WATER QUALITY SURVEY SUMMARY

FOR THE

CANADIAN RIVER & SELECT TRIBUTARIES

(CANADIAN HEADWATERS TO THE TEXAS BORDER &
CIMARRON RIVER, CONCHAS RIVER, UTE CREEK, AND REVUELTO CREEK)

2006

Prepared by

Surface Water Quality Bureau
New Mexico Environment Department

May 2010

This page left intentionally blank.

PRINCIPAL INVESTIGATORS

Survey Leads

Water Chemistry:	Shelly Drinkard
Biology/Habitat:	Gary Schiffmiller
Watershed Protection:	Chris Cudia
TMDL writers:	Shelly Drinkard Heidi Henderson
GIS/Mapping :	Bill Skinner

Surface Water Quality Bureau Office: (505) 827-0187

Water quality surveys and assessments conducted by the New Mexico Environment Department Surface Water Quality Bureau are completed to fulfill Section 106 of the Clean Water Act [33 USC 1251 et seq.], *Work Program for Water Quality Management.* This project was funded by a grant from the U.S. Environmental Protection Agency.

This page left intentionally blank.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF ACRONYMS

ALU	Aquatic Life Use
AU	Assessment Unit
DO	Dissolved Oxygen
MAS	Monitoring and Assessment Section
NMAC	New Mexico Administrative Code
RGA	Rapid Geomorphic Assessment
RHA	Rapid Habitat Assessment
SCI	Stream Condition Index
SFNF	Santa Fe National Forest
STORET	Storage and Retrieval System
SWQB	Surface Water Quality Bureau
TMDL	Total Maximum Daily Load
USEPA	United States Environmental Protection Agency
WWTP	Wastewater Treatment Plant
WQS	Water Quality Standards

EXECUTIVE SUMMARY

The Monitoring and Assessment Section (MAS) of the Surface Water Quality Bureau (SWQB) conducted a water quality survey of Canadian River Watershed between March and November 2006. This survey focused on the mainstem of the Canadian River from the Colorado border to the Texas border as well as a number of tributary streams, such as Chicorica Creek, Raton Creek, Cimarron River, Pajarito Creek, Ute Creek, and Revuelto Creek (**Figure 1** and **Table 1**).

The primary purpose of this survey was to collect chemical, physical, and biological data to evaluate water quality within the watershed. The data collected are assessed against New Mexico Water Quality Standards (WQS; NMAC 2007) and impaired waters are summarized in the Integrated List portion of the biennial *State of New Mexico Integrated Clean Water Act §303(d)/305(b) Report*. It is important to note that both the assessment protocols and water quality standards are revised periodically to incorporate new information and refinements. Any assessment conclusions presented in this report are based on water quality standards and assessment protocols that existed at the time the report was developed. The U.S. Environmental Protection Agency (USEPA) uses the most recent state-developed assessment protocols and the most recent USEPA-approved water quality standards when deciding whether or not to approve impairment determinations on the biennial *New Mexico Integrated List of Impaired Waters*. Therefore, the current impairment conclusions in the Integrated List supersede assessment conclusions in this survey report if they should differ.

Water chemistry sampling occurred at 35 survey stations which were selected based on previous survey findings and proximity to potential sources. Chemical analyses included total nutrients, total and dissolved metals, major anions and cations, radionuclides, and microbiological collections. In addition, data loggers were deployed at select stations to monitor diurnal trends in temperature, pH, dissolved oxygen, conductivity, and turbidity.

Additional data on the physical habitat and biological communities were collected for this survey. Two qualitative assessments were performed to provide general information on the health of the habitat and structure of the stream: the Rapid Geomorphic Assessment (RGA) and the Rapid Habitat Assessment (RHA). These observational assessments combined with the quantitative canopy measurements provide an indication of riparian health.

Biological surveys collected benthic macroinvertebrate, periphyton, and fish community data. The macroinvertebrate community is generally the first to show a response to certain stressors such as the fine sediment suspended in the water column or settled on the bottom of the channel. Currently information is compiled on all identified taxa to create a stream condition index score (SCI) which expresses the relative condition of the macroinvertebrate community based on the diversity, tolerance, and feeding habitats of those taxa present in the stream reach. Macroinvertebrate data were assessed at 5 sites as well as 2 reference sites; all 5 study sites rated fair (refer to **Sedimentation/Siltation** bullet under Cimarron River Subwatershed for more information).

Water quality in the **Canadian River Watershed** was found to be generally good. The most common cause of impairment in the Canadian Headwaters near Raton, NM was nutrients,

whereas *E. coli* was the most common impairment along the mainstem of the Canadian River. Water quality sampling also found *E. coli* and nutrient exceedences in Pajarito Creek near Tucumcari, NM and boron exceedences in Revuelto Creek near Logan, NM. Water quality sampling in Chicorica Creek (Canadian River to headwaters), Conchas River (Conchas Lake to headwaters), and Ute Creek (Ute Reservoir to headwaters) found no exceedences of applicable water quality criteria.

Water quality in the **Cimarron River Subwatershed** was found to be relatively impacted. Primary findings of the surface water quality assessment are as follows:

- ***E. coli*:** Available data exceed the applicable criterion in Cieneguilla Creek, Sixmile Creek, Ute Creek, Rayado Creek, North Ponil Creek, and Ponil Creek.

- **Nutrients:** Assessment of available data indicate nutrient enrichment in Cieneguilla Creek, Cimarron River, Moreno Creek, Ponil Creek above US 64, and Sixmile Creek, with possible enrichment in North Ponil Creek and lower Rayado Creek.

- **Temperature:** Available data indicate that temperature impairments are widespread throughout the Cimarron Watershed. Stream reaches listed for temperature include Cieneguilla Creek, Sixmile Creek, Moreno Creek, Ute Creek, South Ponil Creek, Middle Ponil Creek, North Ponil Creek, upper Ponil Creek, upper Rayado Creek, and the Cimarron River from Cimarron Village to Turkey Creek.

- **Turbidity:** Available water quality data exceed the historic, segment specific criterion of 25 NTU in Cieneguilla Creek, Sixmile Creek, Ute Creek, North Ponil Creek, upper Ponil Creek, and the Cimarron River from Cimarron Village to Turkey Creek. Biological assessments using macroinvertebrate data from the same locations verified the turbidity impairments in several of these stream reaches, however benthic macroinvertebrate data are needed to confirm the turbidity listings for Sixmile Creek, Ute Creek, and Cimarron River.

- **Arsenic:** In the Cimarron River (Cimarron Village to Eagle Nest Lake), available data exceed the domestic water supply criterion of 2.3 μg/L but did not exceed the human health criterion of 9.0 μg/L. Ute Creek (Cimarron River to headwaters) and Eagle Nest Lake, tributaries to this reach of the Cimarron River, also exceed the domestic water supply criterion.

- **Sedimentation/Siltation:** A total of 5 stream reaches were found to have a biological assessment score, based on macroinvertebrate sampling, signifying impaired conditions. However of these 5 reaches, only Cieneguilla Creek had greater than 20% fine sediment indicating a biological impairment due to sedimentation/siltation. Middle Ponil Creek, North Ponil Creek, and upper and lower Ponil Creek exhibited normal amounts of fine sediment, 16%, 20%, 11%, and 6% respectively. Middle Ponil, North Ponil, and Ponil Creeks were listed for benthic-macroinvertebrate bioassessments until the exact cause of the biological impairment is determined.

- **Aluminum:** Assessment of available data resulted in the delisting all of the AUs previously listed for aluminum.

NMED collected fish in Chicorica, Raton, Rayado, and Ute creeks. No previously unknown species were collected in any except Ute Creek. In addition to several historically known species in Ute Creek, NMED collected largemouth bass and yellow bullhead, both of which were historically unknown in Ute Creek. These species presumably gained access to Ute Creek from Ute Reservoir and were able to colonize upstream reaches of Ute Creek due to sustained high flow in recent years despite the fact that at the time and location we sampled, Ute Creek consisted of a series of isolated pools.

1.0 INTRODUCTION

The Canadian River watershed (US Geological Survey [USGS] Hydrologic Unit Codes [HUCs] 11080001, 11080002, 11080003, 11080004, 11080005, 11080006, 11080007, 11080008, and 11090101) is part of the vast drainage system of the Arkansas River that covers approximately 121,729 square kilometers (47,700 square miles) in three states. The Canadian Watershed encompasses about one-sixth the land area of New Mexico or about 4455 square kilometers (1720 square miles, or 1.1 million acres). Historic and current land uses in the watershed include farming, ranching, recreation, and municipal related activities. Much of the land ownership adjacent to the river is private, but the Bureau of Land Management and the State of New Mexico also own and manage tracts of public lands in the eastern portions of the watershed. The Canadian River watershed is located in Omernick Level III Ecoregion 21 (Southern Rockies) in the headwaters and Level III Ecoregion 26 (Southwestern Tablelands) in the lowlands with mean maximum July temperatures ranging from 21 to 34°C (69 to 93°F). The elevation range for sampling sites in the survey was 1,072 meters (3517 feet) to 2,574 meters (8445 feet) above sea level. Annual precipitation ranges from 76 centimeters (30 inches) in the mixed conifer forests at higher elevations to 38 centimeters (15 inches) in the semi-arid grasslands at lower elevations (NRCS 2007).

The Monitoring and Assessment Section (MAS) of the Surface Water Quality Bureau (SWQB) conducted a water quality survey of the Canadian River Watershed between March and November, 2006. This water quality survey included 35 sampling sites (**Figure 1 and Table 1**). Most sites were sampled 8 times, while some secondary sites were sampled only one to four times. Monitoring these sites enabled an assessment of the cumulative influence of the physical habitat, water sources, and land management activities upstream from the sites.

Water samples were analyzed for plant nutrients, ions, total and dissolved metals, bacteria, radionuclides, and anthropogenic organic compounds. Variables such as dissolved oxygen (DO), pH, turbidity, and specific conductance were measured in the field. Physical habitat and benthic macroinvertebrate and periphyton communities were surveyed to determine the impacts of excessive nutrients and stream bottom deposits on aquatic life within a stream. The type of monitoring done at each site is summarized in **Tables 2 and 3**.

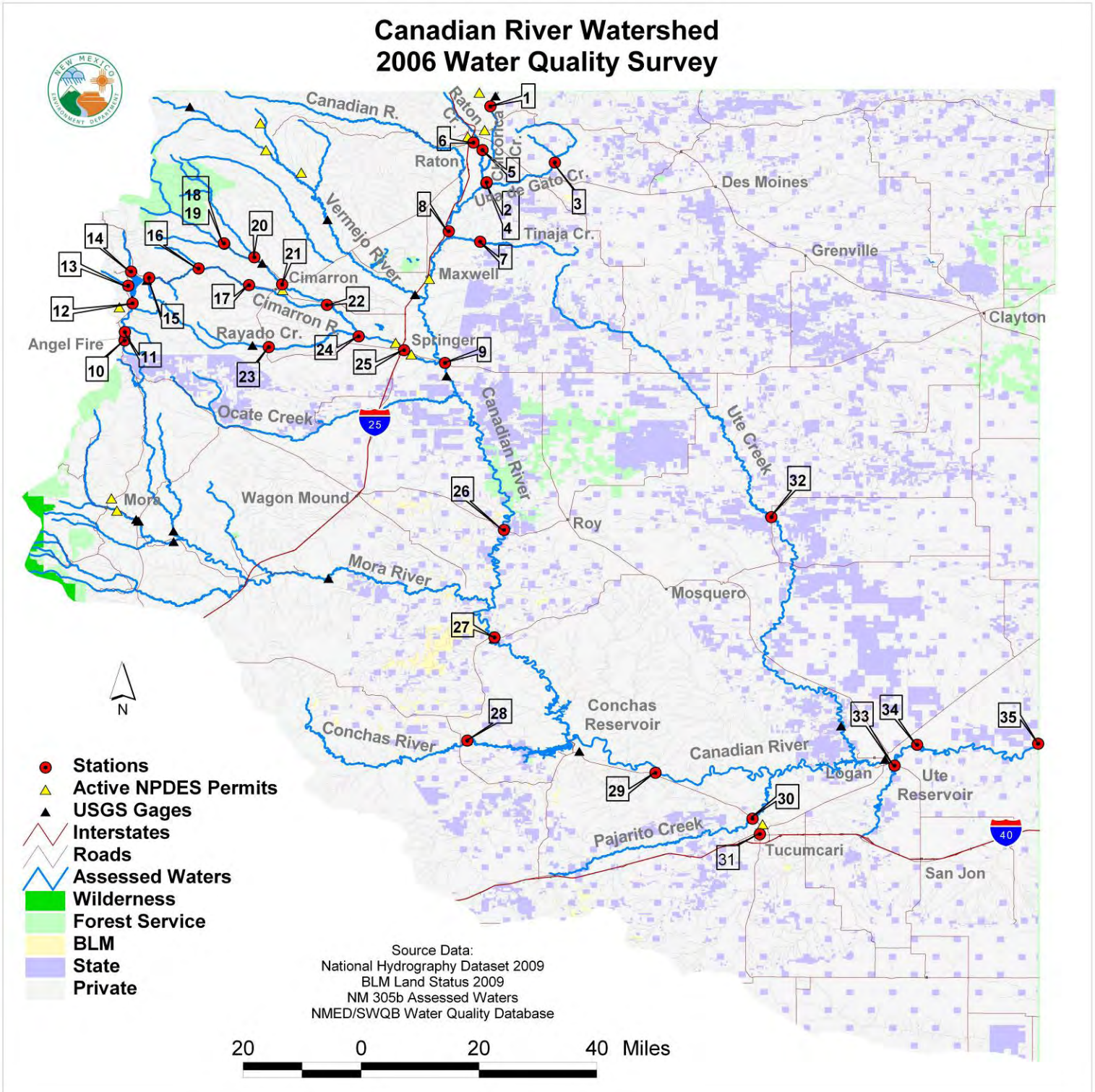

Figure 1. Canadian River water quality study area and sampling stations. See Table 1 for details on sampling locations.

2.0 NEW MEXICO WATER QUALITY STANDARDS

State water quality standards constitute the baseline of water quality standards (WQS) in effect for Clean Water Act purposes. The United States Environmental Protection Agency (USEPA) approved water quality standards were used to determine if waterbodies throughout the watershed are supporting their designated uses. The applicable WQS for all assessment units in this study of the Canadian River Watershed are set forth in sections 20.6.4.301, 20.6.4.303, 20.6.4.305, 20.6.4.306, 20.6.4.307, and 20.6.4.309 of the *State of New Mexico Standards for Interstate and Intrastate Surface Waters* (NMAC 2007).

20.6.4.301 CANADIAN RIVER BASIN - The main stem of the Canadian river from the New Mexico-Texas line upstream to Ute dam, and any flow that enters the main stem from Revuelto creek.

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

B. Criteria:

(1) In any single sample: pH within the range of 6.6 to 9.0, temperature 32.2°C (90°F) or less and TDS 6,500 mg/L or less at flows above 25 cfs. The use-specific numeric criteria set forth in 20.6.4.900 NMAC are applicable to the designated uses listed above in Subsection A of this section.

(2) The monthly geometric mean of E. coli bacteria 126 cfu/100 mL or less; single sample 410 cfu/100 mL or less (see Subsection B of 20.6.4.14 NMAC).

[20.6.4.301 NMAC - Rp 20 NMAC 6.1.2301, 10-12-00; A, 05-23-05]

20.6.4.303 CANADIAN RIVER BASIN - The main stem of the Canadian river from the headwaters of Ute reservoir upstream to Conchas dam, the perennial reaches of Pajarito and Ute creeks and their perennial tributaries.

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

B. Criteria:

(1) In any single sample: pH within the range of 6.6 to 9.0 and temperature 32.2°C (90°F) or less. The use-specific numeric criteria set forth in 20.6.4.900 NMAC are applicable to the designated uses listed above in Subsection A of this section.

(2) The monthly geometric mean of E. coli bacteria 126 cfu/100 mL or less; single sample 410 cfu/100 mL or less (see Subsection B of 20.6.4.14 NMAC).

[20.6.4.303 NMAC - Rp 20 NMAC 6.1.2303, 10-12-00; A, 05-23-05]

20.6.4.305 CANADIAN RIVER BASIN - The main stem of the Canadian river from the headwaters of Conchas reservoir upstream to the New Mexico-Colorado line, perennial reaches of the Conchas river, the Mora river downstream from the USGS gaging station near Shoemaker, the Vermejo river downstream from Rail canyon and perennial reaches of Raton, Chicorica and Uña de Gato creeks.

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

B. Criteria:

(1) In any single sample: pH within the range of 6.6 to 9.0, temperature 32.2°C (90°F) or less and TDS 3,500 mg/L or less at flows above 10 cfs. The use-specific numeric criteria set forth in 20.6.4.900 NMAC are applicable to the designated uses listed above in Subsection A of this section.

(2) The monthly geometric mean of E. coli bacteria 126 cfu/100 mL or less; single sample 410 cfu/100 mL or less (see Subsection B of 20.6.4.14 NMAC).

[20.6.4.305 NMAC - Rp 20 NMAC 6.1.2305, 10-12-00; A, 05-23-05]

20.6.4.306 CANADIAN RIVER BASIN - The Cimarron river downstream from state highway 21 in Cimarron to the Canadian river and all perennial reaches of tributaries to the Cimarron river downstream from state highway 21 in Cimarron.

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

B. Criteria:

(1) In any single sample: pH within the range of 6.6 to 9.0, temperature 32.2°C (90°F) or less and TDS 3,500 mg/L or less at flows above 10 cfs. The use-specific numeric criteria set forth in 20.6.4.900 NMAC are applicable to the designated uses listed above in Subsection A of this section.

(2) The monthly geometric mean of E. coli bacteria 126 cfu/100 mL or less; single sample 410 cfu/100 mL or less (see Subsection B of 20.6.4.14 NMAC).

[20.6.4.306 NMAC - Rp 20 NMAC 6.1.2305.1, 10-12-00; A, 7-19-01; A, 05-23-05]

20.6.4.307 CANADIAN RIVER BASIN - Perennial reaches of the Mora river from the USGS gaging station near Shoemaker upstream to the state highway 434 bridge in Mora, all perennial reaches of tributaries to the Mora river downstream from the USGS gaging station at La Cueva in San Miguel and Mora counties, perennial reaches of Ocate creek and its tributaries downstream of Ocate, and perennial reaches of Rayado creek downstream of Miami lake diversion in Colfax county.

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

B. Criteria:

(1) In any single sample: temperature 25°C (77°F) or less and pH within the range of 6.6 to 9.0. The use-specific numeric criteria set forth in 20.6.4.900 NMAC are applicable to the designated uses listed above in Subsection A of this section.

(2) The monthly geometric mean of E. coli bacteria 126 cfu/100 mL or less; single sample 410 cfu/100 mL or less (see Subsection B of 20.6.4.14 NMAC).

[20.6.4.307 NMAC - Rp 20 NMAC 6.1.2305.3, 10-12-00; A, 05-23-05]

20.6.4.309 CANADIAN RIVER BASIN - The Mora river and perennial reaches of its tributaries upstream from the state highway 434 bridge in Mora, all perennial reaches of tributaries to the Mora river upstream from the USGS gaging station at La Cueva, perennial reaches of Coyote creek and its tributaries, the Cimarron river and its perennial tributaries above state highway 21 in Cimarron, all perennial reaches of tributaries to the Cimarron river north and northwest of highway 64, perennial reaches of Rayado creek and its tributaries above Miami lake diversion, Ocate creek and perennial reaches of its tributaries upstream of Ocate, perennial reaches of the Vermejo river upstream from Rail canyon and all other perennial reaches of tributaries to the Canadian river northwest and north of U.S. highway 64 in Colfax county unless included in other segments.

A. Designated Uses: domestic water supply, irrigation, high quality coldwater aquatic life, livestock watering, wildlife habitat, municipal and industrial water supply and secondary contact.

B. Criteria:

(1) In any single sample: specific conductance 500 µmhos/cm or less, pH within the range of 6.6 to 8.8 and temperature 20°C (68°F) or less. The use-specific numeric criteria set forth in 20.6.4.900 NMAC are applicable to the designated uses listed above in Subsection A of this section.

(2) The monthly geometric mean of E. coli bacteria 126 cfu/100 mL or less; single sample 235 cfu/100 mL or less (see Subsection B of 20.6.4.14 NMAC).

[20.6.4.309 NMAC - Rp 20 NMAC 6.1.2306, 10-12-00; A, 7-19-01; A, 05-23-05]

Subsection J of Section 20.6.4.900 NMAC, as referenced in the above site-specific criteria, provides a list of water chemistry analytes for which SWQB tests and a range of criteria for varying designated uses. The table of numeric criteria provided in this section is used for assessing streams for use attainment.

Current impairment listings for the Canadian River watershed are included in the *2010-2012 State of New Mexico Clean Water Act §303(d)/ §305(b) Integrated List* (NMED/SWQB 2010). The Integrated List is a catalog of assessment units (AUs) throughout the state with a summary of their current status-assessed/not assessed and impaired/not impaired. Once a stream AU is identified as impaired, a TMDL guidance document is developed for that segment with guidelines for stream restoration. AU names and Water Quality Standards have changed over the

years and the history of these individual changes is tracked in the Record of Decision document associated with the 2010-2012 Integrated List available on the SWQB website.

3.0 METHODS

All water quality data within this project were collected in accordance with the procedures set forth in the *SWQB Quality Assurance Project Plan* (NMED/SWQB 2006) and the *SWQB Standard Operating Procedures for Data Collection* (NMED/SWQB 2007). The data collected as part of this study were later combined with all other readily available or submitted data that meet state quality assurance/quality control requirements to form the basis of designated use attainment determinations. These data were assessed in accordance with protocols established in the *State of New Mexico Procedures for Assessing Standards Attainment for the Integrated §303(d)/§305(b) Water Quality Monitoring and Assessment Report [Assessment Protocols]* (NMED/SWQB 2009).

4.0 SAMPLING SUMMARY

A map of the study area is provided in **Figure 1**. The station numbers, unique station identification codes, and rationale of sampling stations selected for this survey are provided in **Table 1**. Stations are often located near the downstream end of the AUs to include all inputs to the AU. The Angel Fire, Raton, and Tucumcari Wastewater Treatment Plants (WWTP) were sampled to account for pollutant loading from these permitted facilities to the receiving stream.

Table 1. Sampling stations; Canadian River watershed.

MAP #	STATION NAME	STATION ID	SAMPLING RATIONALE
1	Chicorica Creek above Lake Alice	04Chicor034.4	Upper station on Chicorica Creek
2	Chicorica Creek below Uña de Gato Creek	04Chicor010.9	Bottom of AU
3	Uña de Gato Creek below T O dam	04UnaGat020.9	Perennial – upper AU may go dry
4	Uña de Gato Creek above Chicorica Creek	04UnaGat000.1	Bottom of AU
5	Raton Creek 5 miles abv Chicorica Creek	04RatonC007.8	Below Doggett Creek + Raton WWTP
6	Raton WWTP	NM0020273	Effluent Condition
7	Tinaja Creek above Canadian River	04Tinaja010.1	Bottom of AU; BMP implementation
8	Canadian River at Tinaja	04Canadi402.9	Abv Vermejo; Blw Chicorica + Raton
9	Canadian River above Cimarron River at NM 56	04Canadi352.7	Bottom of AU
10	Cieneguilla Creek at Angel Fire Road	05Cieneg019.3	Abv Angel Fire; Background condition
11	Angel Fire WWTP	NM0030503	Effluent Condition
12	Cieneguilla Creek above Eagle Nest Lake at gage	05Cieneg006.3	Bottom of AU; Blw Angel Fire
13	Sixmile Creek above US 64 near gage	05Sixmil001.4	Bottom of AU
14	Moreno Creek on NM 64 at gage	05Moreno003.7	Bottom of AU

MAP #	STATION NAME	STATION ID	SAMPLING RATIONALE
15	Cimarron R below Eagle Nest Dam at Tolby CG	05Cimarr077.2	Below reservoir
16	Ute Creek above US 64 at Ute Park	05UteCre000.6	Bottom of AU
17	Cimarron River above Cimarron Village at gage	05Cimarr050.8	Bottom of AU
18	South Ponil above Middle Ponil	05SPonil008.5	Bottom of AU
19	Middle Ponil Creek above South Ponil Creek	05MPonil000.1	Bottom of AU
20	North Ponil Creek above South Ponil	05NPonil000.1	Bottom of AU
21	Ponil Creek above NM 64	05PonilC014.9	Bottom of AU
22	Ponil Creek above Cimarron River	05PonilC000.1	Bottom of AU
23	Rayado Creek on NM 21	05Rayado033.8	Reference; Bottom of AU
24	Rayado Creek above Cimarron River	05Rayado001.8	Bottom of AU
25	Cimarron River at gage in Springer	05Cimarr013.4	Bottom of AU
26	Canadian River at State HWY 120 Bridge	06Canadi274.8	Supplement USGS sampling
27	Canadian River at NM 419 near Sanchez	06Canadi232.6	Lowest accessible station in AU
28	Conchas River at gage on NM 104	08Concha025.1	Lowest accessible station in AU
29	Canadian River at NM 104 at milemarker 88	09Canadi144.5	Lowest accessible station in AU
30	Pajarito Creek at NM 104	09Pajari020.0	Lowest accessible station in AU
31	Tucumcari WWTP	NM0020711	Effluent Condition
32	Ute Creek above Highway 102 near Bueyeros	10UteCre104.3	Reference; Perennial portion of AU
33	Revuelto Creek at NM 469 above Canadian R	11Revuel003.9	NM ISC ARS study site; Bottom of AU
34	Canadian River below Ute Dam at the Gravel Pit	09Canadi049.2	NM ISC ARS study site
35	Canadian River above NM/TX State Line	09Canadi001.2	NM ISC ARS study site; Bottom of AU

NOTES:

AU = assessment unit
WWTP = wastewater treatment plant
BMP = best management practice
Abv = above; Blw = below
NM ISC ARS study = New Mexico Interstate Stream Commission Arkansas River Shiner study

Tables 2 and 3 summarize the data collected in each assessment unit and at each station. The number of times each parameter (or suite of parameters) was monitored is indicated. Field data include temperature, specific conductance, pH, dissolved oxygen, and turbidity.

Table 2. SWQB Canadian River watershed sampling summary.

Assessment Unit / Stations	Field Data	Ions	Nutrients	Total Metals	Dissolved Metals	*E. coli*	Cyanide	Radionuclides	Organics	Thermograph	Sonde Deployment	Habitat Survey	Macroinvertebrates	Periphyton	Fish Community
Canadian River (Cimarron River to CO border)															
Canadian River at Tinaja	7	7	7	4	4	4	2	2	-	-	-	-	-	-	-
Canadian River above Cimarron River at NM 56	9	9	9	4	4	6	3	3	-	✓	-	-	-	✓	-
Canadian River (Mora River to Cimarron River)															
Canadian River at State HWY 120 Bridge	6	6	6	3	3	7	3	3	-	✓	-	-	-	-	-
Canadian River (Conchas River to Mora River)															
Canadian River at NM 419 near Sanchez	7	7	7	3	3	6	3	3	-	✓	✓	-	-	✓	-
Canadian River (Ute Reservoir to Conchas Reservoir)															
Canadian River at NM 104 at milemarker 88	7	7	7	3	3	5	3	3	-	✓	✓	-	-	✓	-
Canadian River (TX border to Ute Reservoir)															
Canadian River below Ute Dam at the Gravel Pit	7	7	7	3	3	6	3	3	-	-	-	-	-	-	-
Canadian River above NM/TX State Line	7	7	7	3	3	5	3	3	-	✓	-	-	-	✓	-
Chicorica Creek (East Fork Chicorica to headwaters)															
Chicorica Creek above Lake Alice	7	7	7	4	4	4	2	2	-	✓	✓	-	-	✓	-
Chicorica Creek (Canadian R to East Fork Chicorica)															
Chicorica Creek below Uña de Gato Creek	7	7	7	3	3	3	2	2	-	✓	✓	✓	✓	✓	-
Uña de Gato Creek (HWY 64 to headwaters)															
Uña de Gato Creek below T O dam	7	7	7	4	4	4	2	2	-	✓	✓	-	-	✓	-
Uña de Gato Creek (Chicorica Creek to HWY 64)															
Uña de Gato Creek above Chicorica Creek	6	6	6	3	3	3	2	2	-	✓	✓	✓	✓	✓	-
Raton Creek (Chicorica Creek to headwaters)															
Raton Creek 5 miles abv Chicorica Creek	6	6	6	3	3	5	1	1	1	✓	✓	✓	✓	✓	✓
Raton WWTP	5	3	5	-	-	3	-	-	-	-	-	-	-	-	-
Tinaja Creek (Canadian River to headwaters)															
Tinaja Creek above Canadian River	1	1	1	1	1	1	-	-	-	-	-	-	-	-	-
Conchas River (Conchas Lake to headwaters)															
Conchas River at gage on NM 104	4	4	4	3	3	3	-	-	-	-	-	-	-	-	-
Pajarito Creek (Ute Reservoir to headwaters)															
Pajarito Creek at NM 104	8	8	8	3	3	7	3	3	2	✓	✓	-	-	✓	-
Tucumcari WWTP	7	-	7	-	-	7	-	-	-	-	-	-	-	-	-
Ute Creek (Ute Reservoir to headwaters)															
Ute Creek above Highway 102 near Bueyeros	7	7	7	3	3	6	3	3	-	✓	✓	✓	✓	✓	-
Revuelto Creek (Canadian R to headwaters)															
Revuelto Creek at NM 469 above Canadian River	7	7	7	3	3	6	3	3	-	✓	-	-	-	-	-

Table 3. SWQB Cimarron River watershed sampling summary.

Assessment Unit / Stations	Field Data	Ions	Nutrients	Total Metals	Dissolved Metals	*E. coli*	Cyanide	Radionuclides	Organics	Thermograph	Sonde Deployment	Habitat Survey	Macroinvertebrates	Periphyton	Fish Community
Cieneguilla Creek (Eagle Nest Lake to headwaters)															
Cieneguilla Creek at Angel Fire Road	8	8	8	4	4	6	3	3	-	-	-	-	-	-	-
Angel Fire WWTP	8	-	8	-	-	6	-	-	-	-	-	-	-	-	-
Cieneguilla Creek above Eagle Nest Lake at gage	8	8	8	4	4	6	3	3	3	✓	✓	✓	✓	✓	-
Sixmile Creek (Eagle Nest Lake to headwaters)															
Sixmile Creek above US 64 near gage	9	9	9	4	4	6	3	3	-	✓	✓	-	-	✓	-
Moreno Creek (Eagle Nest Lake to headwaters)															
Moreno Creek on NM 64 at gage	9	9	9	4	4	6	3	3	-	✓	✓	-	-	✓	-
Cimarron River (Turkey Creek to Eagle Nest Lake)															
Cimarron River below Eagle Nest Dam at Tolby CG	8	8	8	4	4	6	3	3	-	-	✓	-	-	✓	-
Ute Creek (Cimarron River to headwaters)															
Ute Creek above US 64 at Ute Park	9	9	9	4	4	6	3	3	-	✓	-	-	-	✓	-
Cimarron River (Cimarron Village to Turkey Creek)															
Cimarron River above Cimarron Village at gage	8	8	8	4	4	6	3	3	-	✓	✓	-	-	✓	-
South Ponil Creek (Ponil Crk to headwaters)															
South Ponil above Middle Ponil	8	8	8	3	3	5	3	3	-	✓	-	-	-	-	-
Middle Ponil Creek (South Ponil to Greenwood Crk)															
Middle Ponil Creek above South Ponil Creek	9	9	9	4	4	6	3	3	-	✓	✓	✓	✓	✓	-
North Ponil Creek (South Ponil Crk to Seally Cyn)															
North Ponil Creek above South Ponil	8	8	8	4	4	6	3	3	-	✓	✓	✓*	✓*	-	-
Ponil Creek (US 64 to confl North & South Ponil)															
Ponil Creek above NM 64	8	8	8	4	4	6	3	3	-	✓	✓	✓*	✓*	-	-
Ponil Creek (Cimarron River to US 64)															
Ponil Creek above Cimarron River	8	8	8	4	4	6	3	3	-	✓	✓	✓*	✓*	-	-
Rayado Creek (Miami Lake Diversion to headwaters)															
Rayado Creek on NM 21	8	8	8	4	4	7	3	3	-	✓	✓	✓	✓	✓	✓
Rayado Creek (Cimarron R to Miami Lake Diversion)															
Rayado Creek above Cimarron River	9	9	9	4	4	7	3	3	-	✓	-	✓	✓	✓	✓
Cimarron River (Canadian R to Cimarron Village)															
Cimarron River at gage in Springer	9	9	9	4	4	7	3	3	-	-	✓	-	-	✓	-

NOTES: * **Data collected in 2007 because scouring events prevented data collection in 2006.**

5.0 WATER QUALITY IMPAIRMENTS

For many water quality analytes, the State of New Mexico maintains numeric water quality standards, whereas standards for other parameters such as plant nutrients and bottom deposits are narrative. Data are assessed for designated use attainment status for both numeric and narrative water quality standards by application of the *State of New Mexico Procedures for Assessing Standards Attainment for the Integrated §303(d)/§305(b) Water Quality Monitoring and Assessment Report [Assessment Protocols]* (NMED/SWQB 2009). When available, outside sources of data that meet quality assurance requirements are combined with data collected by SWQB during the watershed survey to determine final impairment status. Final designated use impairment status is housed in the Assessment Database (ADB) and is reported in the biennial *State of New Mexico CWA §303(d)/§305(b) Integrated Report* (NMED/SWQB 2010).

5.1 Water Quality Impairments For Numeric Criteria

5.1.1 Physicochemical Data

Water samples were analyzed for major ions, nutrients, total and dissolved metals, bacteria, radionuclides, and anthropogenic organic compounds. Variables such as dissolved oxygen (DO), pH, turbidity, and specific conductance were measured in the field. Results from the water quality data assessment indicated designated use impairments due to arsenic, boron, *E. coli*, and turbidity. **Table 4** provides a summary of the physicochemical assessment conclusions. SWQB's *Assessment Protocol* details the assessment and listing procedures (NMED/SWQB 2009). A complete dataset can be obtained by contacting the SWQB.

Table 4. Summary of Physicochemical Assessment Conclusions

Assessment Unit / Station	Arsenic	Boron	*E. coli* bacteria	Turbidity
Canadian River (Cimarron River to CO border)	FS	FS	FS	
Canadian River at Tinaja	FS	FS	FS	
Canadian River above Cimarron River at NM 56	FS	FS	FS	
Canadian River (Mora River to Cimarron River)	FS	FS	FS	
Canadian River at State HWY 120 Bridge	FS	FS	FS	
Canadian River (Conchas River to Mora River)	FS	FS	**NS**	
Canadian River at NM 419 near Sanchez	FS	FS	**NS**	
Canadian River (Ute Reservoir to Conchas Reservoir)	FS	FS	**NS**	
Canadian River at NM 104 at milemarker 88	FS	FS	**NS**	
Canadian River (TX border to Ute Reservoir)	FS	FS	FS	
Canadian River below Ute Dam at the Gravel Pit	FS	FS	FS	
Canadian River above NM/TX State Line	FS	FS	FS	

Assessment Unit / Station	Arsenic	Boron	*E. coli* bacteria	Turbidity
Chicorica Creek (East Fork Chicorica to headwaters)	FS	FS	FS	
Chicorica Creek above Lake Alice	FS	FS	FS	
Chicorica Creek (Canadian R to East Fork Chicorica)	FS	FS	FS	
Chicorica Creek below Uña de Gato Creek	FS	FS	FS	
Uña de Gato Creek (HWY 64 to headwaters)	FS	FS	FS	
Uña de Gato Creek below T O dam	FS	FS	FS	
Uña de Gato Creek (Chicorica Creek to HWY 64)	FS	FS	FS	
Uña de Gato Creek above Chicorica Creek	FS	FS	FS	
Raton Creek (Chicorica Creek to headwaters)	FS	FS	**NS**	
Raton Creek 5 miles abv Chicorica Creek	FS	FS	**NS**	
Tinaja Creek (Canadian River to headwaters)				
Tinaja Creek above Canadian River				
Conchas River (Conchas Lake to headwaters)	FS	FS	FS	
Conchas River at gage on NM 104	FS	FS	FS	
Pajarito Creek (Ute Reservoir to headwaters)	FS	FS	**NS**	
Pajarito Creek at NM 104	FS	FS	**NS**	
Ute Creek (Ute Reservoir to headwaters)	FS	FS	FS	
Ute Creek above Highway 102 near Bueyeros	FS	FS	FS	
Revuelto Creek (Canadian R to headwaters)	FS	**NS**	FS	
Revuelto Creek at NM 469 above Canadian River	FS	**NS**	FS	
Cieneguilla Creek (Eagle Nest Lake to headwaters)	FS	FS	**NS**	**NS**
Cieneguilla Creek at Angel Fire Road	FS	FS	**NS**	**NS**
Cieneguilla Creek above Eagle Nest Lake at gage	FS	FS	**NS**	**NS**
Sixmile Creek (Eagle Nest Lake to headwaters)	FS	FS	**NS**	**NS**
Sixmile Creek above US 64 near gage	FS	FS	**NS**	**NS**
Moreno Creek (Eagle Nest Lake to headwaters)	FS	FS	FS	FS
Moreno Creek on NM 64 at gage	FS	FS	FS	FS
Cimarron River (Turkey Creek to Eagle Nest Lake)	**NS**	FS	FS	FS
Cimarron R below Eagle Nest Dam at Tolby Campground	**NS**	FS	FS	FS
Ute Creek (Cimarron River to headwaters)	**NS**	FS	**NS**	**NS**
Ute Creek above US 64 at Ute Park	**NS**	FS	**NS**	**NS**
Cimarron River (Cimarron Village to Turkey Creek)	**NS**	FS	FS	**NS**
Cimarron River above Cimarron Village at gage	**NS**	FS	FS	**NS**
South Ponil Creek (Ponil Crk to headwaters)	FS	FS	FS	FS
South Ponil above Middle Ponil	FS	FS	FS	FS
Middle Ponil Creek (South Ponil to Greenwood Crk)	FS	FS	FS	FS

Assessment Unit / Station	Arsenic	Boron	*E. coli* bacteria	Turbidity
Middle Ponil Creek above South Ponil Creek	FS	FS	FS	FS
North Ponil Creek (South Ponil Crk to Seally Cyn)	FS	FS	**NS**	**NS**
North Ponil Creek above South Ponil	FS	FS	**NS**	**NS**
Ponil Creek (US 64 to confl North & South Ponil)	FS	FS	**NS**	**NS**
Ponil Creek above NM 64	FS	FS	**NS**	**NS**
Ponil Creek (Cimarron River to US 64)	FS	FS	**NS**	
Ponil Creek above Cimarron River	FS	FS	**NS**	
Rayado Creek (Miami Lake Diversion to headwaters)	FS	FS	**NS**	FS
Rayado Creek on NM 21	FS	FS	**NS**	FS
Rayado Creek (Cimarron R to Miami Lake Diversion)	FS	FS	FS	
Rayado Creek above Cimarron River	FS	FS	FS	
Cimarron River (Canadian R to Cimarron Village)	FS	FS	FS	
Cimarron River at gage in Springer	FS	FS	FS	

NOTES:

* If a cell is blank for a particular station or AU, it means that parameter was **not assessed** either due to no data or lack of adequate data (i.e., only one data point).
* **NS = Not Supporting**; FS = Fully Supporting

5.1.2 Data from Continuous Monitoring Devices

Temperature data loggers (thermographs) were deployed at selected stations within the study area. YSI multi-parameter sondes were also deployed at selected stations to examine pH and dissolved oxygen (DO). The thermographs and sondes were programmed to record temperature, DO, and/or pH once per hour over their respective collection intervals.

Large datasets generated from data loggers (e.g., sondes and thermographs) are assessed according to protocols developed specifically for such datasets (with few exceptions). This is because, unlike grab sample data, it is not reasonable to list as not supporting on the basis of one or a few exceedences out of several hundred or thousand data points.

Temperature (given in °C) and pH assessment criteria are tied to the criteria in the *State of New Mexico Standards for Interstate and Intrastate Surface Waters* (NMAC 2007). Dissolved oxygen assessment criteria are linked to the presence of sensitive, *i.e.* early life stages, aquatic organisms and designated use, *e.g.* marginal coldwater aquatic life use. SWQB's *Assessment Protocol* provides details of large dataset assessment procedures (NMED/SWQB 2009). **Table 5** summarizes the assessment conclusions based on the thermograph and sonde data.

Table 5. Summary of Thermograph and Sonde Assessment Conclusions

Assessment Unit	Designated Use	Temperature Criterion (°C)	Temperature Assessment	pH Criterion (SU)	pH Assessment	DO Criterion (mg/L)	DO Assessment
Canadian River (Cimarron River to CO border)	MWWAL	≤ 32.2	FS	6.6 – 9.0	no data	≥ 5.0	no data
Canadian River (Mora River to Cimarron River)	MWWAL	≤ 32.2	FS	6.6 – 9.0	no data	≥ 5.0	no data
Canadian River (Conchas River to Mora River)	MMWAL	≤ 32.2	FS	6.6 – 9.0	FS	≥ 5.0	FS
Canadian River (Ute Reservoir to Conchas Reservoir)	MWWAL	≤ 32.2	FS	6.6 – 9.0	FS	≥ 5.0	FS
Canadian River (TX border to Ute Reservoir)	MWWAL	≤ 32.2	FS	6.6 – 9.0	no data	≥ 5.0	no data
Chicorica Creek (East Fork Chicorica to headwaters)	MWWAL	≤ 32.2	FS	6.6 – 9.0	FS	≥ 5.0	FS
Chicorica Creek (Canadian R to East Fork Chicorica)	MWWAL	≤ 32.2	FS	6.6 – 9.0	FS	≥ 5.0	FS
Uña de Gato Creek (HWY 64 to headwaters)	MWWAL	≤ 32.2	FS	6.6 – 9.0	no data	≥ 5.0	no data
Uña de Gato Creek (Chicorica Creek to HWY 64)	MWWAL	≤ 32.2	FS	6.6 – 9.0	FS	≥ 5.0	**NS**
Raton Creek (Chicorica Creek to headwaters)	MWWAL	≤ 32.2	FS	6.6 – 9.0	FS	≥ 5.0	**NS**
Tinaja Creek (Canadian River to headwaters)	MWWAL	≤ 32.2	no data	6.6 – 9.0	no data	≥ 5.0	no data
Conchas River (Conchas Lake to headwaters)	MWWAL	≤ 32.2	no data	6.6 – 9.0	no data	≥ 5.0	no data
Pajarito Creek (Ute Reservoir to headwaters)	MWWAL	≤ 32.2	FS	6.6 – 9.0	FS	≥ 5.0	**NS**
Ute Creek (Ute Reservoir to headwaters)	MWWAL	≤ 32.2	FS	6.6 – 9.0	FS	≥ 5.0	FS
Revuelto Creek (Canadian R to headwaters)	MWWAL	≤ 32.2	FS	6.6 – 9.0	no data	≥ 5.0	no data
Cieneguilla Creek (Eagle Nest Lake to headwaters)	HQCWAL	≤ 20.0	**NS**	6.6 – 8.8	FS	≥ 6.0	**NS**
Sixmile Creek (Eagle Nest Lake to headwaters)	HQCWAL	≤ 20.0	**NS**	6.6 – 8.8	FS	≥ 6.0	**NS**
Moreno Creek (Eagle Nest Lake to headwaters)	HQCWAL	≤ 20.0	**NS**	6.6 – 8.8	FS	≥ 6.0	**NS**
Cimarron River (Turkey Creek to Eagle Nest Lake)	HQCWAL	≤ 20.0	no data	6.6 – 8.8	FS	≥ 6.0	**NS**
Ute Creek (Cimarron River to headwaters)	HQCWAL	≤ 20.0	**NS**	6.6 – 8.8	no data	≥ 6.0	no data
Cimarron River (Cimarron Village to Turkey Creek)	HQCWAL	≤ 20.0	**NS**	6.6 – 8.8	FS	≥ 6.0	FS
South Ponil Creek (Ponil Crk to headwaters)	HQCWAL	≤ 20.0	**NS**	6.6 – 8.8	no data	≥ 6.0	no data
Middle Ponil Creek (South Ponil to Greenwood Crk)	HQCWAL	≤ 20.0	**NS**	6.6 – 8.8	FS	≥ 6.0	FS
North Ponil Creek (South Ponil Creek to Seally Cyn)	HQCWAL	≤ 20.0	**NS**	6.6 – 8.8	FS	≥ 6.0	**NS**
Ponil Creek (US 64 to confl North & South Ponil)	HQCWAL	≤ 20.0	**NS**	6.6 – 8.8	FS	≥ 6.0	**NS**
Ponil Creek (Cimarron River to US 64)	WWAL	≤ 32.2	FS	6.6 – 9.0	FS	≥ 5.0	FS
Rayado Creek (Miami Lake Diversion to headwaters)	HQCWAL	≤ 20.0	**NS**	6.6 – 8.8	FS	≥ 6.0	FS
Rayado Creek (Cimarron R to Miami Lake Diversion)	MCWAL	≤ 25.0	FS	6.6 – 9.0	no data	≥ 6.0	no data
Cimarron River (Canadian R to Cimarron Village)	WWAL	≤ 32.2	no data	6.6 – 9.0	FS	≥ 5.0	**NS**

NOTES:

* "no data" = parameter was **not assessed**.
* **NS = Not Supporting**; FS = Fully Supporting

5.2 Water Quality Impairments For Narrative Criteria

5.2.1 Physical Habitat

It is essential to characterize the physical habitat in order to relate stream biological condition to land use impacts and potential anthropogenic disturbances. The physical habitat components most directly impacting aquatic communities are the stream geomorphology (physical structure), the riparian corridor that supports and protects aquatic life, and the composition of the substrate where the aquatic communities live. Streams existing in similar landscapes express similar compositions of these three attributes and can be compared to a reference site within that group. A reference site is a stream reach that has been exposed to the least amount of human disturbance.

Environmental Monitoring and Assessment Program (EMAP; Peck *et al.* 2006) surveys were conducted to collect data for sedimentation/siltation impairment determinations. **Table 6** describes the watershed size, elevation, and ecoregion of each station where an EMAP survey was conducted. These are the minimum data necessary to categorize the sites by landscape. The reference sites indicated were chosen as the least disturbed by the professional judgment of the Monitoring and Assessment Biology Team.

Table 6. Watershed Characteristics of Reference and Study Sites

Station Name **Italics* indicate reference site	Watershed Area in km^2 (mi^2)	Elevation in meters (feet)	Omernick Ecoregion	Station #
Cieneguilla Crk abv Eagle Nest Lake at gage	179 (69)	2514 (8249)	Southern Rockies	12
Middle Ponil Creek abv South Ponil Creek	225 (87)	2190 (7185)	Southern Rockies	19
North Ponil Creek above Ponil Creek	220 (85)	2052 (6732)	Southern Rockies	20
Rayado Creek on NM 21	*153 (59)*	*1994 (6541)*	*Southern Rockies*	*23*
Chicorica Creek blw Uña de Gato Creek	730 (282)	1981 (6500)	Southwestern Tablelands	2
Ponil Creek above Highway 64	606 (234)	1952 (6404)	Southwestern Tablelands	21
Ponil Creek above Cimarron River	857 (331)	1860 (6102)	Southwestern Tablelands	22
Raton Creek 5 mi abv Chicorica Creek	93 (36)	1963 (6440)	Southwestern Tablelands	5
Rayado Creek abv Cimarron River	526 (203)	1806 (5925)	Southwestern Tablelands	24
Uña de Gato Creek abv Chicorica Creek	326 (126)	1903 (6243)	Southwestern Tablelands	4
Ute Creek at Highway 120	*1279 (494)*	*1676 (5499)*	*Southwestern Tablelands*	*N/A*

Substrate Composition

The size of sediment within a stream system is one of the most important physical attributes in determining the health of aquatic communities. There are two components to sediment load that impact aquatic life: suspended load and bed load. Suspended load is quantified through the measurement of turbidity and total suspended solids. Bed load describes the particles that settle to or roll along the bottom (saltation) of the channel. Larger bed load particles provide increased interstitial space between particles, thus allowing for different aquatic communities than those found among small particles with little or no space. The size of sediment within a stream has a natural progression from course, large particles at high elevation with smaller watershed size gradually decreasing to sand in low elevation streams with large watersheds. Therefore, to determine whether a stream exhibits an unnaturally fine bed load, knowledge of the location of the stream segment within the watershed is necessary. Particles smaller than 2mm are considered "fines", and "percent fines" are considered for assessment purposes (See 20.6.4.13(A) NMAC). The percent fines is calculated by adding the % sand and % silt-clay fractions (**Table 7**). Other metrics in **Table 7** describe the size classes found in the reach, including the size of the 50th and 84th percentiles of the cumulative frequency distribution (D50 and D84), and the mean embeddedness, which is how much of the particles were surrounded by fines.

Table 7. Substrate Composition Data from the Canadian River Watershed

Station Name **Italics* indicate reference site	D50 (mm)	D84 (mm)	% Fines (>2mm)	Mean % Embeddedness
Cieneguilla Creek above Eagle Nest Lake at gage	46	75	5 %**	31 %
Middle Ponil Creek above South Ponil Creek	65	130	16 %	36 %
North Ponil Creek above Ponil Creek	55	109	20%	41%
Rayado Creek on NM 21	*75*	*135*	*4 %*	*21 %*
Chicorica Creek below Uña de Gato Creek	silt	3	81 %	100 %
Ponil Creek above Highway 64	44	128	11 %	38%
Ponil Creek above Cimarron River	46	95	6 %	61%
Raton Creek 5 miles abv Chicorica Creek	48	133	21 %	38 %
Rayado Creek above Cimarron River	silt	very coarse sand	88 %	100 %
Uña de Gato Creek above Chicorica Creek	silt	silt	100 %	100 %
Ute Creek at Highway 120	*59*	*167*	*12%*	*28%*

** Field notes state that streambed was covered in 2 millimeters of silt.

Geomorphology

Quantitatively identifying the current structure of a stream channel allows for a determination of the amount, quality, and variation of habitat available for aquatic communities. A natural, undisturbed stream system maintains equilibrium with the amount of water and sediment that it transports, allowing that system to remain stable. Human impacts may alter the equilibrium of a stream, causing the stream to actively attempt to restore this balance. As the stream attempts to restore equilibrium, it may cause damage to the adjacent riparian habitat or the aquatic communities within the channel. **Table 8** provides a comparison of the geomorphic parameters collected at the reference reaches and study reaches during the 2006 and 2007 EMAP surveys.

Table 8. Geomorphic Data for Canadian River Watershed

Station Name ******Italics* **indicate reference site**	Slope (%)	Bankfull Width (m)	Bankfull height (m)	Width-Depth Ratio
Cieneguilla Crk abv Eagle Nest Lake at gage	< 1 %*	4.6	0.29	15.9
Middle Ponil Creek abv South Ponil Creek	1.7 %	5.2	0.57	9.12
North Ponil Creek above Ponil Creek	1.1 %	2.9	0.21	13.8
Rayado Creek on NM 21	*1.0 %*	*6.3*	*0.23*	*27.4*
Chicorica Creek blw Uña de Gato Creek	< 1 %*	9.0	0.57	15.8
Ponil Creek above Highway 64	0.9 %	6.8	0.30	22.7
Ponil Creek above Cimarron River	0.5 %	5.4	0.51	10.6
Raton Creek 5 mi abv Chicorica Creek	< 1 %*	5.8	0.42	13.8
Rayado Creek abv Cimarron River	0.2 %	9.0	0.33	27.3
Uña de Gato Creek abv Chicorica Creek	< 1 %*	4.2	0.35	12.0
Ute Creek at Highway 120	*1.6 %*	*6.9*	*0.33*	*20.9*

NOTES: * The clinometer was not working during the field survey, thus slope was not measured directly. The slope was estimated from a topographic map as less than 1 %.

Riparian Health

The riparian area is the corridor of vegetation surrounding the stream that provides many beneficial functions to the stream channel. Although there are many benefits to a diverse and healthy riparian area, the most direct effects are shade, soil stability, and organic inputs providing food for the aquatic communities. Two qualitative assessments were performed to provide general information on the health of the habitat and structure of the stream: the Rapid Geomorphic Assessment (RGA) and the Rapid Habitat Assessment (RHA). These assessments

combined with the quantitative canopy measurements (**Table 9**) provide an indication of riparian health.

Table 9. Riparian Cover and Qualitative Scores for the Canadian River Watershed

Station Name ******Italics* **indicate reference site**	Riparian Canopy Cover (% cover)	RGA[1] Stability Score (0-36)	RHA[2] Habitat Score (0-200)
Cieneguilla Creek above Eagle Nest Lake at gage	10 %	12.5	156
Middle Ponil Creek above South Ponil Creek	51 %	12.5	147
North Ponil Creek above Ponil Creek	68 %	12.5	147
Rayado Creek on NM 21	*48 %*	*7*	*169*
Chicorica Creek below Uña de Gato Creek	31 %	18	106
Ponil Creek above Highway 64	57 %	21.5	112
Ponil Creek above Cimarron River	55 %	12.5	125
Raton Creek 5 miles abv Chicorica Creek	9 %	16	139
Rayado Creek above Cimarron River	21 %	14	138
Uña de Gato Creek above Chicorica Creek	46 %	14	108
Ute Creek at Highway 120	*6%*	*10*	*167*

1. The Rapid Geomorphic Assessment is used to identify stable reaches and the destabilizing processes that are active in the reach. A channel stability score is determined by observing a number of channel characteristics and the stage of channel evolution based on the National Sedimentation Lab empirical model (Simon 1989). **Higher scores indicate a more unstable channel**.
2. The Rapid Habitat Assessment (Barbour, *et al.* 1999) provides a qualitative aquatic habitat score that is based primarily on observation of the quality and diversity of in stream habitats. **Higher scores indicate better habitat quality**.

5.2.2 Macroinvertebrate Community and Sedimentation Data

Since the narrative standard for bottom deposits is dependent on biological condition, the assessment of this physically-based narrative sedimentation criteria is determined using a biological response variable that links excess settled sediment levels to designated use attainment. The macroinvertebrate community is generally the first to show a response to certain stressors such as the fine sediment that settles to the bottom of the channel. By collecting data on the macroinvertebrate communities that are present in a stream reach SWQB can identify changes that indicate stress on the community. Depending on the ecoregion of the study site, this can be done by utilizing either the Rapid Bioassessment Protocol (RBP) or Mountain Stream Condition Index (M-SCI) as described in SWQB's main assessment protocol. Application of the biological assessment or degree of impairment is a percentage comparison of the sum of selected metric scores at the study site compared to a reference site or condition. For example, a study site in ecoregion 26 (Southwestern Tablelands) achieving a RBP score greater than 83 percent of the reference site would be deemed non-impaired (**Table 10**). Similarly, when the macroinvertebrate community at a study site in ecoregion 21 (Southern Rockies) has an M-SCI score less than 56.70% of the reference condition, it can be concluded that there is stress on that community and it would be deemed impaired (i.e. non-support) (**Table 11**).

Table 10. Biological Integrity Attainment Matrix using the Rapid Bioassessment Protocol Index[1] for Southwestern Tablelands Sites

% Comparison to Reference Site(s)	Biological Condition Category[2]	Attributes[1]
> 83%	Non-impaired (Full Support)	Comparable to best situation to be expected within ecoregion (watershed reference site). Balanced trophic structure. Optimum community structure (composition & dominance) for stream size and habitat quality.
79 – 54%	Slightly Impaired (Non-Support)	Community structure less than expected. Composition (species richness) lower than expected due to loss of some intolerant forms. Percent contribution of tolerant forms increases.
50 – 21%	Moderately Impaired (Non-Support)	Fewer species due to loss of most intolerant forms. Reduction in EPT index.
< 17%	Severely Impaired (Non-Support)	Few species present. Densities of organisms dominated by one or two taxa.

1. RBP Index, percentages, and biological attributes are taken from Plafkin *et al.,* 1989. Percentage values obtained that are in between the above ranges will require best professional judgment as to the correct placement.
2. New Mexico has combined all but the "Non-impaired" category into "Non-Support" per USEPA Region 6 suggestion.

Table 11. Biological Integrity Attainment Matrix using M-SCI[1] for Southern Rockies Sites

% Comparison to Reference Condition	Biological Condition Category[2]
> 78.36%	Very Good (Full Support)
78.35 – 56.70%	Good (Full Support)
56.69 – 37.20%	Fair (Non-Support)
37.19 – 18.90%	Poor (Non-Support)
> 18.89%	Very Poor (Non-Support)

1. M-SCI Index and percentages based on Jacobi, *et al.* (2006)
2. New Mexico has combined the "very good" and "good" categories into "Full Support," while the remaining categories define "Non-Support."

Sedimentation/Siltation Assessment

In order to assess for excess sedimentation, the biological index score (RBP or M-SCI depending on ecoregion) and the percent fines in the stream reach are assessed independently for their

support of the aquatic life use. Reference sites are currently used to determine the amount of fines appropriate for each stream reach. If a low biological index score coincides with percent fines greater than 20% and this value exceeds a 28% increase from the associated reference site, excess fine sediment is indicated as a cause of impairment. If only the biological index score is low, excess fine sediment is not indicated as a cause of impairment.

Macroinvertebrate data were assessed at 5 sites. All 5 study sites had biological assessment scores in the "fair" range indicating the biological communities in those reaches are stressed. Of these 5 reaches, only Cieneguilla Creek had greater than 20% fine sediment indicating a biological impairment due to sedimentation/siltation. Middle Ponil Creek, North Ponil Creek, and upper and lower Ponil Creek exhibited moderate amounts of fine sediment, 16%, 20%, 11%, and 6% respectively (**Table 12**). According to Appendix D of the Assessment Protocol, raw percent values of ≤ 20% fines at a study site should be evaluated as "Full Support" for sedimentation/siltation regardless of the percent attained at the reference site. However, because the macroinvertebrate communities scored low at these sites, Middle Ponil, North Ponil, and upper and lower Ponil Creeks were listed for benthic-macroinvertebrate bioassessments until the exact cause of the biological impairment is determined.

Table 12. Sedimentation Evaluations for the Canadian River Watershed

Stations	Biological Index Score	% of Reference	% Fine Sediment	% increase over Reference
Cieneguilla Creek above Eagle Nest Lake at gage	52.28*	N/A	5 % + silt	25 % + silt
Middle Ponil Creek above South Ponil Creek	48.75*	N/A	16 %	N/A +
North Ponil Creek above Ponil Creek	55.58*	N/A	20 %	N/A +
Rayado Creek on NM 21	*66.77*	*Reference*	*4 %*	*Reference*
Ponil Creek above Highway 64	36^	67 %	11 %	N/A +
Ponil Creek above Cimarron River	38^	70 %	6 %	N/A +
Ute Creek at Highway 120	*54^*	*Reference*	*12 %*	*Reference*

* Mountain – Stream Condition Index (M-SCI) is used to assess Southern Rockies sites.
^ Rapid Bioassessment Protocol (RBP) Index is used to assess Southwestern Tablelands sites.
+ Raw percent values of ≤20% fines at a study site should be evaluated as "Full Support" regardless of the percent attained at the reference site.

Even though EMAP habitat surveys were conducted on Rayado Creek, Chicorica Creek, and Uña de Gato Creek, these streams were not assessed for sedimentation/siltation because they did not have a representative riffle to collect macroinvertebrate and pebble count data for assessment. According to Appendix D of the Assessment Protocol, it is recommended that biological sampling and pebble counts always be performed concurrently in a representative riffle area to capture an accurate picture of the stressor and response, as the amount of fine substrate present and the biological community changes with stream flow and season. Furthermore, an appropriate, low-gradient, sandy-bottom reference site used to compare and assess macroinvertebrate and pebble count data from these sites could not be located.

5.2.3 Periphyton Community and Nutrient Assessment

The periphyton community is another biological indicator that can express system stress in ways that the macroinvertebrate community may not reveal. The use of periphyton community data is still in early stages of development and does not provide conclusive information on stream health at this time. Periphyton is collected in biological surveys for a community composition analysis and for the quantification of chlorophyll *a* for the second level of nutrient assessments. A Level 1 nutrient screen is performed at each survey station to determine if excess nutrients may be an issue for the reach. If necessary, a series of data is collected for the nutrient Level 2 survey to determine impairment status.

Nutrient Level 2 Assessment

Level 2 nutrient surveys were conducted at sites that were previously listed as impaired due to plant nutrients or that the Level 1 nutrient assessment indicated the possibility of nutrient impairment. For more information on this process refer to the *Nutrient Assessment Protocol for Wadeable, Perennial Streams* (NMED/SWQB 2009). The Level 2 nutrient survey consists of data collection on a number of indicators including total phosphorus, total nitrogen, dissolved oxygen, pH, and periphyton chlorophyll *a* concentration. Chlorophyll *a* is a quantitative measure of algal biomass which is the direct or indirect cause of most problems associated with nutrient impairment. The indicators are compared to applicable criteria or threshold values to generate an exceedence ratio, or the number of exceedences divided by the total number of times the parameter was measured (**Table 13**). For total phosphorus, total nitrogen, and chlorophyll *a*, the threshold values are dependent on the ecoregion and designated aquatic life use.

Table 13. Nutrient Level 2 Assessment Data for Canadian River Watershed

Assessment Unit	Ecoregion	Designated Aquatic Life Use	DO & pH – long term datasets	DO %Sat. – grab (# and % of exceedences)	DO conc – grab (# and % of exceedences)	pH – grab (# and % of exceedences)	Total Nitrogen (# and % of exceedences)	Total Phosphorus (# and % of exceedences)	Chlorophyll *a* exceedence?
Canadian River (Cimarron River to CO border)	Southwest Tablelands	WWAL	no data	7/22 = 32%	0/22 = 0%	1/22 = 5%	13/21 = 62%	12/21 = 57%	no
Chicorica Creek (Canadian River to East Fork Chicorica Creek)	Southwest Tablelands	WWAL	supports WWAL	1/9 = 11%	0/9 = 0%	0/9 = 0%	9/9 = 100%	8/9 = 89%	no
Chicorica Creek (East Fork Chicorica Creek to headwaters)	Southwest Tablelands	WWAL	supports WWAL	0/10 = 0%	0/10 = 0%	0/10 = 0%	9/9 = 100%	7/9 = 78%	no data
Raton Creek (Chicorica Creek to headwaters)	Southwest Tablelands	WWAL	D.O. does NOT support WWAL	3/7 = 43%	1/7 = 14%	0/7 = 0%	7/7 = 100%	7/7 = 100%	no

Assessment Unit	Ecoregion	Designated Aquatic Life Use	DO & pH – long term datasets	DO %Sat. – grab (# and % of exceedences)	DO conc – grab (# and % of exceedences)	pH – grab (# and % of exceedences)	Total Nitrogen (# and % of exceedences)	Total Phosphorus (# and % of exceedences)	Chlorophyll *a* exceedence?
Uña de Gato Creek (Chicorica Creek to Highway 64)	Southwest Tablelands	WWAL	D.O. does NOT support WWAL	2/8 = 25%	0/10 = 0%	0/10 = 0%	5/8 = 62%	5/8 = 62%	no data
Uña de Gato Creek (Highway 64 to headwaters)	Southern Rockies	WWAL	no data	1/11 = 9%	0/11 = 0%	0/11 = 0%	10/10 = 100%	9/10 = 90%	**YES**
Conchas River (Conchas Lake to headwaters)	Southwest Tablelands	WWAL	no data	0/4 = 0%	0/4 = 0%	0/4 = 0%	4/4 = 100%	4/4 = 100%	no data
Pajarito Creek (Ute Reservoir to headwaters)	Southwest Tablelands	WWAL	D.O. does NOT support WWAL	1/10 = 10%	1/10 = 10%	0/10 = 0%	8/10 = 80%	10/10 = 100%	no
Cieneguilla Creek (Eagle Nest Lake to headwaters)	Southern Rockies	HQCWAL	D.O. does NOT support WWAL	4/16 = 25%	0/16 = 0%	0/16 = 0%	16/16 = 100%	16/16 = 100%	no
Sixmile Creek (Eagle Nest Lake to headwaters)	Southern Rockies	HQCWAL	D.O. does NOT support WWAL	0/9 = 0%	0/9 = 0%	0/9 = 0%	4/9 = 44%	4/7 = 57%	no
Moreno Creek (Eagle Nest Lake to headwaters)	Southern Rockies	HQCWAL	D.O. does NOT support WWAL	4/9 = 44%	0/9 = 0%	0/9 = 0%	8/9 = 89%	9/9 = 100%	**YES**
Cimarron River (Turkey Creek to Eagle Nest Lake)	Southern Rockies	HQCWAL	D.O. does NOT support WWAL	4/8 = 50%	0/8 = 0%	0/8 = 0%	8/8 = 100%	7/7 = 100%	**YES**
Ute Creek (Cimarron River to headwaters)	Southern Rockies	HQCWAL	no data	0/9 = 0%	0/9 = 0%	0/9 = 0%	7/9 = 78%	7/8 = 88%	no
Cimarron River (Cimarron Village to Turkey Creek)	Southern Rockies	HQCWAL	supports HQCWAL	0/9 = 0%	0/9 = 0%	0/9 = 0%	9/9 = 100%	7/8 = 88%	yes**
North Ponil Creek (South Ponil Creek to Seally Cyn)	Southern Rockies	HQCWAL	D.O. does NOT support WWAL	0/9 = 0%	0/9 = 0%	0/9 = 0%	6/7 = 86%	6/7 = 86%	no data

Assessment Unit	Ecoregion	Designated Aquatic Life Use	DO & pH – long term datasets	DO %Sat. – grab (# and % of exceedences)	DO conc – grab (# and % of exceedences)	pH – grab (# and % of exceedences)	Total Nitrogen (# and % of exceedences)	Total Phosphorus (# and % of exceedences)	Chlorophyll *a* exceedence?
Ponil Creek (US 64 to confl North & South Ponil)	Southwest Tablelands	HQCWAL	D.O. does NOT support WWAL	2/9 = 22%	0/9 = 0%	0/9 = 0%	8/9 = 89%	8/9 = 89%	no data
Ponil Creek (Cimarron River to US 64)	Southwest Tablelands	WWAL	supports WWAL	3/9 = 33%	0/9 = 0%	0/9 = 0%	8/9 = 89%	8/8 = 100%	no data
Rayado Creek (Miami Lake Diversion to headwaters)	Southern Rockies	HQCWAL	supports HQCWAL	0/10 = 0%	0/10 = 0%	0/10 = 0%	8/9 = 89%	6/9 = 67%	yes**
Rayado Creek (Cimarron R to Miami Lake Diversion)	Southwest Tablelands	MCWAL	no data	3/9 = 33%	0/9 = 0%	0/9 = 0%	8/9 = 89%	6/9 = 67%	no data
Cimarron River (Canadian R to Cimarron Village)	Southwest Tablelands	WWAL	D.O. does NOT support WWAL	6/17 = 35%	1/17 = 6%	0/17 = 0%	14/17 = 82%	5/17 = 29%	no

HQCWAL = High Quality Coldwater Aquatic Life
MCWAL = Marginal Coldwater Aquatic Life
WWAL = Warmwater Aquatic Life
** = Chlorophyll *a* exceeds the ecoregion threshold value but is within the margin of error for this analysis.

5.2.4 Fish Community Data

Fish community data are collected for one or more of the following reasons:

- Development and/or refinement of water quality standards, particularly for designated aquatic life uses and/or temperature criteria.
- Development of fish-based biocriteria and/or bioassessment procedures. Once fish-based bioassessment procedures have been developed, fish community data will then be used as a basis for bioassessment.
- To document and characterize a given water's fish community for comparison with future or past records.

The characteristics of fish species (**Table 14**) provides information on the habits of each species so that correlations can be made with changes in the physical habitat that may be impacting the fish community. **Table 15** provides the results of fish collection in the Canadian Watershed.

Table 14. Characteristics of Fish Species found in Canadian River Watershed, 2006

Species	Common Name	Native	Temperature	Spawning Habit/ Substrate	Reproductive Guild	Feeding Guild
Ameiurus melas	black bullhead	Yes	Warm	Nest guarder/ silt, gravel	Hole nester; cavity spawner	Insectivore/ Invertivore
Ameiurus natalis	yellow bullhead	No	Warm	Nest guarder/ underside of overhanging objects	Hole nester; cavity spawner	Omnivore, Piscivore
Campostoma anomalum	central stoneroller	Yes	Cool	Nonguarder/ gravel	Brood hider; rock and gravel spawner	Herbivore
Catostomus commersoni	white sucker	Yes	Cool	Nonguarder/ open substrate	Rock and gravel spawner with pelagic free embryos	Omnivore
Cyprinella lutrensis	red shiner	Yes	Warm	Nonguarder/ gravel riffles	Crevice spawner	Omnivore
Fundulus zebrinus	plains killifish	Yes	Warm	Nonguarder/ open substrate	Pelagic broadcast spawner	Insectivore/ Invertivore
Lepomis cyanellus	green sunfish	Yes	Warm	Nest guarder/ sand, gravel	Miscellaneous spawner	Insectivore/ Invertivore, Piscivore
Micropterus salmoides	largemouth bass	No	Warm	Nest guarder/ sand, gravel	Miscellaneous spawner	Piscivore
Notropis stramineus	sand shiner	Yes	Warm	Nonguarder/ sand	Broadcast spawner	Omnivore
Oncorhynchus mykiss	rainbow trout	No	Cold	Nonguarder/ gravel	Brood hider; rock and gravel spawner	Insectivore/ Invertivore
Pimephales promelas	fathead minnow	Yes	Warm	Nest guarder/ underside of solid objects	Hole nester; cavity spawner	Omnivore
Platygobio gracilis	flathead chub	Yes	Cool	Nonguarder/ open substrate	Broadcast spawner	Insectivore/ Invertivore
Rhinichthys cataractae	longnose dace	Yes	Cool	Nonguarder/ open gravel substrate	Rock and gravel spawner with pelagic free embryos	Insectivore/ Invertivore
Salmo trutta	brown trout	No	Cold	Nonguarder/ gravel	Brood hider; rock and gravel spawner	Insectivore/ Invertivore
Semotilus atromaculatus	creek chub	Yes	Cool	Nonguarder/ gravel	Brood hider; rock and gravel spawner	Insectivore/ Invertivore

Table 15. Fish Community Data from the Canadian River Watershed, 2006

Station:			Raton Cr 5 mi. abv Chicorica Cr	Rayado Cr on NM 21	Rayado Cr abv Cimarron R	Ute Cr abv NM 102	Chicorica Creek abv Lake Alice
Scientific name	**Common name**	**Temperature**					
Ameiurus melas	black bullhead	Warm				2	
Ameiurus natalis	yellow bullhead	Warm				4	
Campostoma anomalum	central stoneroller	Cool	27				3
Catostomus commersoni	white sucker	Cool		27	5		13
Cyprinella lutrensis	red shiner	Warm			31	1	
Fundulus zebrinus	plains killifish	Warm				9	
Lepomis cyanellus	green sunfish	Warm				3	
Micropterus salmoides	largemouth bass	Warm			1	10	
Notropis stramineus	sand shiner	Warm			40		
Oncorhynchus mykiss	rainbow trout	Cold		1			
Pimephales promelas	fathead minnow	Warm	30		14		2
Platygobio gracilis	flathead chub	Cool	1				
Rhinichthys cataractae	longnose dace	Cool	3	86			16
Salmo trutta	brown trout	Cold		2			
Semotilus atromaculatus	creek chub	Cool	202	56			30
	# of Individuals		263	172	91	29	64
	# of Taxa		5	5	5	6	5
	% Native		100	98.3	98.9	51.7	100
	% Non-native		0	1.7	1.1	48.3	0
	% Cold water		0	1.7	0	0	0
	% Cool water		88.6	98.3	5.5	0	96.9
	% Warm water		11.4	0	94.5	100	3.1

6.0 Discussion

Due to the large volume of data collected during this survey, it will not be included in this report. To acquire specific data, contact the SWQB or search USEPA's STORET database. Water quality monitoring stations were located within the Canadian watershed during the intensive watershed survey to evaluate the impact of tributary streams and ambient water quality conditions. All of the monitoring that was conducting by the SWQB is summarized in **Tables 2 and 3**. Those parameters that exceeded the State's Water Quality Criteria are shown in **Tables 4 and 5** as well as **Tables 12 and 13**.

As a result of assessing data generated during this monitoring effort, impairment determinations of New Mexico water quality standards for **arsenic** were documented for the Cimarron River from Cimarron Village to Eagle Nest Lake and Ute Creek near Cimarron, NM. It should be noted that Eagle Nest Lake, the main contributor of water to this portion of the Cimarron River, is also impaired for arsenic. In addition, there are small legacy hardrock mining operations in the upper watershed that may be contributing to the elevated arsenic levels. Exceedences of the **boron** criterion were documented on Revuelto Creek near Logan, NM. Assessment of available data resulted in the delisting all of the assessment units previously listed for **aluminum**.

Available water quality data exceeded the historic, segment specific **turbidity** criterion in Cieneguilla Creek, Sixmile Creek, Ute Creek, North Ponil Creek, upper Ponil Creek, and the Cimarron River from Cimarron Village to Turkey Creek. Biological assessments using macroinvertebrate data from the same locations verified the turbidity impairments in these stream reaches. Exceedences of **temperature** criteria were documented on Cieneguilla Creek, Sixmile Creek, Moreno Creek, Ute Creek, South Ponil Creek, Middle Ponil Creek, North Ponil Creek, upper Ponil Creek, upper Rayado Creek, and the Cimarron River from Cimarron Village to Turkey Creek. Available data exceed the applicable ***E. coli*** criterion in the Canadian River from Ute Reservoir to Mora River, Cieneguilla Creek, North Ponil Creek, Ponil Creek, Pajarito Creek, Raton Creek, upper Rayado Creek, Sixmile Creek, and Ute Creek near Cimarron, NM.

Impairment of the narrative **plant nutrients** criterion was determined for the Canadian River from Cimarron River to the Colorado border, Cieneguilla Creek, Cimarron River, Moreno Creek, North Ponil Creek, Pajarito Creek, upper Ponil Creek, Raton Creek, lower Rayado Creek, Sixmile Creek, and Uña de Gato Creek. Impairment of the narrative **stream bottom deposits** criterion was determined on Cieneguilla Creek. Water quality sampling in Chicorica Creek, Conchas River, and Ute Creek near Logan, NM found no exceedences of either the numeric or narrative water quality criteria.

A number of assessment units could not be re-assessed due to insufficient data. These "old" impairments will remain on the Integrated Clean Water Act §303(d)/§305(b) list of waters until additional data are available. Total Maximum Daily Load (TMDL) documents will be prepared or updated by the SWQB to address the above noted impairments. Additional water quality data will be collected by the SWQB during the standard rotational period for intensive stream surveys. As a result, targets will be re-examined and potentially revised. When water quality standards have been achieved, the reach will be moved to the appropriate category on the Integrated Clean Water Act §303(d)/§305(b) list of waters.

7.0 References

Barbour, M.T., J. Gerritsen, B.D. Snyder and J.B. Stribling. 1999. *Rapid Bioassessment Protocols for Use in Streams and Wadeable Rivers: Periphyton, Benthic Macroinvertebrates, and Fish*. Second Edition. EPA 841/B-99002. Office of Water, Washington, DC. http://www.epa.gov/owow/monitoring/rbp/

Jacobi G.Z., M.D. Jacobi, M.T. Barbour, and E.W. Leppo. 2006. *Benthic macroinvertebrate stream condition indices for New Mexico wadeable streams.* Jacobi and Associates and Tetra Tech, Inc. for New Mexico Environment Department, Surface Water Quality Bureau. Santa Fe, NM.

New Mexico Administrative Code (NMAC). 2007. *State of New Mexico Standards for Interstate and Intrastate Surface Waters*. 20.6.4. New Mexico Water Quality Control Commission. As amended through August 2007. (20.6.4 NMAC)

New Mexico Environment Department/Surface Water Quality Bureau (NMED/SWQB). 2006. *Quality Assurance Project Plan (QAPP) for Water Quality Management Programs, 2006*.

NMED/SWQB. 2007. *Standard Operating Procedures for Data Collection*. Santa Fe, NM.

NMED/SWQB. 2009. *Procedures for Assessing Standards Attainment for the Integrated CWA §303(d)/§305(b) Water Quality Monitoring and Assessment Report*. Santa Fe, NM.

NMED/SWQB. 2010. *State of New Mexico Clean Water Act §303(d)/§305(b) Integrated List and Report*. Santa Fe, NM.

Natural Resources Conservation Service National Water and Climate Center (NRCS). 2007. http://www.wcc.nrcs.usda.gov/climate/avg/

Peck, D.V., A.T. Herlihy, B.H. Hill, R.M. Hughes, P.R. Kaufmann, D.J. Klemm, J.M. Lazorchak, F.H. McCormick, S.A. Peterson, P.L. Ringold, T. Magee, and M. Cappaert. 2006. *Environmental Monitoring and Assessment Program-Surface Waters Western Pilot Study: Field Operations Manual for Wadeable Streams*. EPA/620/R-06/003. U.S. Environmental Protection Agency, Office of Research and Development, Washington, D.C.

Plafkin, J.L., M.T. Barbour, K.D. Porter, S.K. Gross, and R.M. Hughs. 1989. *Rapid bioassessment protocols for use in streams and rivers.* USEPA. Office of Water Regulations and Standards. EPA/444/4-89-001. Washington, D.C.

Simon, Andrew. 1989. *A Model of Channel Response in Disturbed Alluvial Channels.* Earth Surface Processes and Landforms, Vol. 14: 11-26.