = stream flow in gallons

Applying this conversion using the 100 cfu/100 mL criterion and using the stream flow of 6.94 MGD, the load may be expressed as follows:

100 cfu/100 mL * 1000mL/1 L * 1 L/ 0.264 gallons * 6940000 flow in gallons / day

This yields an assimilative loading limit in the stream of 2.629×10^{10} cfu/day at high flow.

Point sources usually have a defined critical low receiving stream flow such as a 4Q3 at which the criterion must be met. For nonpoint sources it is important to recognize that there may be no single critical flow condition. The water quality criterion may be exceeded during low flow but it is equally likely that criterion will be violated during wet weather events when pollution is washed off the land surface or re-suspended from contaminated sediments. To address this condition, and hopefully to increase the understanding of the TMDL load determination process, a fecal coliform loading curve has been generated (Figure 6.1). This line is developed using the Equation 1, substituting 100 cfu/100 mL, for fecal coliform concentration and varying flow values. To develop this curve for Cañones Creek flow values were estimated as a percentage of the drainage area of Cañones Creek draining to the Abiquiu Dam USGS gage. This provided multiple flow values per month over the last 40 years. It represents examples of both low and high flows from the watershed. This curve is not stream dependent but is dependent upon the designated stream criterion. Therefore, it may be applied to any stream with a like fecal coliform criterion with this range of flows. This curve represents the TMDL loading allocation for fecal coliform on Cañones Creek.

The loading capacity line is shown in Figure 6.1. For any flow value x, one can quickly determine the fecal coliform loading value. For ease in dealing with very large numbers generated from fecal coliform loading conversions, the y-value (fecal coliform concentrations), is expressed as the log 10 transformation of the fecal coliform concentration. The line formed by this series of points may be thought of as a boundary. At any given flow the loading may be below the line, within the boundary, or above the line. Fecal coliform load values falling above the line represent disproportionately high values related to the standard. Fecal coliform load values falling below the line represent low loads relative to the standard.

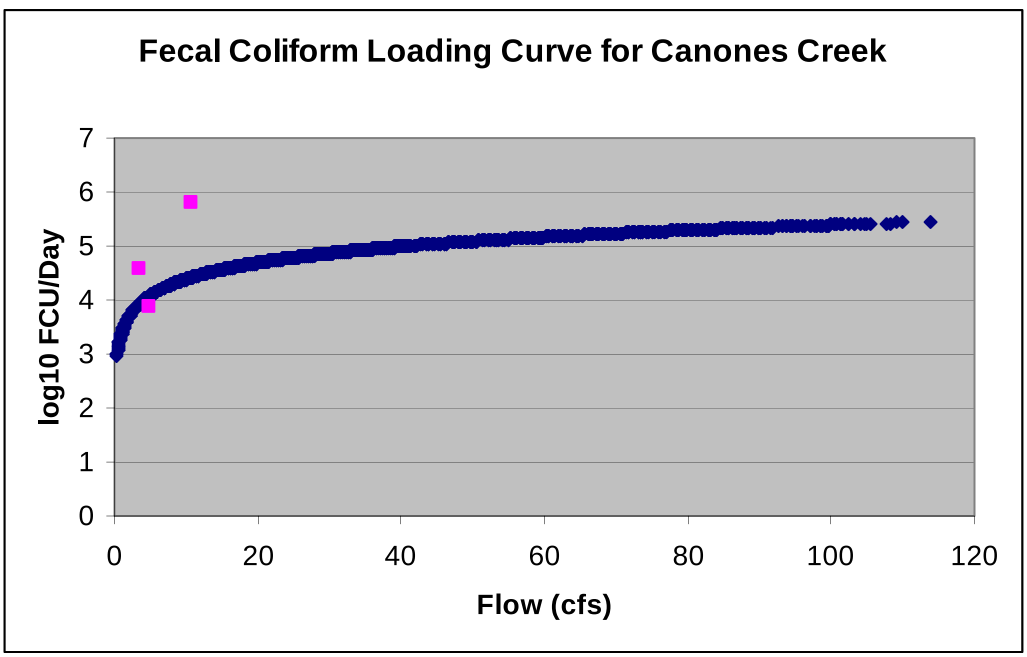


Figure 6.1. Fecal Coliform Loading Curve for Cañones Creek

Waste Load Allocations and Load Allocations

• *Waste Load Allocation*

There are no point source contributions associated with this TMDL. The waste load allocation is therefore zero.

• *Load Allocation*

The nonpoint source is calculated by subtracting the waste load allocation and the margin of safety from the final allowable capacity.

$$TMDL = WLA + LA + MOS$$
$$LA = TMDL – WLA – MOS$$
$$LA = 2.629 \times 10^{10} - 0 - 1.3 \times 10^{9}$$
$$LA = 2.5 \times 10^{10}$$

This allocation can be converted to a target concentration limit using the conversion formula:

$$2.629 \times 10^{10} \text{ cfu/day} * 1 \text{ day}/6940000 \text{ gal} * 0.264 \text{ gal}/1 \text{ L} * .1 \text{ L}/100 \text{ mL}$$

This yields a target 30-day geometric mean of 100 cfu/100 mL. With current levels reaching 2,400 cfu/100 mL in the most recent evaluations, a current measured load of fecal coliform in the watershed is been 6.3×10^{11} cfu/day. To reach the target load, a reduction of 6.0×10^{11} cfu/day in nonpoint source contributions must be achieved (see Table 6.3).

The margin of safety is estimated to be 5 percent of the target load. Results are presented in Table 6.2. Additional details on the chosen margin of safety are presented in section 6.3 below.

Table 6.2 Calculation of TMDL for Fecal Coliform

Location	WLA (cfu/day)	LA (cfu/day)	MOS (5 percent) (cfu/day)	TMDL (cfu/day)
Cañones Creek	0	2.5×10^{10}	1.3×10^{9}	2.629×10^{10}

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

The load reduction that would be necessary to meet the target load was calculated to be the difference between the calculated TMDL (Table 6.2) and the measured load, and is shown in Table 6.3.

Table 6.3. Calculation of Load Reduction for Fecal Coliform

Location	TMDL (cfu/day)	Measured Load (cfu/day)	Load Reduction (cfu/day)
Cañones Creek	2.629×10^{10}	6.3×10^{11}	6.0×10^{11}

It is important to note that these load allocations are estimates based on a high flow condition. It is conceivable, due to differing hydrologic conditions that lesser loads may not exceed water quality standards. Likewise, it is possible that greater load conditions could exceed the water quality standards under certain hydrologic conditions. For this reason the load allocations given here are less meaningful than are the relative percentage reductions. Compliance with this TMDL will be determined based on achieving the nonpoint source 30-day geometric mean of 100 cfu/100 mL.

Identification and Description of Pollutant Sources

Table 6.4 Pollutant Source Summary

Pollutant Sources (percent from each)	**Magnitude** (WLA + LA + MOS)	**Location**	**Potential Sources**
Point: (0 percent)	0		None
Nonpoint: (100 percent) • Fecal Coliform		Cañones Creek	Rangeland and Onsite Wastewater Systems

Linkage Between Water Quality and Pollutant Sources

SWQB fieldwork includes an assessment of the potential sources of impairment (SWQB/NMED 1999). The Pollutant Source(s) Documentation Protocol form and Potential Sources Summary Table in Appendix D provides an approach for a visual analysis of a pollutant source 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 6.4 (Pollutant Source Summary) identifies and quantifies potential sources of nonpoint source impairments along the reach as determined by field reconnaissance and assessment. A further explanation of the sources follows.

Cañones Creek

The primary sources of impairment along this reach have been identified as rangeland and on-site wastewater systems. Notes from field visits in 2002 documented bank erosion and cattle grazing in the riparian zone.

According to the Water Quality Survey of this watershed (SWQB/NMED 1991), activities that may contribute to water quality impairments are livestock grazing, recreation, and silviculture. In addition, the Cañones Creek sampling station was also located below the town of Canones and below the irrigation return flows of this community.

Additional fecal coliform sampling would need to be conducted to more fully characterize sources of fecal coliform bacteria in the Cañones Creek watershed. However, sufficient data exist to support development of a fecal coliform TMDL to address the stream standards violations.

6.3 Margin of Safety (MOS)

TMDLs should reflect a margin of safety based on the uncertainty or variability in the data, the point and nonpoint source load estimates, and the modeling analysis. For this TMDL, there will be no margin of safety for point sources, since there are none. Also, for the nonpoint sources the margin of safety is estimated to be primarily implicit with MOS is 5% of the sum of the WLA and LA for Cañones Creek. This margin of safety is sum of the following two elements:

- *Conservative Assumptions*

  A conservative assumption, treating fecal coliform as a conservative pollutant, that is a pollutant that does not readily degrade in the environment, was used in developing these loading limits.

  Using a more conservative limit of 100 cfu/100 mL, when the standard allows up to 200 cfu/100 mL for individual grab samples, to calculate loading values.

- *Errors in calculating flow*

  Flow estimates were based on actual flows measured in the field at the time of sampling. A conservative MOS for this element is **5 percent**.

6.4 Consideration of Seasonal Variability

During the 1999 water quality survey, fecal coliform exceedances occurred during both high and low flow events. There is no single critical condition for fecal coliform. Higher flows may flush more nonpoint source runoff containing fecal coliform. It is possible the criterion may be exceeded under a low flow condition when there is insufficient dilution of the point source. Evaluation of seasonal variability for potential nonpoint sources is difficult due to limited available data. However, some observations may be made from the available data. Samples collected during the warm weather or high flow period in 1999 yielded high fecal coliform levels. Samples collected in October 1999, which is beyond the warm weather season, yielded lower fecal counts. This allows inference that seasonal inputs may account, in part, for the elevated fecal counts. Additional information will be needed to support or refute this observation. Because of the uncertainty involved, there will be no seasonal allocations for fecal coliform in this TMDL.

6.5 Future Growth

Since most (94 percent) of this watershed is managed by the USFS, it is not likely that growth will occur and lead to a significant increase for fecal coliform, other than a natural increase, that cannot be controlled with best management practice implementation in this watershed.

7.0 Dissolved Oxygen

7.1 Summary

The Abiquiu Creek watershed is approximately 45 square miles. The main stem of Abiquiu Creek, from the mouth on Rio Chama to its headwaters, is approximately 12.93 miles long and a major tributary, Vallecitos Creek, is 5.7 miles in length. During the 1999 SWQB sampling monitoring effort in the Lower Rio Chama watershed, dissolved oxygen (DO) data showed several violations of the New Mexico water quality standard in Abiquiu Creek (see Table 7.1 a). Data were also collected on July 24–25, 2002 using a data sonde (see Table 7.1 b for the statistical data summary and Appendix G for the complete data set). Abiquiu Creek is listed on the 2002-2004 CWA Integrated §303(d)/§305(b) list with dissolved oxygen as a pollutant of concern.

Table 7.1 (a). Results of Dissolved Oxygen Monitoring on Abiquiu Creek at Highway 84 from 1999 Grab Samples

Date	DO (mg/L)	Flow (cfs)
4/19/99	7.1	---
4/20/99	9.0	0.51
4/21/99	7.4	---
4/22/99	7.9	---
7/27/99	**5.0**	---
7/28/99	**3.8**	0.18
9/24/99	8.8	---
10/05/99	6.4	0.251
10/6/99	6.7	---

Bolded values violate the DO standard of 6.0 mg/L.

Table 7.1 (b). Summary Table Results of Dissolved Oxygen Monitoring on Abiquiu Creek from 2002 Data Sonde

```
                  ABIQUIU CREEK
                -- Statistical Report --
==========================================================
>From 07/24/02 17:00 to 07/25/02 05:15
Number of samples: 50
----------------------------------------------------------
Parameter                  Min        Max       Mean       Std
----------------------------------------------------------
Temp (C)                 16.71      23.69      19.19      1.67
SpCond (mS/cm)           0.201      0.247      0.217     0.015
DO Conc (mg/L)            2.47       6.66       5.40      1.27
pH ()                     7.93       8.40       8.10      0.12
DO percent (percent)      26.5       78.6       58.5      14.2
==========================================================
```

The initial step in selecting the appropriate analytical tool for this analysis was to perform an analysis to correlate the impairment to basic causes such as nonpoint contributions, flow conditions, stream and watershed characteristics, seasonal temperature effects, and others. The analysis revealed that the impairment coincides with low flows, slow stream velocities, and shallow water depths.

The steady-state QUAL2E model was selected for the following reasons:

- The critical low flow condition can be reasonably assumed to be steady state.
- The model conforms to the standard practices for developing wasteload allocations.
- It can be developed with a limited data set.
- It can handle branching tributaries.
- It has an established history in modeling dissolved oxygen for TMDLs.

Model Framework
QUAL2E is a comprehensive water quality model developed under a cooperative agreement between Tufts University's Department of Civil Engineering and U.S. EPA's Center for Water Quality Modeling, Environmental Research Laboratory, Athens, Georgia, in the late 1970s. It has been used nationwide and is supported by USEPA. The mass transport processes are described by the one-dimensional finite difference advection-dispersion mass transport equation that includes the effects of advection, dispersion, dilution, constituent reactions and interactions, and sources and sinks.

The model is a steady-state daily average model that uses a modified Streeter-Phelps DO equation. The Streeter-Phelps equation ties together two mechanisms governing DO in a stream: decomposition of organic material and oxygen reaeration. The QUAL2E model simulates ultimate carbonaceous biochemical oxygen demand (CBODu) decay, nitrification, and reaeration. Although the model can simulate algal photosynthesis and respiration, they were omitted for this application because data on and knowledge of algal growth in Abiquiu Creek were not available. An algal assay, done as part of the nutrient assessment and completed on July 24, 2002, by SWQB staff, showed only moderate productivity and did not indicate a nutrient impairment in this reach. Reaction rates for the in-stream processes are input by the user and corrected for temperature by the model. The model output includes water quality conditions in each computational element for DO, CBODu, and ammonia nitrogen (NH_3-N) concentrations. Refer to the users manual document for a more detailed discussion of simulated processes and model parameters (Brown and Barnwell 1987).

Model Configuration
Model configuration involved setting up the model computational grid and setting initial conditions, boundary conditions, and hydraulic and kinetic parameters for the hydrodynamic and water quality simulation. This section describes the configuration and key components of the model.

Computational Grid Setup

The model of Abiquiu Creek includes the CWA Integrated §303(d)/§305(b) listed portion (mainstem) from its headwaters to the Rio Chama, and Vallecitos Creek. Vallecitos Creek is not listed for DO impairment, but it carries flow from a large portion of the watershed, approximately 28.5 square miles, and merges with the mainstem at 3.3 miles from the mouth. The creek was divided into sections called reaches to provide hydrologic ordering of the stream. These reaches begin or end where changes occur in the hydrology of the waterbody in order to maintain hydrologic connectivity. River miles were assigned to the waterbody, beginning with zero at the mouth. Within each reach, the modeled segments were divided into computational elements of 0.3 mile. The hydrologic and water quality characteristics were calculated by the model for each computational element. Figure 7.1 is a representation of the model domain.

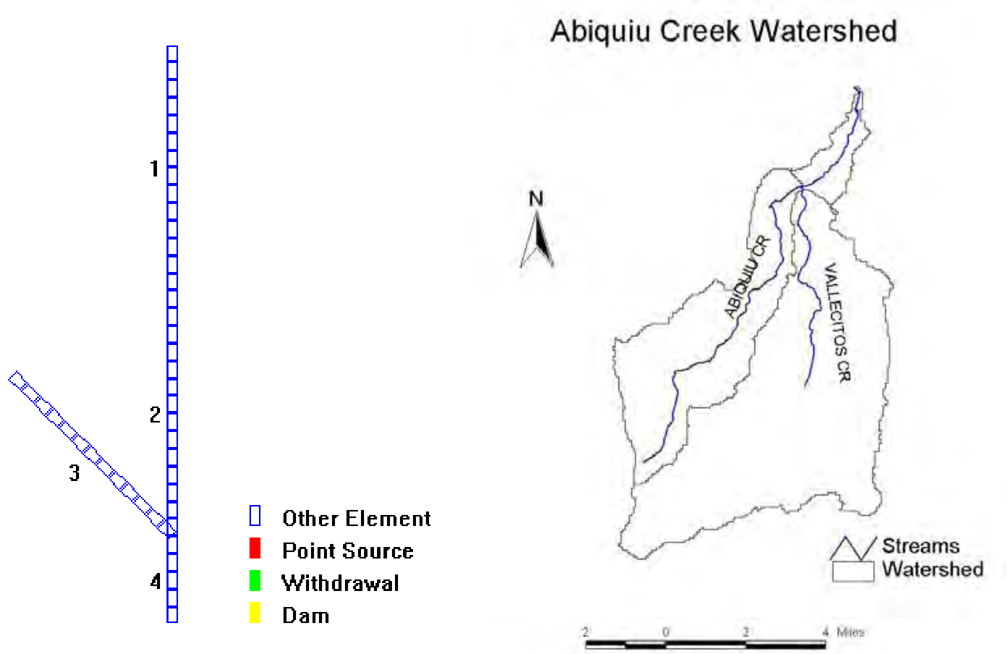


Figure 7.1. Computational Grid and Location Map of Abiquiu Creek and Tributary

7.2 Endpoint Identification

Target Loading Capacity

The target values for dissolved oxygen TMDLs are 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 dissolved oxygen are based on numeric criteria.

Dissolved Oxygen

Abiquiu Creek falls into the standard segment defined in 20.6.4.116 NMAC (formerly 2113), which reads:

> The Rio Chama from its mouth on the Rio Grande upstream to Abiquiu reservoir, the Rio Tusas, the Rio Ojo Caliente, Abiquiu Creek, and El Rito Creek below the town of El Rito.

According to the State's standard, this creek has the designated uses of irrigation, livestock watering, wildlife habitat, coldwater fishery, warmwater fishery, and secondary contact (20.6.4.116 NMAC). The numeric criteria for DO to meet the designated use of a coldwater fishery is that "DO shall not be less than 6.0 mg/L" (20.6.4.900 NMAC).

Many factors influence DO concentrations, including

- Input and oxidation of carbonaceous material (CBODu)
- Input and oxidation of nitrogenous material (NBODu)
- Input and oxygen demand of sediments in the waterbody (SOD)
- Reaeration

The pollutant of concern is biochemical oxygen demand, both carbonaceous (CBODu) and nitrogenous (NBODu), which is expressed in terms of total ultimate biochemical oxygen demand (TBODu). The equation below shows this relationship. The TMDL will be expressed in terms of TBODu, based on the waterbody's assimilative capacity for oxygen-demanding substances.

$$TBODu = CBODu + NBODu$$

Where:

$$5\text{-day CBOD} * 2.54 = CBODu$$

$$\text{Total Kjedahl Nitrogen}*4.57 = NBODu$$

Over the time scale of years, stream bottom sediments act as sinks for oxygen, with carbon and nitrogen removed from the water column (Chapra 1997, Thomann and Mueller 1987). Oxygen is consumed by the oxidation of organic carbon (CBODu) and by the nitrification of ammonia (NBODu) in the bottom sediment. This process is known as sediment oxygen demand (SOD). The role of sediments in the system-wide nutrient budget is especially important during the summer when seasonal low flows diminish tributary nutrient loads. During the summer, warm temperatures enhance biological processes in the sediments (USEPA 1993).

Oxygen-consuming constituents from nonpoint source pollution are delivered to the stream during storm events. Sources can include runoff from fields and leaf litter or plant material from riparian zones. These constituents settle out of the stormwater and become a part of the stream bottom. In slow flowing streams with a high bed-to-channel-volume ratio, large portions of the organic material will settle to the sediment surface and thus increase the SOD. Washoff of settable material (CBODu and NBODu) accumulates and exerts an additional SOD attributable to land-disturbing activities. A stream impacted by heavy loads of oxygen-consuming pollutants, either natural or man-made, will exhibit low DO concentrations during warm low flow periods (Wood 2001; Thomann et al. 1994, Thomann and Mueller 1987, Congalton 1998, and Chapra 1997).

There have been numerous studies for establishing a SOD/TBODu relationship. According to the Streeter-Phelps SOD model, SOD is approximately 130 percent of the downward flux of TBODu (Chapra, 1997) and the TMDL will employ the following relationship to link TBODu and SOD.

SOD = 1.3 * TBODu

Model Parameters

The DO impairment was identified and listed based on the field data collected in 1999. The data were collected at a downstream location (at US 84 highway bridge), 0.3 mile from the river mouth. Among the observed three seasons, spring, summer, and fall, the DO impairment was observed only in the summer under a low flow condition. Since a stream is affected by heavy loads of oxygen-consuming pollutants, either natural or man-made, it will exhibit low DO concentrations during warm low flow periods due to high SOD, the critical condition for this TMDL was selected a summer low flow condition. During thermograph deployment on June 10, 2002, no measurable flow was recorded in Abiquiu Creek. There is no long-term data to represent the critical condition for Abiquiu Creek. In the absence of this data, the observed low flow condition on 07/28/99 was therefore assumed to be representative of critical conditions in the creek during the summer low-flow period. Best professional judgments were made to set the initial conditions for 5-day CBOD and groundwater DO concentration, in which no observed data are available.

Initial conditions based on observations from Abiquiu Creek

- Model temperature was set to 21.7 ºC as observed on 07/28/99.
- Dissolved oxygen was set to 90 percent saturation (6.3 mg/L) for inflow based on the observed temperature and elevation of Abiquiu Creek.
- The observed low flow of 0.18 cfs on 07/28/99 was set as the critical stream flow. Based on the critical stream flow, 0.004 cfs/sq.mile (per area flow) was used to estimate the low flow in the reaches and tributary. The flow was distributed by area over the watershed.
- Instream Organic-N, NH_3-N, and NO_2-N were set to 0.2 mg/L, 0.1 mg/L, and 0.1 mg/L, respectively as observed on 07/28/99.

Initial conditions based on best professional judgment

- Ultimate Carbonaceous Oxygen Demand (CBODu) was assumed as 2.0 mg/L based on USGS observations of 5-day CBOD in Rio Chama on 6/3/1969 at 14:30 (USGS 8286500). Abiquiu Creek is a tributary of the Lower Rio Chama and the above-mentioned conditions were observed near the confluence of Abiquiu Creek with the

Rio Chama. The observations at Rio Chama (USGS 8286500) are at observed an altitude within 1000’ of the main stem Abiquiu Creek. Lower Chama has no point sources. Therefore, the 5-day CBOD in Rio Chama reasonably represents the initial condition of Abiquiu Creek, where the primary source of impairment is non-point sources.

- Abiquiu Creek is a sandy stream (lots of fines), and the oxygen replenishment in the interstitial places is very limited. In general, the groundwater entering the stream at this condition has a low concentration of DO (EPA 1991). Therefore, one can assume that the Abiquiu Creek has low DO concentration. As a conservative assumption, the DO of groundwater was assumed to be 2.0 mg/L.

Saturation DO is sensitive to elevation or atmospheric pressure and temperature. The QUAL2E model estimates the saturation DO based on the atmospheric pressure. The average elevation of Abiquiu Creek is approximately 6,500 feet. By comparing the historical July atmospheric pressure of adjacent climate records from Albuquerque International Airport (5,300 feet and 24.8 in inches of mercury), Farmington Four Corners (5,500 feet and& 24.6 in inches of mercury), and Alamosa San Luis Valley (7,500 feet and 23 in inches of mercury), the model atmospheric pressure was set to 24 in inches of mercury.

Coefficients are needed to describe the water quality reaction rates within the stream. Initial estimates were obtained from QUAL2E default values, general literature values (USEPA 1985), and from the QUAL2E user’s manual (Brown and Barnwell 1987). Water quality coefficients are presented in Table 7.2.

Table 7.2. Water Quality Calibration Rates and Coefficients

Parameter	Description	Units	Value
K1	Carbonaceous Biochemical Oxygen Deoxygenation Rate	1/day	0.1
CKNH2	Organic Nitrogen Hydrolysis	1/day	0.1
CKNH3	Ammonia Oxidation Rate	1/day	0.25
CKNO2	Nitrite Oxidation Rate	1/day	2.5

Channel hydraulics, reaeration rate, and SOD substantially influence the concentration of DO in the streams. Due to the lack of data for these parameters, the following assumptions were made:

- Based on field observation, the channel profile was assumed to be a parabolic.
- In sandy bottom streams, SOD values range from 0.2 to 1 g $m^{-2}d^{-1}$(Chapra 1997).)As Abiquiu creek is a sandy stream, the baseline (existing) SOD rate was set to 0.08 grams per square feet per day (0.86g $m^{-2}d^{-1}$).
- The reaeration rate is either set by the user or by formulas available in QUAL2E. As reported by USEPA (1985), many empirical formulas which estimate reaeration rate based on hydraulic parameters and/or flow work well within the depth range of 1 to 10 feet. The flow depth is less than 1 foot in Abiquiu Creek. Therefore, the reaeration coefficient was used as a calibration parameter of the Abiquiu DO model.

Assumptions

- No surface runoff driven nonpoint loadings are entering the stream during the low flow summer condition.
- The main cause of low DO during low flow is attributable to the SOD.
- A detailed assessment of channel geometry was not performed; therefore, stream velocities and channel depths were approximated.

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 at water quality standards the target load will vary based on the changing flow. Management of the load should set a goal attainment, not meeting the calculated target load.

Waste Load Allocations and Load Allocations

• *Waste Load Allocation*
There are no point source contributions associated with this TMDL. The waste load allocation is therefore zero.

• *Load Allocation*
The load allocation was determined using the QUAL2E model.

Model Results
Calibration was an iterative process. The model reaeration rate was adjusted until the model predictions fit the DO observation. In-stream DO data were collected at the US Highway 84 bridge, which is approximately 0.3 mile from the mouth. Although the analysis focused on the entire 12.93 miles, the calibration was limited to observation at 0.3 mile. Figure 7.2 shows the longitudinal change in DO for the calibration low flow condition. The figure also shows the flow at each element. The changes in DO at river miles 7.5 and 3.3 are associated with the inflow from the drainage area reach number 2 and the tributary flow, respectively.

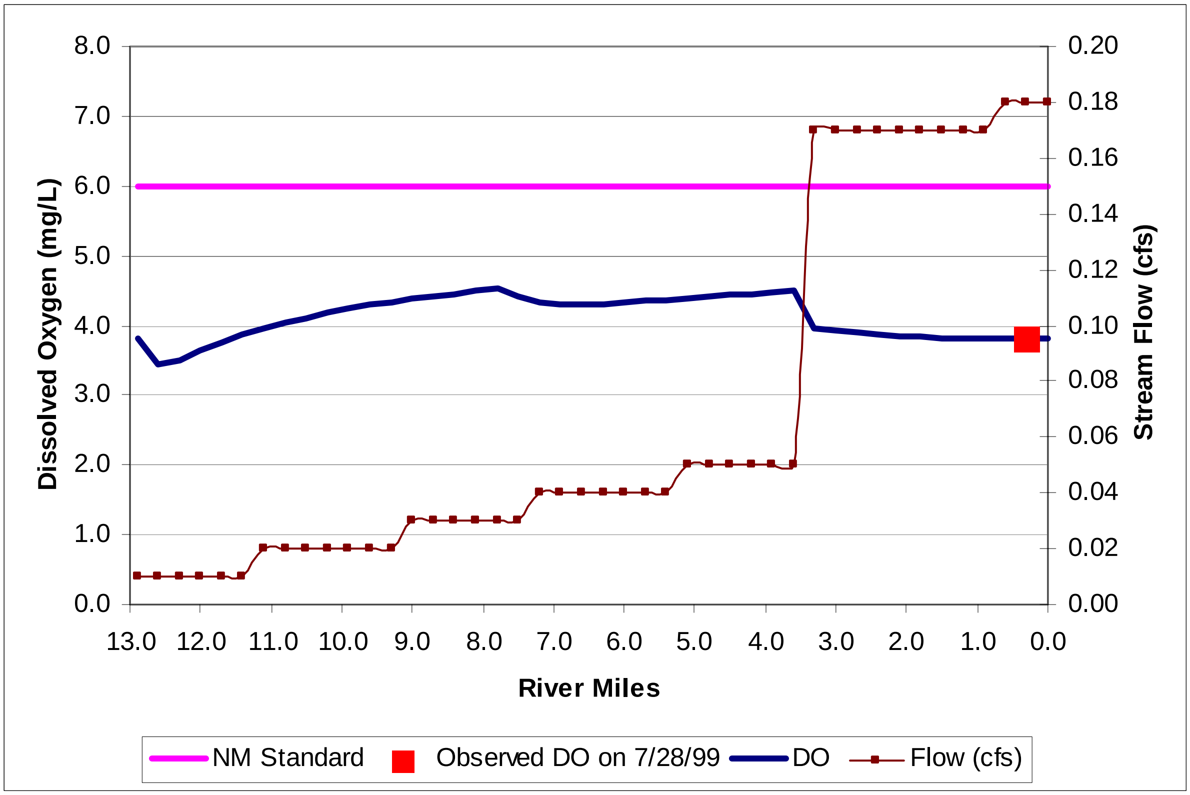


Figure 7.2. Model-predicted DO for Existing Critical Conditions of the Abiquiu Creek

The calibration or baseline model run reflects the summertime low flow condition of Abiquiu Creek. The baseline condition model was run adjusting the SOD (while keeping the rest of the calibrated parameters the same), to bring the in-stream average DO concentration up to or above 6.0 mg/L (representing the state standard). This involved an iterative process to determine the SOD rate that would not violate water quality standards for DO (Figure 7.3).

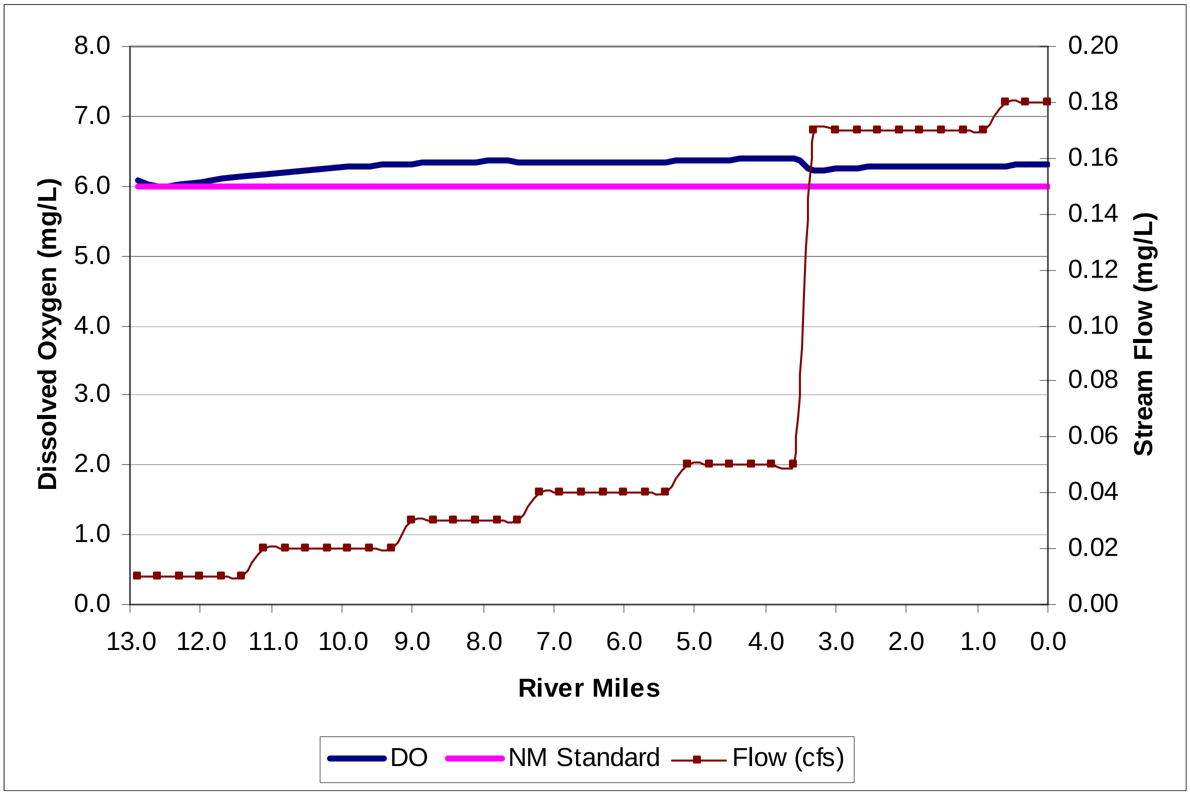


Figure 7.3 Model-predicted DO Concentrations in the Abiquiu Creek with for the TMDL scenario.

TMDL Scenario
SOD at which the DO will meet the standard is 0.015 g/ft^2day. It is equivalent to 0.012 g/ft^2day TBODu based on the Streeter-Phelps SOD model.

Identification and Description of pollutant source(s)

Potential pollutant sources are listed for the segment in Table 7.3.

Table 7.3. Pollutant Source Summary for Dissolved Oxygen

Pollutant Sources (percent from each)	**Magnitude** (Load Allocation + MOS)	**Location**	**Potential Sources**
Point: None (0 percent)	0		None
Nonpoint: (100 percent) Dissolved oxygen As SOD As TBODu	 0.015 g/ft^2day 0.012 g/ft^2day	 Abiquiu Creek	 Land Disposal, Rangeland, Hydromodification, Removal of Riparian Vegetation, Streambank Modification/Destabilization, and Road Maintenance or Runoff

Linkage Between Water Quality and Pollutant Sources

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

SWQB fieldwork includes an assessment of the potential sources of impairment (SWQB/NMED 1999). The Pollutant Source(s) Documentation Protocol form and Potential Sources Summary Table in Appendix C 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 7.3 (Pollutant Source Summary) 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, which is predominantly State and privately managed land, but also the upland and upstream areas in a more holistic watershed approach to implementing this TMDL.

Abiquiu Creek

The primary sources of DO impairment in Abiquiu Creek are rangeland, land disposal (on-site wastewater systems), hydromodification (channelization), removal of riparian vegetation, streambank modification/destabilization, and road maintenance or runoff. Field notes indicate that this creek goes dry in places during the year. Upstream activities, such as grazing, confined feeding operations, natural springs, residential area runoff and wastewater systems, and the highway 84 bridge, may be contributing to the DO impairment. There is a healthy riparian area along the reach.

The above-mentioned watershed activities increase nutrient rich and organic enriched substances in the stream. It results in high SOD and low DO. Reduction/control in watershed activities associated to nutrient rich and organic enriched substances will result in lower SOD and higher DO.

7.3 Margin of Safety (MOS)

The MOS is one of the required elements of a TMDL. There are two basic methods for incorporating the MOS (USEPA, 1991):

- Implicitly incorporate the MOS using conservative model assumptions to develop allocations.
- Explicitly specify a portion of the total TMDL as the MOS; use the remainder for allocations.

The margin of safety for this TMDL was expressed implicitly through implicit conservative assumptions that provide a margin of safety. Specific conservative assumptions include:

For the TMDL analysis, the temperature was kept the same as for the existing condition (21.7 ^{o}C). TMDL implementation may include such activities as planting riparian vegetation that serves to increase shade and decrease in-stream temperature. These activities will result in increased DO saturation concentration due to an increased the ability to absorb more oxygen from the atmosphere. This approach results in SOD reduction being the primary factor to meet the DO standard in the TMDL scenario and thus potentially a large load reduction than it ultimately necessary. In sandy bottom streams, SOD values range from 0.2 to 1 g $m^{-2}d^{-1}$(Chapra 1997). For the current critical condition, the SOD rate was set to 0.86 g $m^{-2}d^{-1}$, close to the high end of the range.

7.4 Consideration of Seasonal Variation

Data used in the calculation of this TMDL were collected during the spring, summer, fall of 1999, and summer of 2002 in order to ensure coverage of any potential seasonal variation in the system. Critical conditions were set to low-flow for dissolved oxygen since data violations were measured during low summer flows. A flow measurement taken during the 1999 summer sampling run was used in the calculations.

7.5 Future Growth

Estimates of future growth do not indicate a significant decrease of DO that cannot be controlled with BMP implementation in this watershed.

8.0 MONITORING PLAN

Pursuant to § 106(e)(1) of the federal Clean Water Act, the SWQB has established appropriate monitoring methods, systems, and procedures in order to compile and analyze data on the quality of the surface waters of New Mexico. In accordance with the New Mexico Water Quality Act, 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 uses a rotating basin system approach to monitor water quality. In this system, a select number of watersheds are intensively monitored each year with an established return frequency of every 5 to 7 years. The SWQB maintains current quality assurance and quality control plans to cover all monitoring activities. This document, called the Quality Assurance Project Plan (QAPP), is updated and certified annually by USEPA Region 6 (SWQB/NMED 2001b). In addition, the SWQB identifies the data quality objectives required to provide information of sufficient quality to meet the established goals of the program. The SWQB's current priorities for monitoring are driven by the CWA Integrated §303(d)/§305(b) list of streams requiring TMDLs. Short-term efforts will be directed toward those waters that are on the USEPA TMDL consent decree list (Forest Guardians and Southwest Environmental Center v. Carol Browner, Administrator, USEPA, Civil Action 96-0826 LH/LFG, 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 (SWQB/NMED 2000).

Long-term monitoring for assessments will be accomplished through the establishment of sampling sites that are representative of the waterbody and that can be revisited every 5 to 7 years. This information will provide time-relevant information for use in CWA Integrated §303(d)/§305(b) listing and 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 that makes implementation of corrective activities 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.

It should be noted that a basin would not be ignored during the years 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 CWA Integrated §303(d)/§305(b) listing processes.

The following draft schedule covers sampling seasons 1998 through 2004 and will be followed in a consistent manner to support the New Mexico Unified Watershed Assessment (UWA) and the Nonpoint Source Management Program. This sampling regime allows characterization of seasonal variation and thorough sampling in spring, summer, and fall for each of the watersheds. Revisions to the schedule may be occasionally necessary based on staff and monetary resources, which fluctuate annually.

- 1998 Jemez watershed, Upper Chama Watershed (El Vado to border), Cimarron watershed, Santa Fe River, San Francisco Watershed
- 1999 Lower Chama watershed (Rio Grande to El Vado), Red River watershed, Middle Rio Grande, Gila River watershed (summer and fall), Santa Fe River
- 2000 Gila River watershed (spring), Dry Cimarron watershed, Upper Rio Grande 1 (Pilar to Colorado border)
- 2001 Upper Rio Grande 2 (Cochiti Reservoir to Pilar), Upper Pecos watershed (Fort Sumner to headwaters)
- 2002 Canadian River 1, San Juan River watershed, Mimbres watershed
- 2003 Lower Pecos watershed (TX border to Ft. Sumner), Rio Ruidoso watershed
- 2004 Rio Puerco watershed, Lower Rio Grande (Texas border to Isleta Pueblo boundary)

9.0 IMPLEMENTATION PLAN

Purpose

The purpose of this implementation plan is to outline appropriate steps to align the loads to the load capacities developed for the pollutants specified in this TMDL document. It is also a plan of action to protect and maintain surface water quality throughout the Lower Rio Chama watershed. Many of the activities that cause water quality impairments (e.g., the removal of riparian vegetation and streambank destabilization) are the cumulative effects of land practices that cause degradation of the watershed and the affected streams. Some of these impacts have their origins in past events and are compounded by inappropriate land management practices today. The key to changing these practices and improving the condition of the entire watershed is education. An understanding of the attributes of a quality stream environment, a healthy watershed, and how important clean water is to the future of all stakeholders is an integral part of the process.

This plan for the Lower Rio Chama watershed focuses on prevention and remediation for nonpoint source pollution–that is, pollution that cannot be attributed to a single source such as the outfall pipe of a factory. Previously, individual or discrete projects to address nonpoint sources of pollution have had limited long-term success. Nonpoint source pollution control projects are most effective when multiple sources are addressed and activities are coordinated under a watershed plan throughout the affected area. This is because the watershed approach integrates land use, climate, hydrology, drainage, and vegetation effects on water quality. The watershed approach also calls for all stakeholders in the watershed to participate.

Strategy

The mission of the SWQB Watershed Protection Section is to implement progressive watershed-based restoration and protection programs to reduce human-induced pollutants from nonpoint sources in order to meet water quality standards and beneficial uses of surface water and ground water resources. In recent years, the SWQB Watershed Protection Section has focused its resources to promote a collaborative approach to identifying and reducing the impact of priority nonpoint sources of pollution.

The first step of this approach is to engage local interest and involvement in locating and defining the problems and implementing the solutions on the land. Table 9.1 lists potential stakeholders in the Lower Rio Chama watershed.

Table 9.1. Potential Stakeholders in the Lower Chama Watershed

Lower Rio Chama Watershed Stakeholders
Land Owners
Ranchers
Agriculturists
Homeowners
Businesses
Land Management Agencies
Carson National Forest
Santa Fe National Forest
Bureau of Land Management
New Mexico Department of Game and Fish
New Mexico State Parks
U.S. Department of the Army, Corps of Engineers
Government Agencies Providing Technical Expertise and Other Resources
New Mexico Environment Department
Natural Resources Conservation Service
Interstate Stream Commission Regional Water Planning
Rio Arriba County
NMSU Cooperative Extension Service
Soil and Water Conservation District
USGS Water Resources Division
USDA Fish and Wildlife Service
USDA Farm Service Agency
USEPA Region 6
Interest Groups
Acequia Associations
Rocky Mountain Elk Foundation
Trout Unlimited
Sierra Club
Quivira Coalition
New Mexico Cattle Growers' Association
Rio Grande Restoration
Los Rios River Runners
Northern New Mexico Community College
Youth Groups
Boy Scouts and Girl Scouts
Rocky Mountain Youth Corps
Youth Conservation Corps
Local schools

Ranchers, agriculturists, and other private interests own a substantial portion of the Lower Rio Chama watershed. In addition, the land is also under the jurisdiction of the Carson National Forest, the Santa Fe National Forest, Bureau of Land Management, the New Mexico Department of Game and Fish, New Mexico State Parks, and U.S. Department of the Army, Corps of Engineers. The collaborative approach also includes the involvement of agencies and interest groups that can provide technical expertise, knowledge of the watershed, volunteer labor, and other needed resources. Local schools and students and other community organizations and environmental groups can also provide volunteer time and labor.

After all stakeholders are located and provided information about crucial water quality impairments and degradation of the watershed, the next critical step is to engage stakeholders in joining forces to restore the watershed, and identify the "sparkplugs"—those individuals with the time and the drive to address the challenges concerning the relationship of the community, landholders, and groups to the Rio Chama watershed. These diverse factions are ultimately brought together to form a watershed alliance.

The next step is development of a locally accepted remediation plan that efficiently achieves pollution load reductions and then maintains and protects water quality from future impairments. This remediation plan or Watershed Management Plan (WMP) will document past remedial actions and future restoration projects and activities that will improve the condition of the watershed to meet water quality goals. The involvement of all interests and stakeholders in the development of this plan and unification of community activities through a watershed approach is likely to achieve far-reaching and long-term results.

The Meridian Institute received a CWA 319 grant in 2003 to begin formation of a watershed group in the Rio Chama watershed. This group will develop a Watershed Restoration Action Strategy (WRAS) that will expand on the general information provided in this Implementation section in order to address the items discussed in this TMDL document as well as the Upper Chama TMDL document.

Watershed Goals

The Lower Rio Chama watershed poses a unique set of conditions that set the stage for restoration. The first and foremost is that several reaches in the watershed are designated high quality coldwater fisheries (HQCWF), including Rio Vallecitos, Rio del Oso, El Rito Creek, Polvadera Creek, Poleo Creek, Cañones Creek, Rio Cebolla, Coyote Creek, Canjilon Creek, Chihuahuenos Creek, Rio Gallina, Clear Creek, Cecilia Canyon Creek, Rito Resumidero, Rio Puerco de Chama, Rito Encino, and Rito Redondo. The designated use of HQCWF applies to all the impaired stream reaches mentioned in this document, except Abiquiu Creek, which is designated both a coldwater and warmwater fishery. The significance of the HQCWF designation is that standards that apply to these surface waters support a more sensitive coldwater fishery habitat, and watershed restoration efforts should be focused on this goal.

Several stream reaches sampled have been characterized as meeting water quality standards (Photo 9.1). Local landowners and stakeholders can use stream stretches in the watershed that are identified as meeting water quality standards and designated uses as models or reference conditions for restoration goals.

Other designated uses that apply to reaches in the watershed include domestic water supply, fish culture, irrigation, livestock watering, wildlife habitat and recreational uses such as fishing, wading, and other limited seasonal contact activities. Most of the criteria that apply to these designated uses will be met if those of the high quality coldwater fishery are achieved. The water quality criteria and antidegradation policy that applies to these stream reaches ultimately protect all of these uses.

Photo 9.1. Upper Reach of El Rito Creek 1.3 miles above a Private Inholding. This Reach Meets all Water Quality Standards and Designated Uses.

9.1 Turbidity

Introduction

Turbidity reduces the penetration of light through natural waters and appears as cloudy water. Suspended solids such as clay, silt, ash, plankton, and organic materials cause turbidity in surface waters. Some level of turbidity is a function of a stream's natural process of moving water and sediment. However, land surface disturbance activities and removal of vegetation can create conditions for erosion of fine soil material that washes into a stream and causes excessive turbidity. Turbidity can harm aquatic life by decreasing light available for plant growth, increasing water temperature, clogging the gills of aquatic fauna, and covering habitat. The turbidity standard addresses excessive sedimentation, which can also lead to the formation of excessive stream bottom deposits that can impact the aquatic ecosystem. Turbidity is a qualitative measure of water clarity or opacity and is reported in nephelometric turbidity units (NTU). The measured loads for turbidity are expressed in pounds per day of total suspended solids (TSS).

The following are examples of sources that can cause excessive turbidity:

- runoff from exposed soil (such as construction sites)
- improperly maintained dirt roads and embankments
- eroded streambanks
- activities occurring within stream channels that re-suspend sediments (such as gravel mining and low water crossings)
- removal of riparian vegetation
- naturally occurring situations, in some cases

Process

Using the information given in previous sections of this document and with further reconnaissance by stakeholders and landowners in the watershed, a land treatment strategy should be developed to guide the selection and implementation of BMPs to reduce turbidity. In addition, because time and funding are critical elements of implementing a plan, critical areas within a watershed or land treatments with the potential to produce significant results should be prioritized.

Agricultural practices have a significant effect on water quality in the Lower Chama watershed. Some of the ways in which agriculture can cause turbidity are through sediment-laden runoff from land cleared for farming and in irrigation return flows; overgrazing and trampling of uplands, which lead to loss of grass cover and increased bare ground; and removal or trampling of streambank (riparian) vegetation by domestic animals, which may lead to bank erosion.

Landowners in the watershed can reverse the erosion process and loss of topsoil by using improved grazing management that leads to more continuous grass cover and less bare ground. Laser leveling of irrigated croplands and the use of buffer strips reduces sediment-laden runoff from irrigation return flows. With the help and technical guidance that members of a watershed alliance can provide, landowners can work to restore appropriate channel sinuosity and stable streambank environments through the installation of vegetative and other in-stream structures. Restoring riparian vegetation not only stabilizes soils along streambanks and floodplains but also attenuates erosive stream power and flood flows. The implementation of practices such as these to reduce turbidity will improve water quality and also benefit the landowners through the improvement of long-term soil productivity, increased organic litter, improved moisture retention, enhanced water infiltration, and reduced soil compaction.

Other strategies that will contribute to reducing turbidity include proper road maintenance practices and drainage controls, relocation of recreation trails away from riparian areas, plantings along streambanks, and hydrogeomorphic river restoration. The

SWQB will work with private landowners and community organizations to develop and implement a watershed-wide plan.

Additional sources of information for BMPs to address turbidity are listed below in the Agriculture, Forestry, Riparian and Streambank Stabilization, Roads, Stormwater, and Miscellaneous portions of section 9.7 below. Some of these documents are available for reading at the New Mexico Environment Department, Surface Water Quality Bureau, Watershed Protection Section Library, 1190 St. Francis Drive, Santa Fe, New Mexico.

Performance Targets

Interim load reduction targets will be used to determine if control actions implemented are successful and standards attained. The interim load reduction targets will be established by the number and kind of BMPs implemented, the number of stream reach miles treated or positively affected by treatment of related areas, and the time it normally takes to see the results of the implemented BMPs. For example, interim load reduction targets for turbidity will be decreased turbidity values as a result of items such as:

- decreased erosion from streambanks,
- increased amount and health of riparian vegetation,
- increased vegetative cover in contributing upland areas, and
- increased miles of properly maintained roads.

In some cases, the results of implementation and maintenance of the most effective BMPs may likely take years to a decade to achieve.

Interim load reduction targets will be established by SWQB staff and will be re-evaluated periodically, depending on type and timing of BMP implementation. Furthermore, these interim load reduction targets will become part of the watershed management plan (WMP). As additional information becomes available during the identification and quantification of the sources of pollution, the targets, load capacity, and allocations may need to be changed. In the event that new data or information show that changes are warranted, TMDL revisions will be made with assistance of the Lower Rio Chama watershed stakeholders. The re-examination process will involve monitoring pollutant loading, tracking implementation and effectiveness of controls, assessing water quality trends in the waterbody, and re-evaluating the TMDL for attainment of water quality standards. Although specific targets and allocations are identified in the TMDL, the ultimate success of the TMDL is not whether these targets and allocations are met, but whether beneficial uses and water quality standards are achieved.

9.2 Temperature

Introduction

Water temperature influences the metabolism, behavior, and mortality of fish and other aquatic organisms. Temperature affects the amount of oxygen that can be dissolved in water, the rate of photosynthesis of algae and other aquatic plants, the rates of growth, reproduction and decomposition of aquatic life, and the sensitivity of organisms to toxic wastes, parasites, and diseases. Normal water temperature varies both seasonally and throughout the day. Local indigenous aquatic communities are adapted to these natural daily and seasonal temperature fluctuations. However, changes to the normal temperature regime of a stream can eliminate indigenous populations, affect existing community structure and geographical distribution of species, and can support colonization of other species not found in the existing aquatic community.

Human-related pollution can change water temperature to the detriment of the aquatic community. The numeric water quality criterion for temperature of 20 °C (68°F) is applied to streams sampled in this study to maintain the designated use of a high quality coldwater fishery and to protect cold-water aquatic life. Recorded maximum temperatures were higher than the criterion on the Rio Vallecitos and Polvadera Creek. The temperature increases may kill many of the aquatic organisms that live in these streams. In order to meet the water quality standard, maximum stream temperatures must be reduced on both of these streams. Temperature load reductions expressed in joules/meter2/second are given in Table 4.4.

Some factors that can significantly increase water temperature include summer urban runoff, shallow stream depth, point sources of pollution, turbidity, insufficient shading, decreased base flow, ambient air temperature, and stream orientation (north/south or east/west). The following are examples of causes of temperature increases in aquatic ecosystems:

- reduction of shade caused by removal of streamside vegetation
- collapse of undercut banks where fish and water are protected from incident sunlight
- reduction of ground water discharge to the stream caused by reduced infiltration to the local water table
- excessive turbidity that absorbs sunlight
- alterations in stream geomorphology leading to a higher width-to-depth ratio and thus wider and shallower streams
- stormwater that flows across hot surfaces such as streets and enters a stream, increasing water temperatures

Process

The Pollutant Source Summary (Table 4.5) lists the land activities that are potentially contributing to higher stream temperatures in the stream reaches mentioned above. The potential pollution sources and the resulting degradation that impacts each stream are described further in the Linkage of Water Quality and Pollutant Sources (section 4.2).

There are a number of BMPs that address temperature, depending on the source of the problem. Many of the same impacts that can contribute to turbidity and stream bottom deposits also contribute to higher temperatures in streams. Below are some remedial actions that may address temperature:

- Reestablishment of appropriate woody and grassy riparian and wetland species applicable to the affected area provides canopy cover and shading for temperature control and helps prevent streambank collapse. Riparian and wetland vegetation can be restored by planting and seeding and by fencing riparian exclosures, and/or by promoting infiltration that raises the local water table.

- River restoration involving such actions as reconfiguring the river’s sinuosity and/or altering the processes of degradation and aggradation returns the river to a natural and stable morphology, which incorporates a lower width-to-depth ratio. This lowered ratio means that the stream has become narrower and deeper and that pools have reestablished. Thus, the stream can maintain cooler temperatures with the increased channel depth and reduced water surface exposed to solar radiation.
- Collection of stormwater runoff in detention ponds and reduction of the percentage of impervious surfaces in urban settings can reduce thermal pollution in runoff and can promote infiltration to the local water table where water temperatures are cooled and returned to recharge local streams as base flow.
- Limiting in-stream diversion to maintain adequate in-stream flow and stream depth will reduce water temperature extremes.
- Gravel operations that widen stream channels and/or lower streambed elevation, thereby leaving adjacent riparian and wetland vegetation “high-and-dry,” should be stopped. In New Mexico, most activities that result in fill material (e.g., sand, gravel) entering waters of the United States are regulated. The Corps of Engineers and USEPA regard the use of mechanized earth-moving equipment to conduct land-clearing, ditching, channelization, in-stream mining and gravel operations, or other earth-moving activity in waters of the United States as resulting in a discharge of dredged material, unless project-specific evidence shows that the activity results in only incidental fallback (33 CFR [Code of Federal Regulations] Ch II Part 323.2). Permits are required from the Corps of Engineers and certification from the SWQB to conduct activities in the waters of the United States.

The number of beneficial or designated uses usually decreases with declining water quality. Surface water quality temperature criteria are assigned to protect beneficial and designated uses. Temperature modifications from human activities associated with one use, such as livestock watering or in-stream withdrawals, should not compromise the protective needs of other uses within the same stream classification. Moreover, it is critically important that cumulative effects of human activities and uses on water temperature be considered holistically and not individually. A holistic approach is more readily feasible using the watershed geographic area and when all those with an interest in the river are involved. Stream uses and impacts should also be evaluated within an ecosystem context. To be acceptable, all beneficial uses must fit within the temperature regimes provided in nature.

A critical role of the watershed approach is to provide a forum to convey the benefits to the landowners and other stakeholders that will entice them to voluntarily implement modifications to activities and uses of the river that are causing impairments. Watershed-wide collaborations are a means to implement strategies benefiting users, activities and water quality. Incentives such as improved sport fishing and the influx of recreation dollars into the local economy, enhancement of grazing resources, and increased property values can be demonstrated to promote stewardship of local water resources.

Additional sources of information on BMPs to address temperature are listed in the Agriculture, Forestry, Riparian and Streambank Stabilization, Roads, Stormwater, and Miscellaneous portions of section 9.7 below. Some of these documents are available for reading at the New Mexico Environment Department, Surface Water Quality Bureau, Watershed Protection Section Library, 1190 St. Francis Drive, Santa Fe, New Mexico.

Performance Targets

Interim load reduction targets will be used to determine whether control actions are successful and standards attained. The interim load reduction targets will be established by the number and kind of BMPs implemented, the number of stream reach miles treated or positively affected by treatment of related areas, and the time it normally takes to see the results of the implemented BMPs. For example, interim load reduction targets will be lower stream temperature values as a result of factors such as the following:

- degree of success of riparian plantings
- an increase in the percentage of stream canopy cover
- a decrease in the width-to-depth ratio of the stream

In some cases, the results of implementation and maintenance of the most effective BMPs may likely take years to a decade to achieve.

Interim load reduction targets will be established by SWQB staff and will be reevaluated periodically, depending on the type and timing of BMP implementation. Furthermore, the interim load reduction targets will become part of the watershed management plan (WMP). As additional information becomes available during the identification and quantification of the sources of pollution, the targets, load capacity, and allocations may need to be changed. In the event that new data or information show that changes are warranted, TMDL revisions will be made with the assistance of the Lower Rio Chama watershed stakeholders. The reexamination process will involve monitoring pollutant loading, tracking implementation and effectiveness of controls, assessing water quality trends in the waterbody, and reevaluating the TMDL for attainment of water quality standards. Although specific targets and allocations are identified in the TMDL, the ultimate success of the TMDL is not whether these targets and allocations are met, but whether beneficial uses and water quality standards are achieved.

9.3 Chronic Aluminum

Introduction

The uptake and transport of metals in surface water can pose a considerable nonpoint source pollution problem. Metals such as aluminum, lead, copper, iron, and zinc can occur naturally in watersheds in amounts ranging from trace amounts to highly mineralized deposits. Some metals are essential to life at low concentrations but are toxic at higher concentrations. Metals such as cadmium, lead, mercury, nickel, and beryllium represent known hazards to human health. The metals are continually released into the aquatic environment through natural processes, including weathering of rocks, landscape erosion, and geothermal or volcanic activity. The metals may be introduced into a waterway via headcuts, gullies, or roads. Depending on the characteristics of the metal, it can be dissolved in water, deposited in the sediments, or both. Metals become dissolved metals in water as a function of the pH of a water system. In urban settings, stormwater runoff can increase the mobilization of many metals into streams.

The following are examples of sources that can cause aluminum contamination:

- Resource extraction, recreation, some agricultural activities, and erosion can contribute to nonpoint source pollution of surface water by aluminum.
- Stormwater runoff in industrial areas may have elevated aluminum in both sediments and the water column.

Process

For Cañones Creek and the Rio Vallecitos, one of the primary focuses will be on the control of aluminum to the extent possible.

During the TMDL process in this watershed, point sources have been reviewed and will be addressed through the permit process. No point sources have been identified in these watersheds that could contribute to higher chronic aluminum levels.

The nonpoint sources will need to address aluminum exceedances through BMP implementation. BMPs can be implemented to address and remediate metal contamination. They include the following:

- Improving the pH in a stream—Neutral to alkaline pH waters generally do not pose a metal exceedance problem. An acidic pH dissolves available metals. In such a case, a remedy for metals contamination could be an adjustment of the pH of runoff before it enters the waterbody. One approach may be the construct an anoxic alkaline drain to raise the pH and precipitate the contained metals. An anoxic alkaline drain is constructed by placing a high pH material in a trench between runoff and the stream to be used as a buffer (*Red River Groundwater Investigation*- NMED-SWQB-Nonpoint Source Pollution Section, D. Slifer1996).

- Installing constructed wetlands—Wetlands are used to filter runoff water and sediment from source areas in the watershed. Metals may be bound up in the root systems of wetland vegetation, and thus prevented from entering a waterway. (*The Use of Wetlands for Improving Water Quality to Meet Established Standards*, Filas and Wildeman 1992.)

- Improving stormwater control and construction BMPs—Stormwater and construction BMPs can be used to divert flows off metal-producing areas, directing them away from streams into areas where the flows may infiltrate, evaporate, or accumulate in sediment retention basins. (*Conservation Design for Stormwater Management: A Design Approach to Reduce Stormwater Impacts from Land Development and Achieve Multiple Objectives Related to Land Use*, Delaware Department of Natural Resources and Environmental Control, Sediment and Stormwater Program and the Environment Management Center, Brandywine Conservancy 1997.)

Additional sources of information for BMPs to address chronic aluminum are listed below in the Mining, Riparian and Streambank Stabilization, Stormwater/Urban, and Miscellaneous portions of section 9.7 below. Some of these documents are available for reading at the New Mexico Environment Department, Surface Water Quality Bureau, Watershed Protection Section Library, 1190 St. Francis Drive, Santa Fe, New Mexico.

Performance Targets

Interim load reduction targets will be used to determine whether control actions are successful and standards attained. The interim load reduction targets will be established by the number and kind of BMPs implemented, the number of stream reach miles treated or positively affected by treatment of related areas, and the time it normally takes to see the results of the implemented BMPs. For example, interim load reduction targets will be decreased aluminum values as a result of factors such as the following

- increases in wetland areas to filter associated reductions in metals concentrations found in the stream
- increases in stabilized streambanks and enhanced riparian areas to decrease erosion and potential loading of sediment associated with metals into a stream
- re-design/upgrades of the existing wastewater treatment plant .

Interim load reduction targets will be established by SWQB staff and will be reevaluated periodically, depending on the type and timing of BMP implementation. Furthermore, the interim load reduction targets will become part of the watershed management plan (WMP). As additional information becomes available during the identification and quantification of the sources of pollution, the targets, load capacity, and allocations may need to be changed. In the event that new data or information show that changes are warranted, TMDL revisions will be made with the assistance of the Lower Rio Chama watershed stakeholders. The reexamination process will involve monitoring pollutant loading, tracking implementation and effectiveness of controls, assessing water quality trends in the waterbody, and reevaluating the TMDL for attainment of water quality standards. Although specific targets and allocations are identified in the TMDL, the ultimate success of the TMDL is not whether these targets and allocations are met, but whether beneficial uses and water quality standards are achieved.

9.4 Fecal Coliform

Introduction

Total coliform bacteria are a collection of relatively harmless microorganisms that live in large numbers in the intestines of humans and other warm-blooded animals, as well as cold-blooded animals. These bacteria aid in the digestion of food. A specific subgroup of this collection is fecal coliform bacteria, the most common member being *Escherichia coli.* These organisms may be separated from the total coliform group by their ability to grow at elevated temperatures and are associated only with the fecal material of warm-blooded animals.

The presence of fecal coliform bacteria in aquatic environments indicates that the water has been contaminated with the fecal material of humans or other animals. Source water may be contaminated by pathogens or disease-producing bacteria or viruses, which can also exist in fecal material. Some waterborne pathogenic diseases are typhoid fever, viral and bacterial gastroenteritis, and hepatitis A. The presence of fecal contamination is an indicator that a potential health risk exists for individuals exposed to this water. Fecal coliform bacteria may occur in ambient water as a result of the overflow of domestic sewage or nonpoint sources of human and animal waste.

The following are examples of sources that can cause fecal coliform contamination:

- Overflow of domestic sewage from septic systems due to improper installation or maintenance of the systems
- Ineffective treatment of sewage at wastewater treatment plants (none in this watershed)
- Transport of pet wastes from lawns into watercourses
- Runoff from animal feedlots
- Runoff from stables
- Improperly managed grazing activities in or around streams
- Naturally occurring contamination from wildlife such as migratory birds or elk

Process

For Cañones Creek, one of the primary focuses will be on the control of fecal coliform to the extent possible.

During the TMDL process in this watershed, any point sources will be reviewed and will be addressed through the permit process. The nonpoint sources will need to address fecal coliform exceedances through BMP implementation.

The following are BMPs that are often used to control fecal coliform contamination of rivers:

- The siting of barns, corrals, paddocks, etc., away from watercourses and in areas that drain away from the nearest watercourse. This prevents animal waste that is transported out of the confined area from reaching waterbodies. In addition, filtering vegetation can be maintained between facilities and waterbodies to act as a filter and help capture and retain pollutants. (*Pollution Control for Horse Stables and Backyard Livestock*, USEPA 1994)

- Removal of manure and soiled straw bedding on a daily basis to a storage area where there is no chance of water quality contamination. Effective storage units include plastic garbage cans with lids, composters, and fly-tight wooden or concrete storage sheds. (*Pollution Control for Horse Stables and Backyard Livestock*, USEPA 1994)

- Removal of pet waste from lawns, sidewalks, gutters, etc. Pet feces can be washed into watercourses causing bacterial contamination and boosting nutrient levels. The wastes should be disposed of in the trash or flushed down a toilet. (*Common Sense Guide to Rural Environmental Protection*, USEPA Region 4 1992)

- Rangeland improvements such as riparian fencing and upland water developments help keep cattle from concentrating in the riparian areas and contaminating watercourses with animal waste. (*Soil and Water Conservation Practices Handbook*, USDA Forest Service, Southwestern Region)

Additional sources of information on BMPs to address fecal coliform are listed in the Mining, Riparian and Streambank Stabilization, Stormwater/Urban, and Miscellaneous portions of section 9.7 below. Some of these documents are available for reading at the New Mexico Environment Department, Surface Water Quality Bureau, Watershed Protection Section Library, 1190 St. Francis Drive, Santa Fe, New Mexico.

Performance Targets

Interim load reduction targets will be used to determine whether control actions are being implemented and standards attained. For this TMDL, the interim load reductions to be established will vary and will be determined by the BMPs implemented. For example, interim load reduction targets for fecal coliform will consist of decreased fecal coliform values as a result of factors such as:

- a change in grazing management on a private or public land that involves riparian fencing
- ensured compliance with permit limits for wastewater treatment plants and any other point sources in the watershed

- public outreach efforts to inform watershed stakeholders about the impacts on water quality associated with stables, corrals, etc.
- measures the landowner or land manager can take to address the waste management issues

Interim load reduction targets will be established by SWQB staff and will be reevaluated periodically, depending on the type and timing of BMP implementation. Furthermore, the interim load reduction targets will become part of the watershed management plan (WMP). As additional information becomes available during the identification and quantification of the sources of pollution, the targets, load capacity, and allocations may need to be changed. In the event that new data or information show that changes are warranted, TMDL revisions will be made with the assistance of the Lower Rio Chama watershed stakeholders. The reexamination process will involve monitoring pollutant loading, tracking implementation and effectiveness of controls, assessing water quality trends in the waterbody, and reevaluating the TMDL for attainment of water quality standards. Although specific targets and allocations are identified in the TMDL, the ultimate success of the TMDL is not whether these targets and allocations are met, but whether beneficial uses and water quality standards are achieved.

9.5 Dissolved Oxygen

Introduction

Dissolved oxygen concentrations refer to the amount of oxygen dissolved in water. Oxygen is a sparingly soluble gas and its concentration in water is usually measured in parts per million or milligrams per liter. The capacity of water to hold oxygen in solution is inversely proportional to the water temperature. Increased water temperature lowers the concentration of dissolved oxygen at saturation. The amount of oxygen that can dissolve in water increases with increasing atmospheric pressure (USEPA 1991b).

Dissolved oxygen is critical for the biological community in a stream. Plant respiration and decomposition of dead vegetation consume dissolved oxygen in the water. A lack of dissolved oxygen creates stress for all aquatic organisms and can cause fish kills. A landowner may have seen fish gulping for air at the water surface during warm weather, indicating a lack of dissolved oxygen. Increases in primary productivity can increase the number of invertebrates and fish in streams. However, excessive plant growth and decomposition can limit aquatic populations by decreasing dissolved oxygen concentrations. Nocturnal respiration can cause oxygen depletion in waters with high primary productivity and low aeration rates.

Reduced base flow, either naturally occurring (drought) or through anthropogenic actions, will also result in higher temperatures, slower water movement and, therefore, decreased dissolved oxygen levels.

The following are examples of factors that can contribute to low dissolved oxygen levels:

- Sources of organic matter that can contribute to increased levels of BOD, such as:
    - Point source nutrient contributions can come from wastewater ineffectively treated
    - Nonpoint sources of nutrients can be related to agricultural activities, such as overapplication of fertilizer on fields or animal waste runoff, including confined animal operations and grazing activities
    - Stormwater runoff in urban areas can include fertilizer from lawns and pet waste
    - Septic tanks, cesspools, or any other mechanism for removal of liquid waste from human habitation are large contributors to surface water nutrients when ground water is shallow or systems have been improperly installed
    - Recreational areas such as horse trails or heavily used fishing areas, where the riparian vegetation has been removed or reduced, can contribute nutrients if waste materials are transported by runoff into the stream. When vegetated riparian areas are removed, the filtering mechanism for the runoff is also removed
- Any increases in water temperature leading to decreases in dissolved oxygen levels, including
    - Any losses of shade provided by riparian areas that are removed or reduced.
    - Removal of water, through diversion, can reduce base stream flow and may possibly contribute high nutrient levels and temperatures increases.

Process

For Abiquiu Creek, one of the primary focuses will be to ensure adequate levels of dissolved oxygen to the extent possible.

During the TMDL process in this watershed, point sources have been reviewed and will be addressed through the permit process. No point sources have been identified in these watersheds that could contribute to low dissolved oxygen levels.

The nonpoint sources will need to address dissolved oxygen impairments through BMP implementation. BMPs can be implemented to address low dissolved oxygen levels. They include the following:

- Filter strips and vegetated buffers. These BMPs are particularly advantageous BMPs for dealing with runoff from agricultural fields and stormwater drains because the vegetation would absorb a percentage of the nutrients. These BMPs would also prevent sediment loading and turbidity in the river system by providing a filtering process for the runoff. (*Guidance Specifying Management Measures for Sources of Nonpoint Pollution in Coastal Waters*, USEPA 1993.)

- Detention basins. These are effective techniques for the control of pollutant discharges from stormwater runoff and confined animal operations. The basins would isolate potentially polluted runoff from streams. (*Urban Targeting and BMP Selection*, USEPA 1990)

- Following source control management. Reduced and efficient application of fertilizer on agricultural fields, lawns, and golf courses can effectively prevent nutrient loading in runoff, which can lead to low dissolved oxygen in waterbodies. (*New Mexico Farm-A-Syst Farmstead Assessment System*, New Mexico State University, College of Agriculture and Home Economics, Cooperative Extension Service, Plant Sciences Department 1992)

- Maintaining a healthy riparian ecosystem. The riparian ecosystems functions to filter sediments from runoff will take up nutrients through root systems and provide shade to reduce ambient sunlight and water temperatures, both potentially leading to increased dissolved oxygen levels. (*Revegetating Southwest Riparian Areas*, New Mexico State University, College of Agriculture and Home Economics, Cooperative Extension Service)

Additional sources of information on BMPs to address low dissolved oxygen are listed in the Mining, Riparian and Streambank Stabilization, Stormwater/Urban, and Miscellaneous portions of section 9.7 below. Some of these documents are available for reading at the New Mexico Environment Department, Surface Water Quality Bureau, Watershed Protection Section Library, 1190 St. Francis Drive, Santa Fe, New Mexico.

Performance Targets

Interim performance targets will be used to determine whether control actions are being implemented and standards attained. For this TMDL, the interim performance targets to established will vary and will be determined by the BMPs implemented. For example, interim performance targets for dissolved oxygen will be increased dissolved oxygen values as a result of factors such as:

- increases in stabilized streambanks and enhanced riparian areas to decrease water temperature and potentially increase dissolved oxygen levels
- increased rates of reaeration along the stream, possibly by increasing the stream's gradient in areas
- decreased inputs of organic debris that may cause large biochemical oxygen demand
- monitoring within a time frame and continued public outreach efforts to inform watershed stakeholders about measures to prevent further water quality impairment.

Interim load reduction targets will be established by SWQB staff and will be reevaluated periodically, depending on the type and timing of BMP implementation. Furthermore, the interim load reduction targets will become part of the watershed management plan

(WMP). As additional information becomes available during the identification and quantification of the sources of pollution, the targets, load capacity, and allocations may need to be changed. In the event that new data or information show that changes are warranted, TMDL revisions will be made with the assistance of the Lower Rio Chama watershed stakeholders. The reexamination process will involve monitoring pollutant loading, tracking implementation and effectiveness of controls, assessing water quality trends in the waterbody, and reevaluating the TMDL for attainment of water quality standards. Although specific targets and allocations are identified in the TMDL, the ultimate success of the TMDL is not whether these targets and allocations are met, but whether beneficial uses and water quality standards are achieved.

9.6 Additional BMP References and Sources of Information

Additional sources of information on BMPs to address a variety of landuse practices and concerns are listed below. Some of these documents are available for reading at the New Mexico Environment Department, Surface Water Quality Bureau, Watershed Protection Section Library, 1190 St. Francis Drive, Santa Fe, New Mexico:

Agriculture

Web sites: http://www.nm.nrcs.usda.gov/

Bureau of Land Management. 1990. Cows, Creeks, and Cooperation: Three Colorado Success Stories. Colorado State Office.

Cotton, Scott E., and Ann Cotton. Wyoming CRM: Enhancing our Environment.

Goodloe, Sid, and Susan Alexander. Watershed Restoration through Integrated Resource Management on Public and Private Rangelands.

Grazing in New Mexico and the Rio Puerco Valley Bibliography.

USEPA and The Northwest Resource Information Center, Inc, 1990. Livestock Grazing on Western Riparian Areas.

USEPA and The Northwest Resource Information Center, Inc. 1993. Managing Change: Livestock Grazing on Western Riparian Areas.

Forestry

New Mexico Natural Resources Department. 1983. Water Quality Protection Guidelines for Forestry Operations in New Mexico.

New Mexico Department of Natural Resource. 1980. New Mexico Forest Practice Guidelines. Forestry Division, Timber Management Section

State of Alabama. 1993. Alabama's Best Management Practices for Forestry.

Mining

Web sites: http://www.epa.gov/region2/epd/98139.htm

http:www.epa.gov/OSWRCRA/hazwast/ldr/mining/docs/hhed1196.pdf

Caruso, B.S., and R. Ward. 1998. Assessment of Nonpoint Source Pollution from Inactive Mines Using a Watershed Based Approach. Environmental Management, vol. 22, no.2. Springer-Verlag New York Inc. pp. 225-243.

Cohen, R.R.H., and S.W. Staub. 1992. Technical Manual for the Design and Operation of a Passive Mine Drainage Treatment System. U.S. Bureau of Land Management and U.S. Bureau of Reclamation, Denver, CO.

Coleman, M.W. 1996, Anoxic Alkaline Treatment of Acidic, Metal-Loaded Seeps Entering the Red River, Taos Co., NM. Paper presented at New Mexico Governor's 1996 Conference on the Environment, Albuquerque Convention Center, abstract in program. Published in New Mexico Environment Department-NonPoint Source newsletter Clearing the Waters vol. 3, no. 1, summer, Santa Fe.

Coleman, M.W. 1999. Geology-Based Analysis of Elevated Aluminum in the Jemez River, North-Central New Mexico. Unpublished Report to USEPA Region 6, New Mexico Total Maximum Daily Load (TMDL) Team, New Mexico Environment Department, Surface Water Quality Bureau, Santa Fe, 2 p.

Coleman, M.W. 2000. Rio Puerco Watershed Mining Impacts. New Mexico Environment Department, Clean Water Act (CWA) Section 319(h) Grant Project Summary Report to USEPA Region 6 Dallas. New Mexico Environment Department, Surface Water Quality Bureau, Watershed Protection Section, Santa Fe.

Eger, P., and K. Lapakko. 1988. Nickel and Copper Removal From Mine Drainage by a Natural Wetland. U.S. Bureau of Mines Circular 9183. pp. 301-309.

Filas, B., and T. Wildeman. 1992. The Use of Wetlands for Improving Water Quality to Meet Established Standards. Nevada Mining Association Annual Reclamation Conference, Sparks, NV.

Girts, M.A., and R.L.P. Kleinmann. 1986. Constructed Wetlands for Treatment of Mine Water. American Institute of Mining Engineers Fall Meeting, St. Louis, MO.

Holm, J.D., and T. Elmore. 1986. Passive Mine Drainage Treatment Using Artificial and Natural Wetlands. Proceedings of the High Altitude Revegetation Workshop, no. 7. pp. 41-48.

Kleinmann, R.L.P. 1989. Acid mine drainage: U.S. Bureau of Mines, research and developments, controlling methods for both coal and metal mines. Engineering Mining Journal 190:16i-n.

Machemer, S.D. 1992. Measurements and Modeling of the Chemical Processes in a Constructed Wetland Built to Treat Acid Mine Drainage. Colorado School of Mines Thesis T-4074, Golden, CO.

Metish, J.J., and others. 1998., Treating Acid Mine Drainage From Abandoned Mines in Remote Areas. USDA Forest Service Technology and Development Program, AMD Study 7E72G71, Missoula, MT, US Govt. Printing Office: 1998-789-283/15001.

Royer, M.D., and L. Smith. 1995. Contaminants and Remedial Options at Selected Metal-Contaminated Sites. Battelle Memorial Institute-Columbus Division, under contract # 68-CO-0003-WA41 to Natl. Risk Management Lab-Office of Research and Development, USEPA. EPA/540/R-95/512.

Slifer, D.W. 1996. Red River Groundwater Investigation. New Mexico Environment Department Surface Water Quality Bureau Nonpoint Source Pollution Section; CWA Section 319 (h) Grant Project Final Report to USEPA Region 6 - Dallas.

USEPA. 1996. Seminar Publication Managing Environmental Problems at Inactive and Abandoned Metals Mine Sites. Office of Research and Development, EPA/625/R-95/007.

Wakao, N., T. Takahashi, Y. Saurai, and H. Shiota. 1979. A treatment of acid mine water using sulfate-reducing bacteria. Journal of Ferment. Technology 57(5):445-452.

Riparian and Streambank Stabilization

Colorado Department of Natural Resources. Streambank Protection Alternatives. State Soil Conservation Board.

Meyer, Mary Elizabeth. 1989. A Low Cost Brush Deflection System for Bank Stabilization and Revegetation.

Missouri Department of Conservation. Restoring Stream Banks With Willows. (pamphlet)

New Mexico State University. Revegetating Southwest Riparian Areas (pamphlet). College of Agriculture and Home Economics, Cooperative Extension Service.

State of Pennsylvania Department of Environmental Resources. 1986. A Streambank Stabilization and Management Guide for Pennsylvania Landowners. Division of Scenic Rivers.

State of Tennessee. 1995. Riparian Restoration and Streamside Erosion Control Handbook. Nonpoint Source Water Pollution Management Program.

Roads

*Becker, Burton C., and Thomas Mills. 1972. Guidelines for Erosion and Sediment Control Planning and Implementation. Maryland Department of Water Resources, # R2-72-015***.**

Bennett, Francis William, and Roy Donahue. 1975. Methods of Quickly Vegetating Soils of Low Productivity, Construction Activities. USEPA, Office of Water Planning and Standards Report # 440/9-75-006.

Hopkins, Homer T., and others. Processes, Procedures, and Methods to Control Pollution Resulting from all Construction Activity. USEPA Office of Air and Water Programs, EPA Report 430/9-73-007.

New Mexico Natural Resources Department. 1983. Reducing Erosion from Unpaved Rural Roads in New Mexico, A Guide to Road construction and Maintenance Practices. Soil and Water Conservation Division.

New Mexico State Highway and Transportation Department and USDA-Soil Conservation Service. Roadside Vegetation Management Handbook.

New Mexico Environment Department. 1993. Erosion and Sediment Control Manual. *Surface Water Quality Bureau.*

USDA Forest Service Southwestern Region. 1996. Managing Roads for Wet Meadow Ecosystem Recovery. FHWA-FLP-96-016.

USEPA. 1992. Rural Roads: Pollution Prevention and Control Measures (handout).

Stormwater/Urban

Web site: http://www.epa.gov/ordntrnt/ORD/WebPubs/nctuw/Pitt.pdf

Brede, A.D., L.M. Cargill, D.P. Montgomery, and T.J. Samples. 1987. Roadside Development and Erosion Control. Oklahoma Department of Transportation, Report No. FHWA/OK 87 (5).

Delaware Department of Natural Resources and Environmental Control. 1997. Conservation Design for Stormwater Management: A Design Approach to Reduce Stormwater Impacts from Land Development and Achieve Multiple Objectives Related to Land Use. Sediment and Stormwater Program & the Environment Management Center, Brandywine Conservancy.

Taylor, Scott, and G. Fred Lee. 2000. Stormwater Runoff Water Quality Science/ Engineering Newsletter, Urban Stormwater Runoff Water Quality Management Issues, vol. 3, no. 2. May 19.

Miscellaneous

Web site: http://www.epa.gov/OWOW/NPS

Constructed Wetlands Bibliography, www.nal.usda.gov/wqic/Constructed_Wetlands_all/index.htmL

New Mexico Environment Department. 2000. A Guide to Successful Watershed Health, Surface Water Quality Bureau.

Roley, William Jr. Watershed Management and Sediment Control for Ecological Restoration.

Rosgen, D. 1996. Applied River Morphology. Chapter 8 —Applications (Grazing, Fish Habitat).

State of Tennessee Nonpoint Source Water Pollution Management Program. 1995. Riparian Restoration and Streamside Erosion Control Handbook.

The Federal Interagency Stream Restoration Working Group. 1998. Stream Corridor Restoration. Principles, Processes, and Practices. Chapter 8– Restoration Design; Chapter9–Restoration Implementation, Monitoring, and Management.

USDA Forest Service Southwestern Region. Soil and Water Conservation Practices Handbook. Section 23— Recreation Management, Section 25— Watershed Management, Section 41 —Access and Transportation Systems and Facilities.

USEPA. 1993. Guidance Specifying Management Measures for Sources of Nonpoint Pollution in Coastal Waters. Office of Water, Coastal Zone Act Reauthorization Amendments of 1990. EPA840-B-92-002.

Interagency Baer Team. 2000. Cerro Grande Fire Burned Area Emergency Rehabilitation (BAER) Plan. Section F—Specifications.

10.0 OTHER IMPLEMENTATION ITEMS

10.1 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 Management Plan (WMP). The WMP 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 to reduce and prevent impacts on 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.

SWQB staff will provide any technical assistance such as selection and application of BMPs needed to meet WMP goals. Implementation of BMPs within the watershed to reduce pollutant loading from nonpoint sources will be on a voluntary basis. Reductions from point sources will be addressed in revisions to discharge permits. 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 WMP. With assistance from SWQB, stakeholders are encouraged to develop watershed groups in order to identify the following components of a successful WMP:

- the public outreach method(s) and structure that will be used to engage and maintain public and governmental involvement, including local, state, federal, and tribal governments. This should include a process for cross-agency coordination and a process for continuous public involvement.

- any monitoring and evaluation activities based on water quality goals and outcomes needed to refine the problems or assess progress towards achieving water quality goals. If monitoring is required to clarify or refine the water quality problems and sources, it should be done following a specific plan including concise goals and targeting, specific performance measures, and a firm end date.

- the specific water quality problems to be addressed, the sources of pollution, and the relative contribution of sources. WMPs should support a comprehensive approach to addressing all nonpoint sources in a targeted watershed. The WMP should also ensure that water quality benefits are demonstrated in the short term. One mechanism that can be used in such a strategy is having individuals serving as watershed coordinators/evaluators.

• a blueprint of the actions to be taken and desired water quality goals and outcomes (i.e., implementation of pollution controls and natural resource restoration measures). This may include implementation of tasks identified in source water protection programs and/or actions to implement TMDLs. This should include a discussion in the WMP as to how all program components will be applied (technical, financial, and educational) to the water quality program.

• a schedule for implementation of needed restoration measures and identification of appropriate lead agencies to oversee implementation, maintenance, monitoring and evaluation.

• funding needs to support the implementation and maintenance of restoration measures. This should include funding that would be available through federal assistance programs, state funds, and other resources.

10.2 Time Line

The table below details the proposed implementation timeline.

Table 10.1 Proposed Implementation Timeline

Implementation Actions	Year 1	Year 2	Year 3	Year 4	Year 5
Public Outreach and Involvement	X	X	X	X	X
Establish Milestones	X				
Secure Funding	X		X		
Implement Management Measures (BMPs)		X	X		
Monitor BMPs		X	X	X	
Determine BMP Effectiveness				X	X
Reevaluate Milestones				X	X

10.3 Clean Water Act §319(h) Funding Opportunities

The Watershed Protection Section of the SWQB provides § 319(h) funding made available by USEPA to assist in implementation of BMPs to address water quality problems on reaches listed on the CWA Integrated §303(d)/§305(b) list or 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 state agencies. Proposals are submitted by applicants through a Request for Proposal (RFP) process and require a nonfederal match of 40 percent of the total project cost consisting of funds and/or in-kind services. Further information on funding from the Clean Water Act §319

(h) can be found at the New Mexico Environment Department's Web site: http://www.nmenv.state.nm.us.

10.4 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 Section 1100E and Section 1105C) (NMWQCC 1995b) 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 request for proposals (RFP) process coincidental 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 Watershed Restoration Action Strategy. The cooperation of watershed stakeholders will be pivotal in the implementation of these TMDLs as well.

11.0 PUBLIC PARTICIPATION

Public participation was solicited in the development of this TMDL (see Appendix J). The draft TMDL was made available for a 30-day comment period starting **. Response to comments is attached as Appendix K of this document. The draft document notice of availability was extensively advertised in newsletters, e-mail distribution lists, Web page postings (http://www.nmenv.state.nm.us), and press releases to area newspapers.

REFERENCES CITED

Behnke, R.J., and M. Zarn. 1976. *Biology andManagement of Threatened and EndangeredWestern Trouts*. USDA Forest Service, General Technical Report RM-28. Fort Collins, CO. 45 pp.

Borland, J.P. 1970. *A Proposed Streamflow-Data Program for New Mexico*. USGS Open File Report. 71 pp.

Brookes, A. 1986. Response of aquatic vegetation to sedimentation downstream from river channelization works in England and Wales. *Biological Conservation* 38:352–367.

Brown, L.C., and T.O. Barnwell. 1987. *The Enhanced Steam Water Quality Models QUAL2E and QUAL2E-UNCAS: Documentation and User Manual*. EPA/600/3-87/007.

Chapra, Steven C. 1997. *Surface Water-Quality Modeling*. McGraw-Hill Companies, Inc., New York, NY.

Cinquemani, V., J.R. Owenby, and R.G. Baldwin. 1978. *Input Data for Solar Systems*. U.S. Department of Energy. Environmental Resource and Assessments Branch. 192 pp.

Congalton, Phoebe. 1998. *Leaf Litter and Organic Soil-Quality & Decomposition Across an Urban-Rural Land-Use Gradient*. <http://courses.mbl.edu/SES/data/project/1998/congalton.pdf> Accessed April 1, 2003.

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.

Forest Guardians and Southwest Environmental Center v. Carol Browner, Administrator, USEPA, Civil Action 96-0826 LH/LFG, 1997.

Gray, Donald M. (editor). 1970. *Handbook on the Principles of Hydrology*. Water Information Center, Port Washington, NY.

Leopold, L.B., M.G. Wolman, and J.P. Miller. 1964. *Fluvial Processes in Geomorphology*. Dover Publications, Inc., New York, NY.

Matlock, Marty D., Kevin R. Kasprzak, and G. Scott Osborn. 2003. Sediment oxygen demand in the Arroyo Colorado River. *Journal of the American Water Resources Association* 39(2)267–275.

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

NMAC (New Mexico Administrative Code) 20.6.2. 2002. *New Mexico Water Quality Control Commission Regulations*. September 2002. State of New Mexico.

NMAC (New Mexico Administrative Code) 20.6.4. 2002. *Standards for Interstate and Intrastate Surface Waters.* October 2002. State of New Mexico.

SWQB/NMED (Surface Water Qualty Bureau/New Mexico Environment Department). 1991. *Intensive Water Quality Survey of Tributaries to Abiquiu Reservoir: Rio Puerco de Chama, Rio Gallina, and Encino, Poleo, Canones, and Coyote Creeks in Rio Arriba County, New Mexico*. April 22–25, 1991.

SWQB/NMED (Surface Water Qualty Bureau/New Mexico Environment Department). 1999. *Draft Pollutant Source Documentation Protocol*. Santa Fe, NM. Revised 10/2/00.

SWQB/NMED (Surface Water Qualty Bureau/New Mexico Environment Department). 2000. *State of New Mexico Procedures for Assessing Standards Attainment for 303(d) List and 305(b) Report Assessment Protocol*. Santa Fe, NM.

SWQB/NMED (Surface Water Qualty Bureau/New Mexico Environment Department). 2001a. *Special Water Quality Survey of the Lower Rio Chama, Watershed Between El Vado Dam and San Juan Pueblo, Rio Arriba, Sandoval, and Taos Counties, New Mexico.* Santa Fe, NM.

SWQB/NMED (Surface Water Qualty Bureau/New Mexico Environment Department). 2001b. *Quality Assurance Project Plan (QAPP) for Water Quality Management Programs*. Santa Fe, NM.

SWQB/NMED (Surface Water Qualty Bureau/New Mexico Environment Department). 2001c. *Draft Protocol for the Assessment of Temperature*. Santa Fe, NM.

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

TVA (Tennessee Valley Authority). 1972. *Heat and Mass Transfer Between a Water Surface and the Atmosphere*. Water Resour. Lab. Rep. 14. Norris, TN. 166 pp.

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 and Wildlife Service, Fort Collins, CO. 200 pp.

Thomann, Robert V., and John A. Mueller. 1987. *Principles of Surface Water Quality Modeling and Control*. HarperCollins Publishers, Inc., New York, NY.

Thomann, Robert V., James Collier, Arthur Butt, Elizabeth Casman, and Lewis Linker. 1994. *Response of the Chesapeake Bay Water Quality Model to Loading Scenarios*. Chesapeake Bay Program Technology Transfer Report CBP/TRS 101/94.

USEPA (U.S. Environmental Protection Agency). 1985. *Rates, Constants and Kinetics Formulations in Surface Water Quality Modeling* (2nd ed.). EPA/600/3-85/040. Office of Research and Development, Environmental Research Laboratory, Athens GA.

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

USEPA (U.S. Environmental Protection Agency). 1991b. *Guidance for Water Quality-Based Decisions: The TMDL Process*. EPA 440/4-91-001. U.S. Environmental Protection Agency, Office of Water, Washington, DC.

USEPA (U.S. Environmental Protection Agency). 1993. *Manual: Nitrogen Control*. EPA /625/R-93/010. U.S. Environmental Protection Agency, Office of Research and Development, Washington, DC.

USEPA (U.S. Environmental Protection Agency). 1999a. *Protocol for Developing Total Maximum Daily Loads. Book 2, Streams and Rivers. Part 1, Biochemical Oxygen Demand/Dissolved Oxygen and Nutrients/Eutrophication*. Section 4.2.1.2. EPA 823-B-097-002. U.S. Environmental Protection Agency, Washington, DC.

USEPA (U.S. Environmental Protection Agency). 1999b. *Protocol for Developing Nutrient TMDLs.* EPA 841-B-99-007. U.S. Environmental Protection Agency, Washington, DC.

USFS (U.S. Forest Service). 1998. *WinXSPRO Channel Cross-Section Analyzer*. Fort Collins, CO.

USGS (U.S. Geological Survey). 1982. *Streamflow Characteristics Related to Channel Geometry of Streams in Western United States*. Technical Paper 2193. 17 pp.

USGS (U.S. Geological Survey). 1993. *Methods for Estimating Magnitude and Frequency of Floods in Southwestern United States*. Open File Report 93-419. 211 pp.

USGS (U.S. Geological Survey). 1999. *Stream Segment Temperature Model (SSTEMP) Version 1.0.0*. (Latest download off Web is version 1.2.2.) Revised April 1999. Biological Resources Division, Midcontinent Ecological Science Center, Fort Collins, CO.

USGS (U.S. Geological Survey). 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*. WRIR 01-4271. Albuquerque, NM. 22 pp.

Van Nieuwenhuyse, E.E., and J.D. LaPierre. 1986. Effects of placer gold mining on primary production in subarctic streams of Alaska. *Water Resources Bulletin* 22:91–99.

Wood, Tamara M. 2001. *Sediment Oxygen Demand in Upper Klamath and Agency Lakes, Oregon 1999*: U. S. Geological Survey Water-Resources Investigations Report 01-4080, 13p.

APPENDICES

Appendix A: Summary of Delisting Letters for the Lower Chama Watershed

Appendix B: Relationships Between Turbidity and TSS for Turbidity Impaired Reaches in the Lower Chama Watershed

Appendix C: Conversion Factor Derivation

Appendix D: Pollutant Source(s) Documentation Protocol Forms

Appendix E: Thermograph Summary Data and Graphics

Appendix F: Hydrology and Meteorological Input Data for SSTEMP

Appendix G: SSTEMP Model Run Inputs and Outputs

Appendix H: Dissolved Oxygen Data from July 24–25, 2002 Data Sonde

Appendix I: Dissolved Oxygen Modeling Worksheet (QUAL2E)

Appendix J: Public Participation Process Flowchart

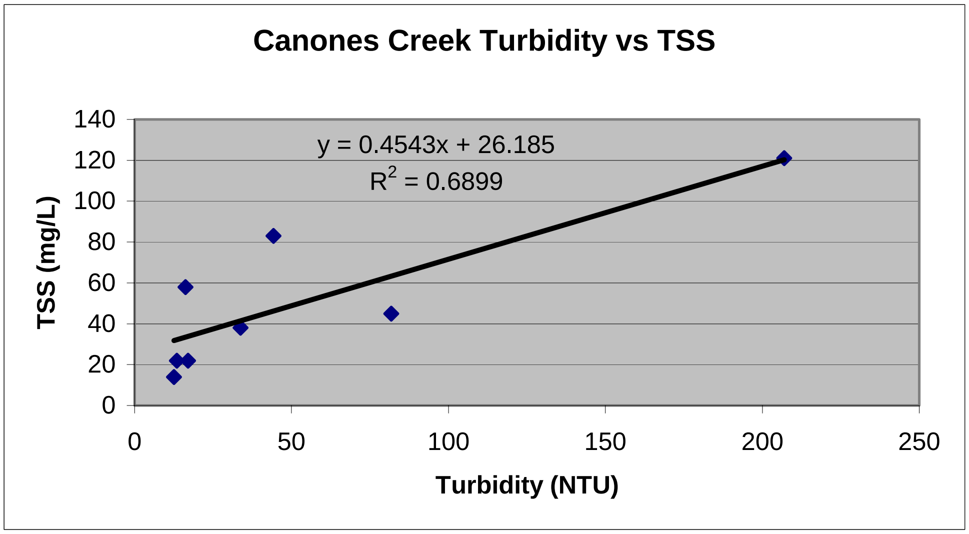
Appendix K: Response to Comments

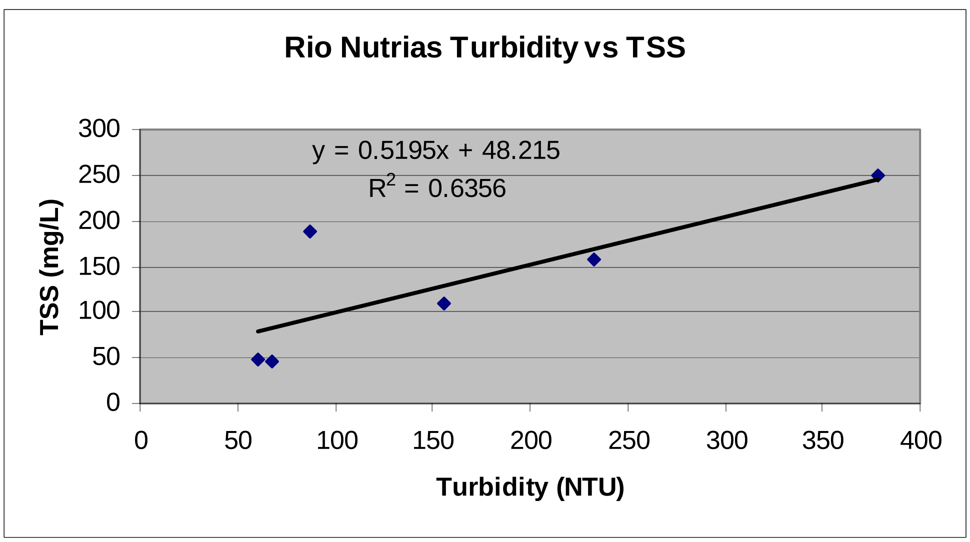
Appendix A: Summary of Delisting Letters for the Lower Chama Watershed

- Temperature Assessment and Delisting Rationale for Canones Creek
- Stream Bottom Deposit Assessment and Delisting Rationale for Polvadera Creek
- Plant Nutrients Assessment and Delisting Rationale for Abiquiu Creek
- Stream Bottom Deposit Assessment and Delisting Rationale for Abiquiu Creek
- Conductivity Assessment and Delisting Rationale for Canjilon Creek
- Dissolved Oxygen Assessment and Delisting Rationale for Canjilon Creek
- Temperature Assessment and Delisting Rationale for Canjilon Creek
- Turbidity Assessment and Delisting Rationale for Canjilon Creek
- Conductivity Assessment and Delisting Rationale for the Rio Cebolla
- Aluminum Assessment and Delisting Rationale for the Rio Chama
- Stream Bottom Deposit Assessment and Delisting Rationale for Chihuahuenos Creek
- Stream Bottom Deposit Assessment and Delisting Rationale for Coyote Creek
- Aluminum Assessment and Delisting Rationale for El Rito Creek
- Plant Nutrients Assessment and Delisting Rationale for El Rito Creek
- Turbidity Assessment and Delisting Rationale for El Rito Creek
- Stream Bottom Deposit Assessment and Delisting Rationale for the Rio Gallina
- Stream Bottom Deposit Assessment and Delisting Rationale for the Rio del Oso
- Temperature Assessment and Delisting Rationale for the Rio del Oso
- Turbidity Assessment and Delisting Rationale for the Rio del Oso
- Aluminum Assessment and Delisting Rationale for the Rio Ojo Caliente
- Stream Bottom Deposits Assessment and Delisting Rationale for the Rio Ojo Caliente
- Stream Bottom Deposit Assessment and Delisting Rationale for the Rio Tusas

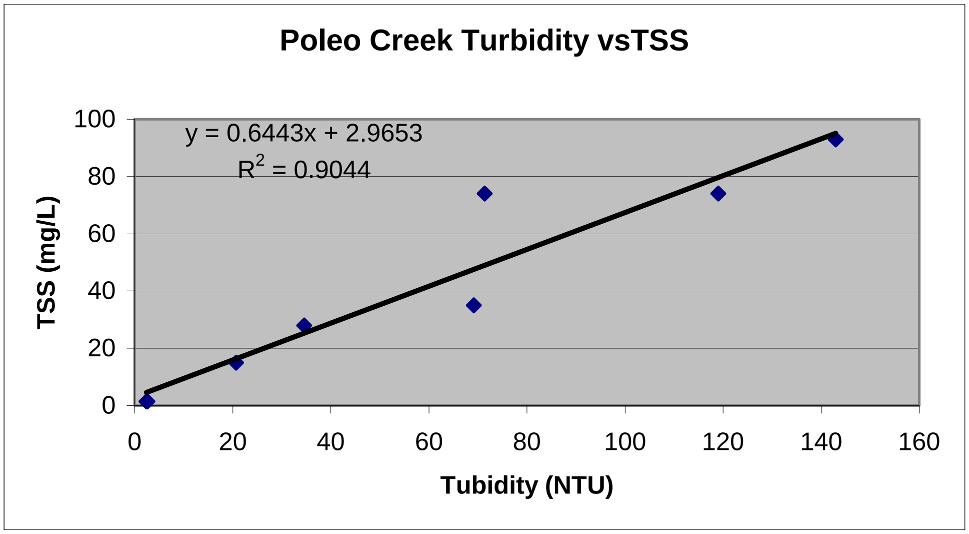
The assessments and delisting rationale are housed in the SWQB Administrative Record and are available upon request.

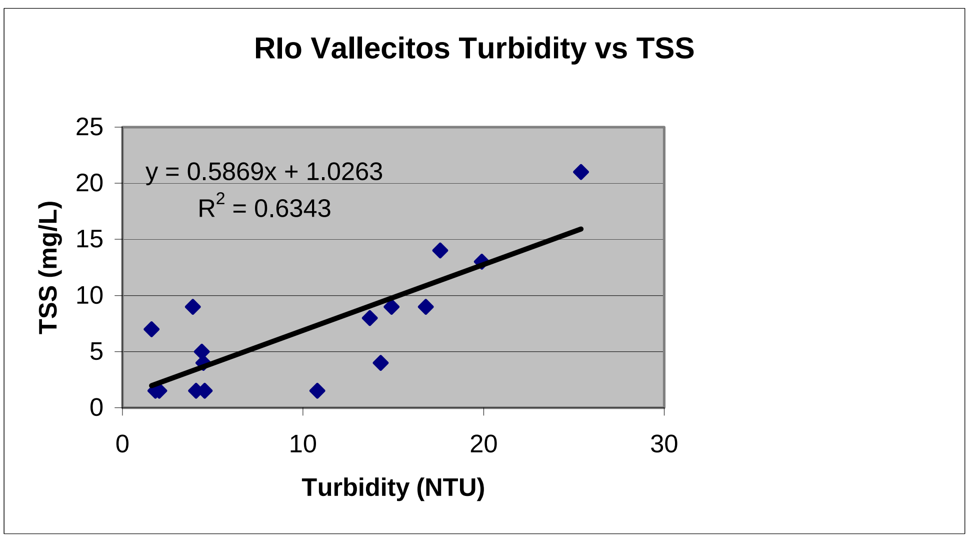
Appendix B. Relationships between Turbidity and TSS for Turbidity Impaired Reaches in the Lower Chama Watershed.





Appendix B. Continued





Appendix C. Conversion Factor Derivation

8.34 Conversion Factor Derivation

Million gallons/day **x** Milligrams/liter **x** 8.34 = pounds/day

10^6~~gallons~~/day **x** 3.7854 liters/~~1 gallon~~ **x** 10^{-3}gram/liter **x** 1 pound/454 ~~grams~~ = pounds/day

10^6 (10^{-3}) (3.7854)/454 = 3785.4/454

= 8.3379
= **8.34**

Appendix D. Source Documentation Sheet and Sources Summary Table

Source Documentation Sheet

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:

SEGMENT NUMBER:
BASIN:
PARAMETER:

STAFF MAKING ASSESSMENT:
DATE:

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 8400
- ☐ 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 O[illegible] 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

Appendix D Continued

Lower Chama TMDL Potential Sources Summary

Reach	Parameter	Source Sheets	Details
Canones	Turbidity	Rangeland Silviculture Removal of Riparian Vegetation, Streambank Modification/Destabilization	• Cañones Creek above confluence with Chihuahuenos Creek has good riparian vegetation with boulders, cobble and little embeddedness (4/29/02) •Cañones Creek at State Road 167 below Canones has beaver dams (4/29/02) •At State Road 1 bank erosion at bridge. Cows in riparian zone. Severe lack of riparian vegetation. C-type stream. Lower Creek—incising stream upstream from bridge, boulders/cobble/sand embeddedness (lots of sand). (4/29/02)
	Chronic aluminum	Natural and Unknown	See turbidity
	Fecal Coliform	Rangeland Land Disposal (onsite wastewater systems)	•Site is below town of Canones and may be influenced by irrigation return flows (1991) •downstream of the town of Canones are beaver dams (4/29/02)
Nutrias	Turbidity	Agriculture (irrigated crop production) Rangeland Removal of Riparian Vegetation Streambank Modification/Destabilization Road Maintenance (improperly placed culvert)	•box culvert may be causing some of the problems in this reach, the structure may block flow, especially during high flows (4/29/02) •overgrazing in the area (4/29/02) •Hwy 84 box culvert overpass acts as grade control. Has overgrazed. Incising (1) bank erosion (2) box culvert hwy. Sand banks about 8 foot high. Some willows established on left ascending bank and right ascending bank. Young, but may become established (mature) if drought persists for 2 more years and they are not ripped out by high flows. (4/29/02)
Poleo	Turbidity	Agriculture Silviculture (road construction or maintenance) Removal of Riparian Vegetation	

Reach	Parameter	Source Sheets	Details
		Streambank Modification/Destabilization Natural	
Polvadera	Temperature	Removal of Riparian Vegetation	•lots of cows and totally trashed out (4/29/02) •Poor range management, no vegetative overstory, trash (cars) in creek (4/29/02) •Sand in stream with some cobble •Spring fed banks throughout
Vallecitos	Turbidity	Agriculture (irrigated crop production) Rangeland Resource Extraction (surface mining) Hydromodification Road Maintenance or Runoff Removal of Riparian Vegetation Streambank Modification/Destabilization Recreational Activities	•Vallecitos Creek 8.4 miles above Vallecitos looks pretty good, although some channelization/berms alongside the stream (we noticed this in 1999), some beaver activity (4/29/02) •stream a little wide near the bridge at the lower station (below gypsum mine), but a lot of riparian vegetation upstream and downstream of the bridge, stream substrate consists of boulders, some sand, little embeddedness (4/29/02) •at the lower Vallecitos site, water levels much lower than in 1999 (4/29/02) •Irrigated pasturage (4/29/02) •Some ranchettes alongside the creek in the lower portions (4/29/02)
	Chronic aluminum	Resource Extraction (surface mining) Hydromodification	See turbidity
	Temperature	Removal of Riparian Vegetation Streambank Modification/Destabilization Recreational Activities Rangeland	See turbidity
Abiquiu	DO	Rangeland Land Disposal (onsite wastewater systems) Hydromodification (channelization) Removal of Riparian Vegetation Streambank Modification/Destabilization Road Maintenance or Runoff	•could not take sample, water ¼” deep, could not sample macroinvertebrates or nutrients at this site, not enough water to support plant growth (06/10/02) •No algae (macrophytes) in the stream, springs upstream, substrate mainly sand, residential areas upstream, grazing, may be confined feeding operations upstream of sampling sites, bridge may impact sediment, vegetation includes a lot of cottonwoods, cattails, and willows covering the main channel (7/24/02)

Photos

No photos available of Poleo Creek

Rio Nutrias

Rio Nutrias

Cañones Creek

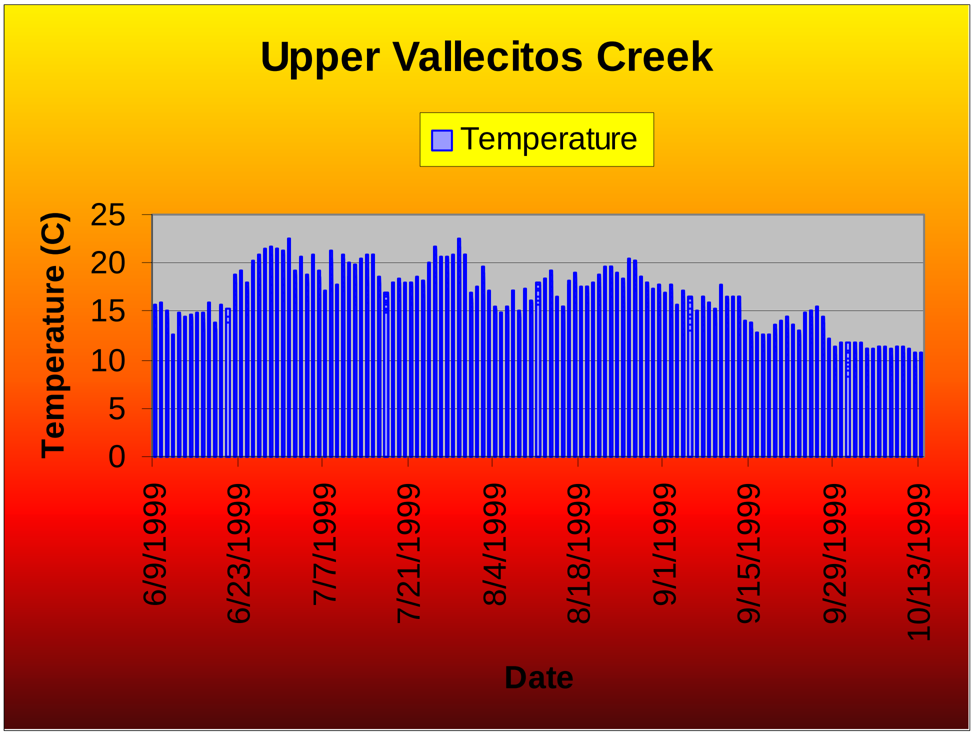
Polvadera Creek


Rio Vallecitos (lower station)

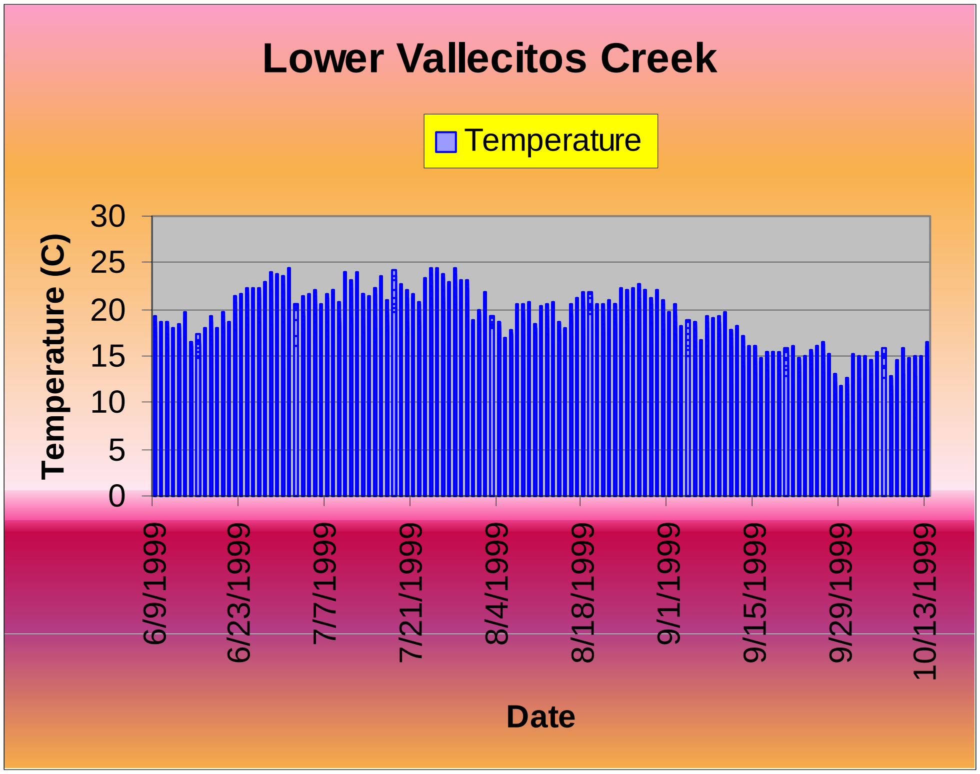
Abiquiu Creek

Abiquiu Creek

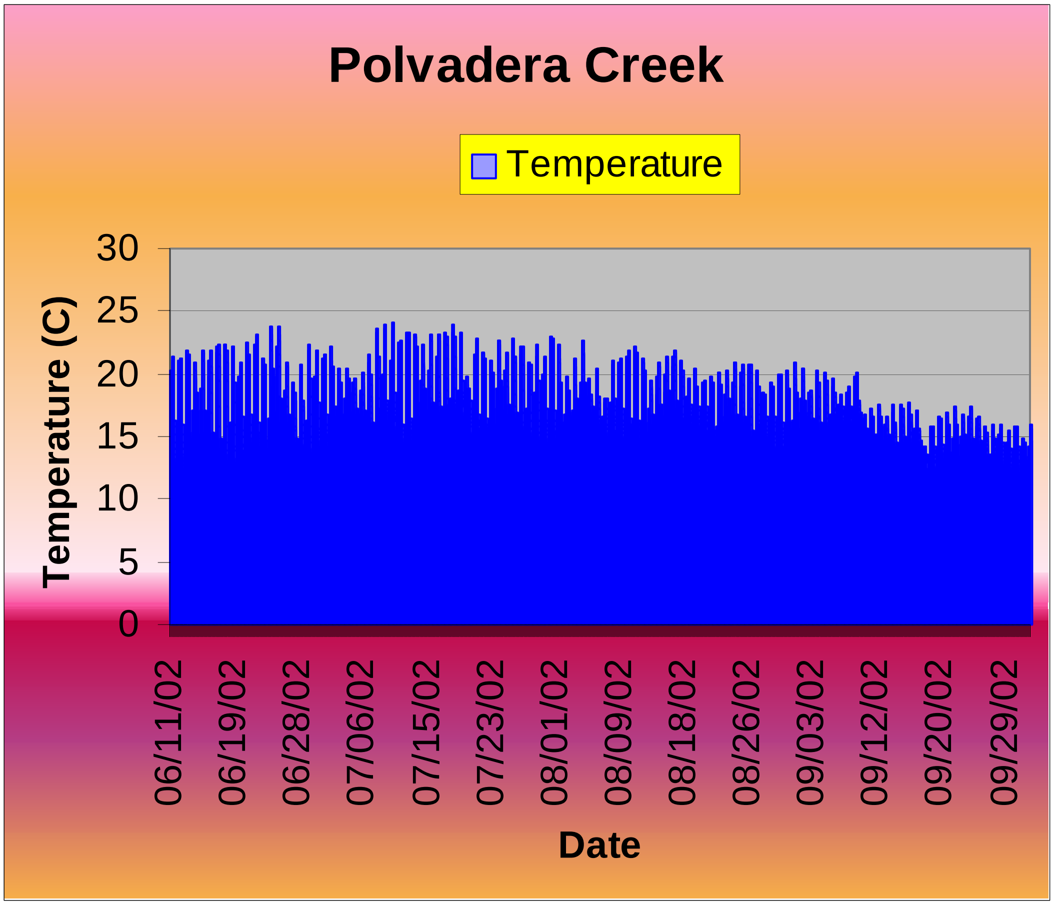
Appendix E. Thermograph Summary Data and Graphics



Total Readings	3030
Max. Temp.	22.46
# Values >20	***80***
Percent Values >20	***0.7***
Avg. Temp.	13.8
Min. Temp.	4.03
Variance	11.8



Total Readings	3031
Max. Temp.	24.53
# Values >20	***413***
Percent Values >20	***13.6***
Avg. Temp.	16.0
Min. Temp.	3.54
Variance	15.0



Total Readings	2718
Max. Temp.	24.13
# Values >20	***302***
Percent Values >20	***11.1***
Avg. Temp.	16.4
Min. Temp.	10.99
Variance	6.6

Appendix F: Hydrology and Meteorology Input Data for SSTEMP

4Q3 Information (used in the SSTEMP model run for Rio Vallecitos):

$$4Q3 = 7.1023 \times 10^{-5} * DA^{0.68} * P_w^{3.59} * s^{1.23}$$

DA = drainage area, in square miles (183)
P_w = average basin mean winter precipitation 1961-1990, in inches (6.68)
S = Slope (.002)

4Q3 = .001 cfs

Air Temperature Corrections:

Ta = To + Ct * (Z-Zo)
where:

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

Information from Albuquerque Dam Site, *www.wrcc.dri.edu*.

Waterbody	Zo	Z	Ct	To	Ta
Polvadera	1939	2192	-0.00656	10.4	8.7
Vallecitos	1939	2352	-0.00656	10.4	7.7

Relative Humidity Corrections:

Rh = Ro * [1.0640 ^ (To-Ta)] * [(Ta+273.16)/(To+273.16)]
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)
^ = exponentiation

Information from Albuquerque Dam Site, *www.wrcc.dri.edu*.

Waterbody	To	Ta	Ro	Rh
Polvadera	10.4	8.7	.6	.66
Vallecitos	10.4	7.7	.6	.71

Appendix G: SSTEMP Model Run Inputs and Outputs

Temperature Modeling Input Worksheet (SSTEMP)

Location: ________Polvadera Creek_____
Reviewer and Date: __KDors___7/11/03_________________

Is there Thermograph Data for this Reach?   Yes
Name of Thermograph Data File___Polvadera.xls____
Time of year to model for __(mm/dd)__8/16_________

Hydrology Parameter	Units	Description	Value	Notes
Instream Flow	cfs	Mean Flow. See documentation for exceptions. Assumptions are for steady state flow.	1.4	Used SWQB data 7/25/99 and 10/5/99 average.
Inflow Temperature	C and F	Mean daily water temp at inflow	16.4 C 61.52 F	Used SWQB data from thermograph field sheet.
Segment Outflow	cfs	Account for inflow from SMALL tributaries, groundwater, etc. Anything contributing more than 10 percent of the flow should be separated into another segment. Can use 4Q3.	1.4	Used SWQB data 7/25/99 and 10/5/99 average. Did not use the 4Q3 because this reach has springs along it and may actually be slightly gaining.
Accretion Temperature	C and F	Temperature of the lateral inflow, barring tributaries, generally should be the same as groundwater temperature.	10.4 C 50.7 F	Found at www.wrcc.dri.edu (Abiquiu Dam site)

Geometry Parameter	Units	Description	Value	Notes
Latitude	Degrees Minutes	Read off standard topographic map	36 10’ 59”	Used SWQB data from thermograph field sheet.
Dam at head of segment?		Check box if yes, do not check box if no	Do not check	

Geometry Parameter	Units	Description	Value	Notes
Segment Length	Miles	Segment length for which you want to predict outflow temperature. Estimated from topographic map, but measured length is preferred.	12.2	Got from CWA Integrated §303(d)/§305(b) list
Upstream Elevation	Feet	Read off standard topographic map	7850	
Downstream Elevation	Feet	Read off standard topographic map **DO NOT ENTER A DOWNSTREAM ELEVATION LARGER THAN AN UPSTREAM ELEVATION**	6619	
Width's A	Seconds /ft^2	May be derived by calculating the wetted width-discharge relationship. Plot three widths on the Y-axis, Plot three discharge's on the X-Axis (log-log). The slope of the line is the "B" term. The "A" term is the Y- intercept when X=1. Better to solve for "A" from: $A=W/Q^B$ (see manual).	8	Used SWQB geomorphic data from 9/29/00. This was calculated using WinxsPro as well with the same results.
Width's B Term	NA	From B above, see manual.	.01	
Manning's n	NA	Empirical measure of the segment's "roughness." Not very sensitive in model environment. Get from geomorphic data or use default value of 0.035.	.032	Used SWQB geomorphic data from 9/29/00.

Meteorology Parameter	Units	Description	Value	Notes
Air Temperature	C and F	Mean daily air temp for period to be modeled.	8.7 C 47.7 F	Use formula in manual to calculate. ***This is the most important variable for this model.***
Maximum Air Temperature	C and F	Is a special case of an override condition.	Do not check, model estimates.	Do not check, model estimates.
Relative Humidity	Percent	Mean daily relative humidity for period to be modeled. Adjust for location using formula in manual.	66	Found at www.wrcc.dri.edu (Abiquiu Dam site. Used the early morning value.)
Wind Speed	mph		8.9	Found at www.wrcc.dri.edu (Abiquiu Dam site)
Ground Temperature	C and F	Use mean annual temperature.	10.4 C 50.7 F	Found at www.wrcc.dri.edu (Abiquiu Dam site)
Thermal Gradient	J/M^2/sec/C	Rate of thermal input (or output) from the streambed to the water.	1.65	Use 1.65 as default.
Possible Sun	Percent	Surrogate for cloud cover.	76	Found at www.wrcc.dri.edu (Abiquiu Dam site)
Dust Coefficient	NA	Amount of Dust in the Air. May be calibrated by using known ground level solar radiation data. See manual for table of representative values.	6.5	Used the average of the 3-10 summer representative values.
Ground Reflectivity	Percent	Measure of the amount of short-wave radiation reflected back from the earth into the atmosphere. See manual for table of representative values.	24	Used average of 15-33 for flat ground grass representative values.
Solar Radiation	J/m^2/sec			Leave blank model calculates.

Shade Parameter	Units	Description	Value	Notes
Total Shade	Percent	Refers to how much of the segment is shaded by vegetation, cliffs, etc. Represents the percent of the incoming solar radiation that does not reach the water. Use field notes, densiometer readings etc.	10	Estimate from field observations, and photos.

Polvadera Input and Output
Calibration Run

```
"SSTEMP (2.0.8)  ","03/11/2004  05:14 pm"
"NoName"
"English",         "Segment Inflow (cfs)",            "1.400"
"English",         "Inflow Temperature (°F)",         "61.520"
"English",         "Segment Outflow (cfs)",           "1.400"
"English",         "Accretion Temp. (°F)",            "50.700"
"English",         "Latitude (degrees)",              "36.000"
"English",         "Segment Length (mi)",             "12.200"
"English",         "Upstream Elevation (ft)",         "7850.00"
"English",         "Downstream Elevation (ft)",       "6619.00"
"English",         "Width's A Term (s/ft²)",          "8.000"
"English",         "  B Term where W = A*Q**B",       "0.010"
"English",         "Manning's n",                     "0.032"
"English",         "Air Temperature (°F)",            "44.200"
"English",         "Relative Humidity (%)",           "66.000"
"English",         "Wind Speed (mph)",                "8.900"
"English",         "Ground Temperature (°F)",         "50.700"
"English",         "Thermal gradient (j/m²/s/C)",     "1.650"
"English",         "Possible Sun (%)",                "76.000"
"English",         "Dust Coefficient",                "6.500"
"English",         "Ground Reflectivity (%)",         "24.000"
"English",         "Solar Radiation (Langleys/d)",    "433.990"
"English",         "Total Shade (%)",                 "10.000"
"English",         "Segment Azimuth (degrees)",       "-15.011"
"West Side Variables"
"English",         "Topographic Altitude (degrees)",  "24.981"
"English",         "Vegetation Height (ft)",          "25.000"
"English",         "Vegetation Crown (ft)",           "15.000"
"English",         "Vegetation Offset (ft)",          "5.000"
"English",         "Vegetation Density (%)",          "50.000"
"East Side Variables"
"English",         "Segment Azimuth (degrees)",       "15.011"
"English",         "Topographic Altitude (degrees)",  "35.000"
"English",         "Vegetation Height (ft)",          "20.000"
"English",         "Vegetation Crown (ft)",           "15.000"
"English",         "Vegetation Offset (ft)",          "75.000"
"English",         " Maximum Air Temp (°F)",          "47.891"
"Dam at Head of Segment","Unchecked"
" Maximum Air Temp (°F)","Unchecked"
"Solar Radiation","Disabled"
"Total Shade","Enabled"
"Month/day","10/01"
         "Predicted Mean (°C) = 10.04"
         "Estimated Maximum (°C) = 17.82"
         "Approximate Minimum (°C) = 2.27"
         "Mean Equilibrium (°C) = 10.04"
         "Maximum Equilibrium (°C) = 17.89"
         "Minimum Equilibrium (°C) = 2.20"
```

From thermograph data at Polvadera station

Actual mean Temp (ºC) 10/01/98 = 13.3 Error = ± 24.5%
Actual max Temp (ºC) 10/01/98 = 14.9 Error = ± 19.5%
Actual min Temp (ºC) 10/01/98 = 11.5 Error = ±80.3%

Initial Run for 8/16/98

```
"SSTEMP (2.0.8)  ","08/18/2003  03:09 pm"
"NoName"
"English",         "Segment Inflow (cfs)",              "1.400"
"English",         "Inflow Temperature (°F)",           "61.520"
"English",         "Segment Outflow (cfs)",             "1.400"
"English",         "Accretion Temp. (°F)",              "50.700"
"English",         "Latitude (degrees)",                "36.000"
"English",         "Segment Length (mi)",               "12.200"
"English",         "Upstream Elevation (ft)",           "7850.00"
"English",         "Downstream Elevation (ft)",         "6619.00"
"English",         "Width's A Term (s/ft²)",            "8.000"
"English",         "  B Term where W = A*Q**B",         "0.010"
"English",         "Manning's n",                       "0.032"
"English",         "Air Temperature (°F)",              "47.700"
"English",         "Relative Humidity (percent)",             "66.000"
"English",         "Wind Speed (mph)",                  "8.900"
"English",         "Ground Temperature (°F)",           "50.700"
"English",         "Thermal gradient (j/m²/s/C)",       "1.650"
"English",         "Possible Sun (percent)",                  "76.000"
"English",         "Dust Coefficient",                  "6.500"
"English",         "Ground Reflectivity (percent)",           "24.000"
"English",         "Solar Radiation (Langleys/d)",      "595.200"
"English",         "Total Shade (percent)",                   "10.000"
"English",         "Segment Azimuth (degrees)",         "-15.000"
"West Side Variables"
"English",         "Topographic Altitude (degrees)",    "25.000"
"English",         "Vegetation Height (ft)",            "25.000"
"English",         "Vegetation Crown (ft)",             "15.000"
"English",         "Vegetation Offset (ft)",            "5.000"
"English",         "Vegetation Density (percent)",            "50.000"
"East Side Variables"
"English",         "Segment Azimuth (degrees)",         "15.000"
"English",         "Topographic Altitude (degrees)",    "35.000"
"English",         "Vegetation Height (ft)",            "20.000"
"English",         "Vegetation Crown (ft)",             "15.000"
"English",         "Vegetation Offset (ft)",            "75.000"
"English",         " Maximum Air Temp (°F)",            "51.329"
"Dam at Head of Segment","Unchecked"
" Maximum Air Temp (°F)","Unchecked"
"Solar Radiation","Disabled"
"Total Shade","Enabled"
"Month/day","08/16"
         "Predicted Mean (°F) = 57.23"
         "Estimated Maximum (°F) = 69.92"
         "Approximate Minimum (°F) = 44.53"
         "Mean Equilibrium (°F) = 57.23"
         "Maximum Equilibrium (°F) = 69.95"
         "Minimum Equilibrium (°F) = 44.50"
```

Final Run for 8/16/98

```
"SSTEMP (2.0.8)  ","03/11/2004  05:09 pm"
"NoName"
"English",         "Segment Inflow (cfs)",            "1.400"
"English",         "Inflow Temperature (°F)",         "61.520"
"English",         "Segment Outflow (cfs)",           "1.400"
"English",         "Accretion Temp. (°F)",            "50.700"
"English",         "Latitude (degrees)",              "36.000"
"English",         "Segment Length (mi)",             "12.200"
"English",         "Upstream Elevation (ft)",         "7850.00"
"English",         "Downstream Elevation (ft)",       "6619.00"
"English",         "Width's A Term (s/ft²)",          "6.000"
"English",         "  B Term where W = A*Q**B",       "0.010"
"English",         "Manning's n",                     "0.032"
"English",         "Air Temperature (°F)",            "47.700"
"English",         "Relative Humidity (%)",           "66.000"
"English",         "Wind Speed (mph)",                "8.900"
"English",         "Ground Temperature (°F)",         "50.700"
"English",         "Thermal gradient (j/m²/s/C)",     "1.650"
"English",         "Possible Sun (%)",                "76.000"
"English",         "Dust Coefficient",                "6.500"
"English",         "Ground Reflectivity (%)",         "24.000"
"English",         "Solar Radiation (Langleys/d)",    "595.200"
"English",         "Total Shade (%)",                 "19.000"
"English",         "Segment Azimuth (degrees)",       "-15.011"
"West Side Variables"
"English",         "Topographic Altitude (degrees)",  "24.981"
"English",         "Vegetation Height (ft)",          "25.000"
"English",         "Vegetation Crown (ft)",           "15.000"
"English",         "Vegetation Offset (ft)",          "5.000"
"English",         "Vegetation Density (%)",          "50.000"
"East Side Variables"
"English",         "Segment Azimuth (degrees)",       "15.011"
"English",         "Topographic Altitude (degrees)",  "35.000"
"English",         "Vegetation Height (ft)",          "20.000"
"English",         "Vegetation Crown (ft)",           "15.000"
"English",         "Vegetation Offset (ft)",          "75.000"
"English",         " Maximum Air Temp (°F)",          "51.329"
"Dam at Head of Segment","Unchecked"
" Maximum Air Temp (°F)","Unchecked"
"Solar Radiation","Disabled"
"Total Shade","Enabled"
"Month/day","08/16"
         "Predicted Mean (°C) = 13.34"
         "Estimated Maximum (°C) = 19.94"
         "Approximate Minimum (°C) = 6.74"
         "Mean Equilibrium (°C) = 13.34"
         "Maximum Equilibrium (°C) = 19.99"
         "Minimum Equilibrium (°C) = 6.68"
```

Temperature Modeling Input Worksheet (SSTEMP)

Location: ________Rio Vallecitos_____
Reviewer and Date: __KDors___7/11/03_________________

Is there Thermograph Data for this Reach? Yes
Name of Thermograph Data File___Polvadera.xls____
Time of year to model for __(mm/dd)__8/16_________

Hydrology Parameter	Units	Description	Value	Notes
Instream Flow	cfs	Mean Flow. See documentation for exceptions. Assumptions are for steady state flow.	4.75	Used SWQB data 10/6/99.
Inflow Temperature	C and F	Mean daily water temp at inflow	17.1 C 62.78 F	Used SWQB data from thermograph field sheet.
Segment Outflow	cfs	Account for inflow from SMALL tributaries, groundwater, etc. Anything contributing more than 10 percent of the flow should be separated into another segment. Can use 4Q3.	.002	Calculated the 4Q3 using the USGS method for ungaged watersheds (see Appendix E).
Accretion Temperature	C and F	Temperature of the lateral inflow, barring tributaries, generally should be the same as groundwater temperature.	10.4 C 50.7 F	Found at www.wrcc.dri.edu (Abiquiu Dam site)

Geometry Parameter	Units	Description	Value	Notes
Latitude	Degrees Minutes	Read off standard topographic map	36	
Dam at head of segment?		Check box if yes, do not check box if no	Do not check	
Segment Length	Miles	Segment length for which you want to predict outflow temperature. Estimated from	36.31	Got from CWA Integrated §303(d)/§305(b) list

Geometry Parameter	Units	Description	Value	Notes
		topographic map, but measured length is preferred.		
Upstream Elevation	Feet	Read off standard topographic map	8026	
Downstream Elevation	Feet	Read off standard topographic map **DO NOT ENTER A DOWNSTREAM ELEVATION LARGER THAN AN UPSTREAM ELEVATION**	7500	
Width's A	Seconds /ft^2	May be derived by calculating the wetted width-discharge relationship. Plot three widths on the Y-axis, Plot three discharge's on the X-Axis (log-log). The slope of the line is the "B" term. The "A" term is the Y- intercept when X=1. Better to solve for "A" from: $A=W/Q^B$ (see manual).	7.8	Used SWQB geomorphic data from 7/14/99. This was calculated using WinxsPro as well with the same results.
Width's B Term	NA	From B above, see manual.	.002	
Manning's n	NA	Empirical measure of the segment's "roughness." Not very sensitive in model environment. Get from geomorphic data or use default value of 0.035.	.084	Used SWQB geomorphic data from 7/14/99.

Meteorology Parameter	Units	Description	Value	Notes
Air Temperature	C and F	Mean daily air temp for period to be modeled.	9.9 C 49.8 F	Use formula in manual to calculate. ***This is the most important variable for this model.***
Maximum Air Temperature	C and F	Is a special case of an override condition.	Do not check, model estimates.	Do not check, model estimates.
Relative Humidity	Percent	Mean daily relative humidity for	62	Found at www.wrcc.dri.edu

Meteorology Parameter	Units	Description	Value	Notes
		period to be modeled. Adjust for location using formula in manual.		(Abiquiu Dam site. Used the early morning value.)
Wind Speed	mph		8.9	Found at www.wrcc.dri.edu (Abiquiu Dam site)
Ground Temperature	C and F	Use mean annual temperature.	10.4 C 50.7 F	Found at www.wrcc.dri.edu (Abiquiu Dam site)
Thermal Gradient	J/M^2/sec/C	Rate of thermal input (or output) from the streambed to the water.	1.65	Use 1.65 as default.
Possible Sun	Percent	Surrogate for cloud cover.	76	Found at www.wrcc.dri.edu (Abiquiu Dam site)
Dust Coefficient	NA	Amount of Dust in the Air. May be calibrated by using known ground level solar radiation data. See manual for table of representative values.	6.5	Used the average of the 3-10 summer representative values.
Ground Reflectivity	Percent	Measure of the amount of short-wave radiation reflected back from the earth into the atmosphere. See manual for table of representative values.	24	Used average of vegetation, early and late summer, representative values.
Solar Radiation	J/m^2/sec			Leave blank model calculates.

Shade Parameter	Units	Description	Value	Notes
Total Shade	Percent	Refers to how much of the segment is shaded by vegetation, cliffs, etc. Represents the percent of the incoming solar radiation that does not reach the water. Use field notes, densiometer readings etc.	10	Estimate from field observations, and photos.

Vallecitos Inputs and Outputs

Calibration Run

```
"SSTEMP (2.0.8)  ","03/11/2004  04:46 pm"
"NoName"
"English",         "Segment Inflow (cfs)",             "4.750"
"English",         "Inflow Temperature (°F)",          "48.400"
"English",         "Segment Outflow (cfs)",            "1.400"
"English",         "Accretion Temp. (°F)",             "50.700"
"English",         "Latitude (degrees)",               "36.000"
"English",         "Segment Length (mi)",              "36.310"
"English",         "Upstream Elevation (ft)",          "8026.00"
"English",         "Downstream Elevation (ft)",        "7500.00"
"English",         "Width's A Term (s/ft²)",           "7.800"
"English",         "  B Term where W = A*Q**B",        "0.002"
"English",         "Manning's n",                      "0.084"
"English",         "Air Temperature (°F)",             "47.800"
"English",         "Relative Humidity (%)",            "62.000"
"English",         "Wind Speed (mph)",                 "8.900"
"English",         "Ground Temperature (°F)",          "50.700"
"English",         "Thermal gradient (j/m²/s/C)",      "1.650"
"English",         "Possible Sun (%)",                 "76.000"
"English",         "Dust Coefficient",                 "6.500"
"English",         "Ground Reflectivity (%)",          "24.000"
"English",         "Solar Radiation (Langleys/d)",     "433.781"
"English",         "Total Shade (%)",                  "10.000"
"English",         "Segment Azimuth (degrees)",        "-15.000"
"West Side Variables"
"English",         "Topographic Altitude (degrees)",   "25.000"
"English",         "Vegetation Height (ft)",           "25.000"
"English",         "Vegetation Crown (ft)",            "15.000"
"English",         "Vegetation Offset (ft)",           "5.000"
"English",         "Vegetation Density (%)",           "50.000"
"East Side Variables"
"English",         "Segment Azimuth (degrees)",        "15.000"
"English",         "Topographic Altitude (degrees)",   "35.000"
"English",         "Vegetation Height (ft)",           "20.000"
"English",         "Vegetation Crown (ft)",            "15.000"
"English",         "Vegetation Offset (ft)",           "75.000"
"English",         " Maximum Air Temp (°F)",           "51.609"
"Dam at Head of Segment","Unchecked"
" Maximum Air Temp (°F)","Unchecked"
"Solar Radiation","Disabled"
"Total Shade","Enabled"
"Month/day","10/01"
         "Predicted Mean (°F) = 52.06"
         "Estimated Maximum (°F) = 62.71"
         "Approximate Minimum (°F) = 41.40"
         "Mean Equilibrium (°F) = 52.07"
         "Maximum Equilibrium (°F) = 65.82"
         "Minimum Equilibrium (°F) = 38.31"
```

From thermograph data at Lower Vallecitos station

Actual mean Temp (ºF) 10/01/98 = 48.4 Error = ± 7.6%
Actual max Temp (ºF) 10/01/98 = 59.3 Error = ± 5.8%
Actual min Temp (ºF) 10/01/98 = 38.4 Error = ±7.8%

Initial Run for 8/16/98

```
"SSTEMP (2.0.8)  ","08/19/2003  10:49 am"
"NoName"
"English",         "Segment Inflow (cfs)",             "4.750"
"English",         "Inflow Temperature (°F)",          "62.780"
"English",         "Segment Outflow (cfs)",            "0.001"
"English",         "Accretion Temp. (°F)",             "50.700"
"English",         "Latitude (degrees)",               "36.000"
"English",         "Segment Length (mi)",              "36.310"
"English",         "Upstream Elevation (ft)",          "8026.00"
"English",         "Downstream Elevation (ft)",        "7500.00"
"English",         "Width's A Term (s/ft²)",           "7.800"
"English",         "  B Term where W = A*Q**B",        "0.002"
"English",         "Manning's n",                      "0.084"
"English",         "Air Temperature (°F)",             "49.800"
"English",         "Relative Humidity (percent)",            "62.000"
"English",         "Wind Speed (mph)",                 "8.900"
"English",         "Ground Temperature (°F)",          "50.700"
"English",         "Thermal gradient (j/m²/s/C)",      "1.650"
"English",         "Possible Sun (percent)",                 "76.000"
"English",         "Dust Coefficient",                 "6.500"
"English",         "Ground Reflectivity (percent)",          "24.000"
"English",         "Solar Radiation (Langleys/d)",     "596.071"
"English",         "Total Shade (percent)",                  "10.000"
"English",         "Segment Azimuth (degrees)",        "-15.000"
"West Side Variables"
"English",         "Topographic Altitude (degrees)",   "25.000"
"English",         "Vegetation Height (ft)",           "25.000"
"English",         "Vegetation Crown (ft)",            "15.000"
"English",         "Vegetation Offset (ft)",           "5.000"
"English",         "Vegetation Density (percent)",           "50.000"
"East Side Variables"
"English",         "Segment Azimuth (degrees)",        "15.000"
"English",         "Topographic Altitude (degrees)",   "35.000"
"English",         "Vegetation Height (ft)",           "20.000"
"English",         "Vegetation Crown (ft)",            "15.000"
"English",         "Vegetation Offset (ft)",           "75.000"
"English",         " Maximum Air Temp (°F)",           "53.547"
"Dam at Head of Segment","Unchecked"
" Maximum Air Temp (°F)","Unchecked"
"Solar Radiation","Disabled"
"Total Shade","Enabled"
"Month/day","08/16"
         "Predicted Mean (°F) = 58.10"
         "Estimated Maximum (°F) = 70.71"
         "Approximate Minimum (°F) = 45.49"
         "Mean Equilibrium (°F) = 58.09"
         "Maximum Equilibrium (°F) = 70.71"
         "Minimum Equilibrium (°F) = 45.47"
```

Final Run for 8/16/98 (change total shade to 22.5 % and Width's A term to 7.0)

```
"SSTEMP (2.0.8)  ","03/11/2004  05:03 pm"
"NoName"
"English",         "Segment Inflow (cfs)",             "4.750"
"English",         "Inflow Temperature (°F)",          "62.780"
"English",         "Segment Outflow (cfs)",            "0.001"
"English",         "Accretion Temp. (°F)",             "50.700"
"English",         "Latitude (degrees)",               "36.000"
"English",         "Segment Length (mi)",              "36.310"
"English",         "Upstream Elevation (ft)",          "8026.00"
"English",         "Downstream Elevation (ft)",        "7500.00"
"English",         "Width's A Term (s/ft²)",           "7.000"
"English",         "  B Term where W = A*Q**B",        "0.002"
"English",         "Manning's n",                      "0.084"
"English",         "Air Temperature (°F)",             "49.800"
"English",         "Relative Humidity (%)",            "62.000"
"English",         "Wind Speed (mph)",                 "8.900"
"English",         "Ground Temperature (°F)",          "50.700"
"English",         "Thermal gradient (j/m²/s/C)",      "1.650"
"English",         "Possible Sun (%)",                 "76.000"
"English",         "Dust Coefficient",                 "6.500"
"English",         "Ground Reflectivity (%)",          "24.000"
"English",         "Solar Radiation (Langleys/d)",     "596.071"
"English",         "Total Shade (%)",                  "22.500"
"English",         "Segment Azimuth (degrees)",        "-15.011"
"West Side Variables"
"English",         "Topographic Altitude (degrees)",  "24.981"
"English",         "Vegetation Height (ft)",           "25.000"
"English",         "Vegetation Crown (ft)",            "15.000"
"English",         "Vegetation Offset (ft)",           "5.000"
"English",         "Vegetation Density (%)",           "50.000"
"East Side Variables"
"English",         "Segment Azimuth (degrees)",        "15.011"
"English",         "Topographic Altitude (degrees)",  "35.000"
"English",         "Vegetation Height (ft)",           "20.000"
"English",         "Vegetation Crown (ft)",            "15.000"
"English",         "Vegetation Offset (ft)",           "75.000"
"English",         " Maximum Air Temp (°F)",           "53.547"
"Dam at Head of Segment","Unchecked"
" Maximum Air Temp (°F)","Unchecked"
"Solar Radiation","Disabled"
"Total Shade","Enabled"
"Month/day","08/16"
         "Predicted Mean (°C) = 13.53"
         "Estimated Maximum (°C) = 19.96"
         "Approximate Minimum (°C) = 7.09"
         "Mean Equilibrium (°C) = 13.52"
         "Maximum Equilibrium (°C) = 19.96"
         "Minimum Equilibrium (°C) = 7.08"
```

Appendix H: Dissolved Oxygen data from July 24-25, 2002 data sonde

Date	Time	Temp	SpCond	DO Conc	DO percent	pH
M/D/Y	hh:mm:ss	C	mS/cm	mg/L	percent	
7/24/2002	17:00:00	23.35	0.229	6.57	77.1	8.37
7/24/2002	17:15:00	23.69	0.231	6.65	78.6	8.4
7/24/2002	17:30:00	22.57	0.233	6.45	74.6	8.33
7/24/2002	17:45:00	21.94	0.234	6.4	73.2	8.29
7/24/2002	18:00:00	21.43	0.227	6.44	72.9	8.25
7/24/2002	18:15:00	21.02	0.22	6.39	71.8	8.18
7/24/2002	18:30:00	20.93	0.227	6.35	71.2	8.18
7/24/2002	18:45:00	20.83	0.229	6.41	71.7	8.18
7/24/2002	19:00:00	20.68	0.234	6.46	72	8.19
7/24/2002	19:15:00	20.53	0.234	6.55	72.9	8.2
7/24/2002	19:30:00	20.43	0.234	6.63	73.6	8.22
7/24/2002	19:45:00	20.34	0.234	6.66	73.8	8.22
7/24/2002	20:00:00	20.23	0.237	6.54	72.3	8.22
7/24/2002	20:15:00	20.08	0.242	5.64	62.1	8.22
7/24/2002	20:30:00	19.96	0.242	4.58	50.4	8.21
7/24/2002	20:45:00	19.83	0.242	4.53	49.6	8.2
7/24/2002	21:00:00	19.73	0.244	3.96	43.3	8.21
7/24/2002	21:15:00	19.61	0.246	3.69	40.3	8.21
7/24/2002	21:30:00	19.5	0.247	3.56	38.8	8.17
7/24/2002	21:45:00	19.46	0.224	4.07	44.3	8.17
7/24/2002	22:00:00	19.36	0.206	6.22	67.6	8.17
7/24/2002	22:15:00	19.34	0.206	5.38	58.4	8.14
7/24/2002	22:30:00	19.31	0.207	4.84	52.5	8.09
7/24/2002	22:45:00	19.27	0.207	4.53	49.1	8.06
7/24/2002	23:00:00	19.22	0.208	4.16	45.1	8.03
7/24/2002	23:15:00	19.17	0.209	3.57	38.7	8.01
7/24/2002	23:30:00	19.11	0.21	3.14	33.9	7.98
7/24/2002	23:45:00	19.04	0.21	2.92	31.5	7.96
7/25/2002	0:00:00	18.95	0.211	2.79	30.1	7.95
7/25/2002	0:15:00	18.86	0.21	2.65	28.5	7.94
7/25/2002	0:30:00	18.74	0.21	2.47	26.5	7.93
7/25/2002	0:45:00	18.6	0.21	3.51	37.5	7.93
7/25/2002	1:00:00	18.35	0.208	5.34	56.8	7.95
7/25/2002	1:15:00	18.16	0.207	5.75	61	7.97
7/25/2002	1:30:00	18.06	0.206	5.79	61.3	7.98
7/25/2002	1:45:00	17.97	0.205	5.87	62	7.98
7/25/2002	2:00:00	17.87	0.205	6.03	63.6	7.99
7/25/2002	2:15:00	17.76	0.204	6.2	65.2	8
7/25/2002	2:30:00	17.69	0.204	6.23	65.4	8
7/25/2002	2:45:00	17.61	0.203	6.25	65.5	8
7/25/2002	3:00:00	17.51	0.203	6.2	64.9	8

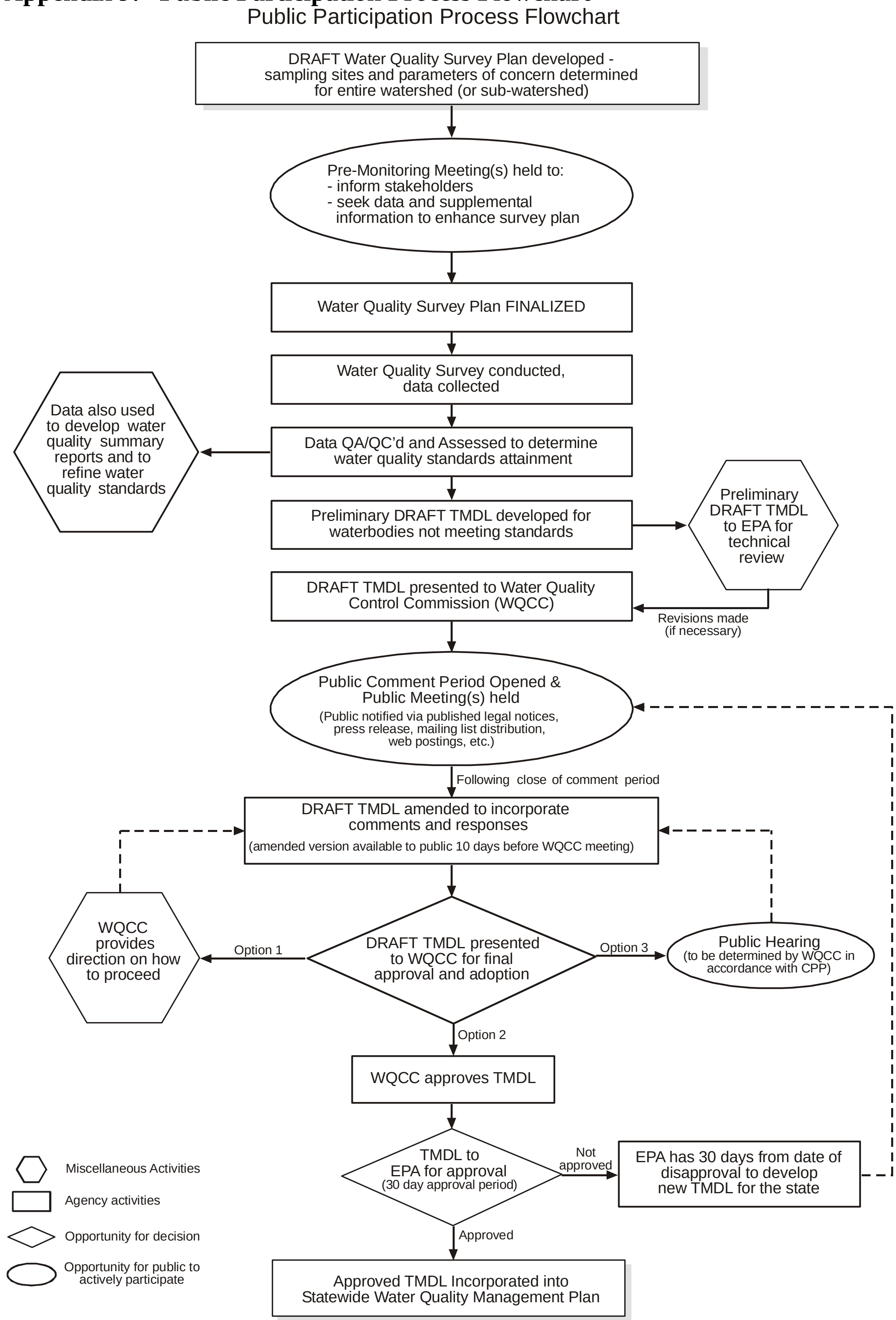
Date	Time	Temp	SpCond	DO Conc	DO percent	pH
7/25/2002	3:15:00	17.43	0.202	6.16	64.3	8.01
7/25/2002	3:30:00	17.34	0.202	6.25	65.2	8.01
7/25/2002	3:45:00	17.24	0.202	6.31	65.6	8.01
7/25/2002	4:00:00	17.14	0.202	6.22	64.6	8.01
7/25/2002	4:15:00	17.05	0.201	6.25	64.7	8.01
7/25/2002	4:30:00	16.95	0.201	6.22	64.4	8.01
7/25/2002	4:45:00	16.87	0.201	6.15	63.5	8.02
7/25/2002	5:00:00	16.8	0.201	5.93	61.1	8.04
7/25/2002	5:15:00	16.71	0.201	6.16	63.4	8.03

Appendix I: Dissolved Oxygen Modeling Worksheet (QUAL2E)

Dissolved Oxygen Modeling Worksheet (QUAL2E)

Model Parameter	Units	Value	Notes
In-stream Flow	cfs	0.18	Observed data on 07/28/99
Incremental Flow	cfs/mi^2	0.04	Observed data on 07/28/99
Inflow Temperature	C and F	21.7 C 71 F	Observed data on 07/28/99
Saturation DO	mg/L	6.3	Based on observed temperature on 07/28/99 and assuming the average elevation of the watershed is 6500'
Organic N	mg/L	0.2	Observed data on 07/28/99
NH_3 N	mg/L	0.1	Observed data on 07/28/99
NO_2 N	mg/L	0.1	Observed data on 07/28/99
5 day CBOD	mg/L	2.0	Assumption based on observations at Rio Chama on 6/3/1969 (Please refer text for more details)
Groundwater DO	mg/L	2.0	Assumption based on EPA guidance (EPA, 1991) for sandy bottom stream. (Please refer text for more details)
Atmospheric pressure	inch. Hg	24	Based on nearby meteorological observations (Please refer text for more details)
Carbonaceous Biochemical Oxygen Deoxygenation Rate	1/day	0.1	Default model parameters based on US EPA guidance (US EPA 1985) and QUAL2E user's manual (Brown and Barnwell 1987)
Organic Nitrogen Hydrolysis	1/day	0.1	Default model parameters based on US EPA guidance (US EPA 1985) and QUAL2E user's manual (Brown and Barnwell 1987)
Ammonia Oxidation Rate	1/day	0.25	Default model parameters based on US EPA guidance (US EPA 1985) and QUAL2E user's manual (Brown and Barnwell 1987)
Nitrite Oxidation Rate	1/day	2.05	Default model parameters based on US EPA guidance (US EPA 1985) and QUAL2E user's manual (Brown and Barnwell 1987)
Current critical SOD	$g\ m^{-2}d^{-1}$	0.86	Assuming sand bottom stream. (Please refer text for more details)

Appendix J: Public Participation Process Flowchart



Appendix K: Response to Comments

No comments were received on this TMDL.