WATER QUALITY SURVEY SUMMARY

FOR THE

JEMEZ RIVER WATERSHED

(FROM SAN YSIDRO TO HEADWATERS EXCLUDING WATERS IN THE VALLES CALDERA NATIONAL PRESERVE*)

2005

Prepared by

Surface Water Quality Bureau
New Mexico Environment Department

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*In 2006, SWQB prepared a separate TMDL bundle for surface waters in the Valles Caldera National Preserve (VCNP). Available at: http://www.nmenv.state.nm.us/swqb/VallesCaldera.

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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
VCNP	Valles Caldera National Preserve
WWTP	Wastewater Treatment Plant
WQS	Water Quality Standards

EXECUTIVE SUMMARY

The Surface Water Quality Bureau conducted a water quality survey of the Jemez River watershed between March and October, 2005. The survey extended from the Jemez River crossing at NM Highway 4 upstream of San Ysidro to the headwaters, excluding waters within the Valles Caldera National Preserve boundary. Tributaries sampled include San Antonio Creek, East Fork Jemez River, Clear Creek, Rio de las Vacas, Rito Palomas, Calaveras Creek, Rio Cebolla, Vallecitos Creek, and the Rio Guadalupe. In addition, five of the area's geothermal springs were sampled once: San Antonio, Spence, Soda Dam, Jemez Springs Municipal Spring, and Giggling Springs Spa.

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* (NMED/SWQB 2008). 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* (Appendix A of NMED/SWQB 2008). 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 37 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 collect temperature, pH, dissolved oxygen, conductivity, and turbidity data to monitor diurnal trends. Biological surveys, which included the collection of macroinvertebrates, periphyton, fish community, and physical habitat characteristics, were conducted at 18 selected stations (fish samples only collected at 9 sites).

Water quality in the upper reaches of the Jemez River and its tributaries was found to be generally good. The most common parameter found in exceedence of current WQS was aluminum, however this is believed to be natural originating from weathering of the highly aluminiferous Valles Caldera volcanic geology (see Appendix A). Consistent with this source, aluminum concentrations tend to be higher during times of high flow, and increases in the East Fork of the Jemez as it passes through the Valles Caldera and continues below the confluence of the East Fork and San Antonio Creek. Other parameters found above WQS include arsenic and boron. These elements are associated with certain hot springs, and consistent with this source their concentration increases dramatically in the area of Soda Dam and tend to be highest during times of low flow.

The total nitrogen and total phosphorus levels are generally higher in this watershed than ecoregion thresholds due in part to the volcanic nature of the Jemez Mountains. However, at most sites response variables did not indicate that the nutrient levels were present in sufficient concentrations to produce undesirable aquatic life or that resulted in the dominance of a nuisance species in these surface waters. In parts of the watershed where human activities have increased the rates of erosion and nutrient loading, such as the lower Jemez River, Rito Penas Negras, and lower Rio de las Vacas, nutrient levels were present in concentrations that produced undesirable aquatic life resulting in a water quality impairment relative the narrative nutrient standard.

Additional data on the biological communities and physical habitat were collected for this survey. Biological surveys consisted of benthic macroinvertebrate and fish community data. 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. Currently information is compiled on all identified species to create a stream condition index score (SCI) which expresses the amount of stress a macroinvertebrate community is encountering based on the diversity of species and the tolerance and feeding habitats of those taxa present in the stream reach. Data were collected from 18 sites during this survey, 8 rated good, 7 fair and 3 poor. Fish collections yielded no previously undocumented species. The only species we expected to collect and did not was Rio Grande chub (*Gila pandora*). This species is historically common and well-documented in the Jemez basin and is considered by some to be in decline in all or parts of its range.

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. In addition the size of sediment within a stream system is one of the most important physical attributes in determining the health of aquatic communities. 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. In the Jemez, stream bottom deposits were a common cause of non-support for the study area. A total of 6 sites survey were found to have fines greater than 20%. Of these four sites were also found to have stream condition index score (SCI), based on macroinvertebrate sampling, indicating fair or poor conditions.

1.0 INTRODUCTION

Geologically, the Jemez River watershed is dominated by the volcanic formations of the Valles Caldera. These basalts and tuffs form the floor and valley walls for much of the length of the East Fork Jemez River, Rio San Antonio and the Rio Cebolla. At the confluence of the Rio San Antonio and the East Fork Jemez River, the Jemez River bed cuts through the volcanic rock and into a series of sedimentary strata that form the valley floor extending through the bottom of the study reach.

Land ownership in the upper Jemez basin is principally public, with approximately 94 percent of the study area managed by the Santa Fe National Forest (SFNF). SFNF has restored over 50 dispersed camping areas and treated about 500 acres for watershed protection. Land use in the upper Jemez River watershed is primarily forested cattle range, with some logging and several pumice mines. Additionally, the area is heavily utilized by the public for fishing, hunting, camping, and off-road vehicle use. The lower watershed downstream of the Rio Guadalupe is primarily agricultural, with water diversions for irrigation.

The Monitoring and Assessment Section (MAS) of the Surface Water Quality Bureau (SWQB) conducted a water quality survey of the Jemez watershed (**Figure 1**) between March and October, 2005. Water chemistry, physical habitat, and biota were studied to characterize the streams and water quality determine impairment. Water chemistry grab sampling was conducted monthly at 37 sites (**Table 2** and **Figure 3**) to capture different portions of the hydrograph, ranging from spring snowmelt to baseflow and summer monsoon runoff. Biological and physical habitat sampling occurred at select stations during the late summer and fall low flow conditions (biological index period). **Figure 2** displays the annual hydrograph of the Jemez River near the village of Jemez Springs, with daily discharge for 2005 and a 50 year monthly average. The river experienced high flow during the spring snowmelt tapering off to low flow conditions throughout the summer months and spiked rises during the late summer monsoon season.

Figure 1. Jemez River Watershed Location within Northern NM

Water samples were analyzed for plant nutrients, ions, total and dissolved metals, *E. coli* bacteria, and radionuclides. Variables such as dissolved oxygen (DO), pH, turbidity, and specific conductance were measured in the field. Physical habitat, periphyton, and benthic macroinvertebrate communities were surveyed to determine if excessive nutrients and settled sediment were impacting aquatic life within a stream. Fish populations were surveyed at select sites for community composition and to continue data pooling for future development of a fish condition index.

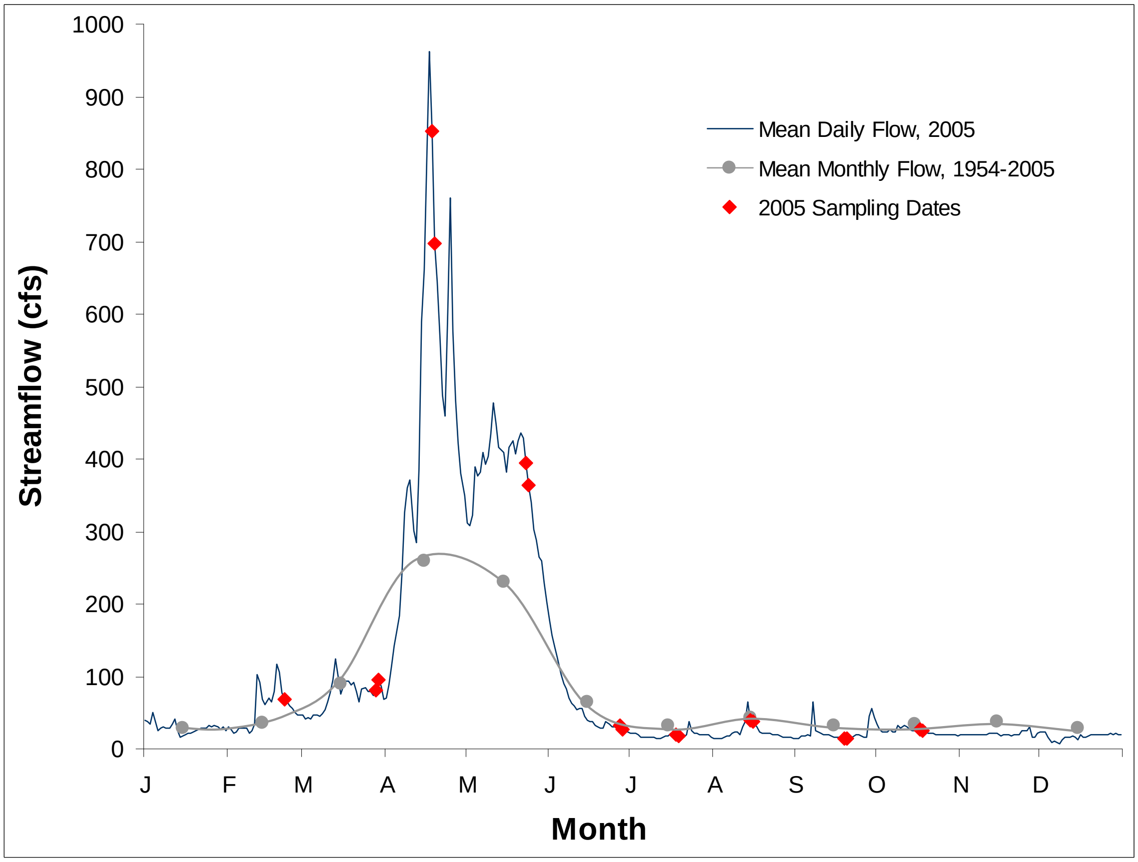


Figure 2. **Discharge of the Jemez River near the Village of Jemez Springs**

The survey extended from the Jemez River crossing at NM Highway 4 upstream of San Ysidro to the headwaters, excluding waters within the Valles Caldera National Preserve (VCNP). Sampled tributaries included: San Antonio Creek, East Fork Jemez River, Clear Creek, Rio de las Vacas, Rito Palomas, Calaveras Creek, Rio Cebolla, Vallecitos Creek, and the Rio Guadalupe. Specific monitoring activities conducted at each site are summarized in **Table 3.** River segments are divided into individual assessment units (AU) based on differing geological and hydrological properties, and each AU is assessed individually, with one or more monitoring sites located within an AU reach. Monitoring these sites over three seasons enabled an assessment of the cumulative influence of the physical habitat, water sources, and land management activities upstream from the sites on water quality.

2.0 WATER QUALITY STANDARDS

State *and* tribal water quality standards constitute the baseline of water quality standards (WQS) in effect for Clean Water Act purposes. The Jemez River within the survey area flows through various jurisdictional boundaries including both state and pueblo lands (Figure 3), however Jemez Pueblo and Zia Pueblo do not have approved WQS at this time. 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 Jemez River Watershed are set forth in sections 20.6.4.107, 20.6.4.108, and 20.6.4.124 of the *State of New Mexico Standards for Interstate and Intrastate Surface Waters* (NMAC 2007).

20.6.4.107 RIO GRANDE BASIN – The Jemez River from the Jemez Pueblo boundary upstream to Soda Dam near the town of Jemez Springs and perennial reaches of Vallecitos creek.

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

B. Criteria:

(1) In any single sample: temperature 25°C (77°F) and pH within the range of 6.6 to 8.8. The use-specific numeric criteria set forth in 20.6.4.900 New Mexico Administrative Code (NMAC) are applicable to the designated uses listed above in subsection A of this section.

(2) The monthly geometric mean of *E. coli* bacteria shall not exceed 126 cfu/100 mL or less, no single sample shall exceed 410 cfu/100 mL (see Subsection B of 20.6.4.14 NMAC).

20.6.4.108 RIO GRANDE BASIN – Perennial reaches of the Jemez River and all its tributaries above Soda Dam near the town of Jemez Springs, except Sulphur Creek above its confluence with Redondo Creek, and perennial reaches of the Guadalupe River and all its tributaries.

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

B. Criteria:

(1) In any single sample: specific conductance 400 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 Subscetion A of this section.

(2) The monthly geometric mean of E. coli bacteria shall not exceed 126 cfu/100 mL or less, no single sample shall exceed 235 cfu/100 mL (see Subsection B of 20.6.4.14 NMAC).

20.6.4.124 RIO GRANDE BASIN - Perennial reaches of Sulphur Creek from its headwaters to its confluence with Redondo Creek.

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

B. Criteria:

(1) In any single sample: pH within range of 2.0 to 9.0 and temperature 30°C (86°F) or less. The use-specific 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 shall not exceed 548 cfu/100 mL, no single sample shall exceed 2507 cfu/100 mL (see Subsection B of 20.6.4.14 NMAC).

(3) The chronic aquatic life criteria of Subsections I and J of 20.6.4.900 NMAC shall also apply.

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 attainability.

Table 1 details the current listings for the Jemez River watershed included in the *2008-2010 State of New Mexico Integrated Clean Water Act §303(d)/ §305(b) Report* (NMED/SWQB 2008) and existing Total Maximum Daily Loads (TMDLs). The *Integrated List* is a catalog of 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. TMDL bundles were developed for various portions of the Jemez River watershed in 1999 (then updated in 2002 and 2004). TMDLs for the VCNP were developed in 2006. 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 2008-2010 Integrated List available on the SWQB website.

Table 1. Summary of existing TMDLs and current impairments from the 2008-2010 Integrated List; Jemez River Watershed

Assessment Unit	Existing TMDLs (date)	2008-2010 Integrated List Impairments
Calaveras Creek (Rio Cebolla to headwaters)	NONE	NONE
Clear Creek (Rio de las Vacas to San Gregorio Lake)	Total Organic Carbon and Turbidity (2002)	Biological Impairment (unknown), Turbidity
Jemez River (Zia Pueblo bnd to Jemez Pueblo bnd)	NONE	Arsenic, Boron
Jemez River (Jemez Pueblo bnd to Rio Guadalupe)	NONE	Aluminum, Arsenic, Biological Impairment (unknown), Boron, Plant Nutrients
Jemez River (Rio Guadalupe to Soda Dam nr Jemez Springs)	Chronic Aluminum (2002) [a], Turbidity and Stream Bottom Deposits (1999/2004)	Aluminum, Arsenic, Biological Impairment (unknown), Boron, Plant Nutrients, Temperature, Turbidity
Jemez River (Soda Dam nr Jemez Springs to East Fork)	Chronic Aluminum (2002) [a], Turbidity and Stream Bottom Deposits (1999)	Aluminum, Arsenic, Biological Impairment (unknown), pH, Temperature, Turbidity
East Fork Jemez River (San Antonio Creek to VCNP bnd)	Turbidity (2002)	Aluminum, Arsenic, Temperature, Turbidity
Redondo Creek (Sulphur Creek to VCNP bnd)	Total Phosphorus (1999), Temperature and Turbidity (2002)	Aluminum, Turbidity
Rio Cebolla (Rio de las Vacas to Fenton Lake)	Stream Bottom Deposits (2002)	NONE
Rio Cebolla (Fenton Lake to headwaters)	Stream Bottom Deposits and Temperature (2002)	Aluminum, Sedimentation/Siltation
Rio de las Vacas (Rio Cebolla to Clear Creek)	Total Organic Carbon and Temperature (2002) [b]	Plant Nutrients, Temperature
Rio de las Vacas (Clear Creek to headwaters)	NONE	Aluminum
Rio Guadalupe (Jemez River to confl with Rio Cebolla)	Chronic Aluminum (2002), Stream Bottom Deposits, and Turbidity (1999/2004)	Aluminum, Temperature, Turbidity
Rito de las Palomas (Rio de las Vacas to headwaters)	NONE	Sedimentation/Siltation, Temperature
Rito Peñas Negras (Rio de las Vacas to headwaters)	Stream Bottom Deposits, Total Organic Carbon, and Temperature (2002)	Plant Nutrients, Sedimentation/Siltation, Temperature
San Antonio Creek (East Fork Jemez to VCNP bnd)	Temperature and Turbidity (2002)	Aluminum, Arsenic, Biological Impairment (unknown), Temperature, Turbidity
Sulphur Creek (San Antonio Creek to Redondo Creek)	NONE	Aluminum, pH, Specific Conductance
Sulphur Creek (Redondo Creek to VCNP bnd)	Conductivity and pH (2002) [c]	Not Assessed
Vallecito Creek (Perennial Prt Div abv Ponderosa to headwaters)	NONE	Aluminum

[a] TMDL developed for the Jemez River from Rio Guadalupe to the confluence of the East Fork of the Jemez River and San Antonio Creek.
[b] TMDLs developed for Rio de las Vacas from Rio Cebolla to Rito de las Palomas.

(c) A Use Attainability Analysis was submitted to EPA because the low pH values in this spring-fed tributary are naturally occurring. The aquatic life use was also changed from high quality coldwater to limited aquatic life, thus removing the specific conductance criterion. Therefore, pH and specific conductance were removed as causes on non support. Aluminum is naturally high in this watershed. The low pH in this assessment unit is likely contributing to increased metals concentrations.

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 2004) and the *SWQB Standard Operating Procedures for Data Collection* (NMED/SWQB 2004). 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 2008).

Biological and habitat sampling procedures were not outlined in the 2004 edition of the Standard Operating Procedures. Macroinvertebrate and periphyton samples were collected from riffle habitats best representing the stream reach being surveyed. Physical habitats were sampled at three cross sections of the stream that represent the variety of habitat available to aquatic life; one cross section was always placed at the riffle site of biological sampling. Macroinvertebrates were collected using either a Hess sampler or a 12 inch kick-net. Three, 30-second kicks were taken in the riffle and composited for the sample. Periphyton samples were a composite of either five or ten rocks, and a delimiter was used to ensure equal surface areas were scraped, brushed, and rinsed clean from each rock. This resultant slurry was composited to form a representative sample. The physical habitat survey procedures measured substrate present with a modified Wolman pebble count, canopy cover, stream bank stability, three measured cross sections, and qualitative habitat and geomorphic observations. Fish communities were sampled with a backpack shocker in a representative stream reach.

4.0 SAMPLING SUMMARY

A map of the study area is provided in **Figure 3**. The station numbers, USEPA Storage and Retrieval database (STORET) identification codes, and rationale of sampling stations selected for this survey are provided in **Table 2**. Stations are often located at AU breaks to include all inputs from that area before entering a new AU. The Jemez Springs Wastewater Treatment Plant (WWTP) was sampled to account for pollutant loading in the stream from the permitted facility.

Table 2. Sampling Stations; Jemez Watershed, 2005.

Map #	STATION NAME	STORET NUMBER	RATIONALE
1	Jemez River above San Ysidro at NM 4	31JemezR037.0	Unclassified segment
2	Jemez River near Canon, below Municipal School	31JemezR046.6	School WWTP impacts
3	Jemez River below Rio Guadalupe	31JemezR048.7	Mixing effects of Guadalupe
4	Jemez River above Rio Guadalupe	31JemezR049.2	Bottom of AU
5	Jemez River below Jemez Springs WWTP	31JemezR057.4	WWTP impacts
6	Jemez Springs WWTP outfall	31JemezR057.9	Effluent condition

Map #	STATION NAME	STORET NUMBER	RATIONALE
7	Jemez River above Jemez Springs WWTP	31JemezR058.6	Village impacts; WWTP reference
8[H]	Giggling Springs hot spring	31JemezGigSpr	Potential source; Sampled once
9[H]	Jemez Springs Municipal hot spring	31JemezHotSpr	Potential source; Sampled once
10	Jemez River at NM 4 Bridge by USFS Station	31JemezR064.2	Bottom of AU
11	Jemez River above Soda Dam	31JemezR064.9	Bottom of AU
12[H]	Soda Dam hot spring	31SodaDamHtSp	Potential source; Sampled once
13	Jemez River at USGS gage below Battleship Rock	31JemezR070.3	Impacts of development
14	East Fork Jemez River above San Antonio Creek	31EFkJem000.1	Bottom of AU
15	East Fork Jemez River below Las Conchas day use area	31EFkJem015.2	Bottom of AU; reference condition
16	San Antonio Creek above East Fork Jemez River	31SanAnt000.1	Bottom of AU
17[H]	Spence hot spring	31SpenceHotSp	Potential source; Sampled once
18	San Antonio Creek below La Cueva	31SanAnt004.7	Bottom of AU; La Cueva impacts
19	Redondo Creek above Sulphur Creek	31Redond000.1	Bottom of AU
20	Sulphur Creek above San Antonio Creek	31Sulphu000.1	Bottom of AU; La Cueva impacts
21	Sulphur Creek above Redondo Creek	31Sulphu001.3	Bottom of AU
22	San Antonio Creek above NM 126	31SanAnt008.4	Bottom of AU
23[H]	San Antonio hot springs	31SanAntHotSp	Potential source; Sampled once
24	San Antonio Creek above San Antonio hot springs	31SanAnt014.5	Bottom of AU
25	San Antonio Creek at VCNP boundary	31SanAnt018.0	SFNF site; reference condition
26	Rio Guadalupe above Jemez River	31RGuada000.1	Bottom of AU
27	Rio Guadalupe at Deer Creek Landing	31RGuada010.0	Mill site and rail yard impacts
28	Rio de Las Vacas above Rio Cebolla	31RVacas000.1	Bottom of AU
29	Rio Cebolla above Rio de las Vacas	31RCebol000.1	Bottom of AU
30	Rio Cebolla below Fenton Lake	31RCebol009.3	Lake and campground impacts
31	Rio Cebolla 0.5 mile above Fenton Lake	31RCebol011.4	Hatchery and septic impacts
32	Rio Cebolla at NM 126	31RCebol013.7	Hatchery impacts
33	Rio Cebolla at campground abv Seven Springs hatchery	31RCebol017.9	Bottom of AU
34	Calaveras Creek on NM 126, above Rio Cebolla	31Calave001.1	Bottom of AU
35	Rio de las Vacas below inholdings at FR 20	31RVacas014.6	SFNF site; septic impacts
36	Rito Peñas Negras at NM 126	31RPNegr000.1	Bottom of AU
37	Rito de las Palomas at NM 126	31RPalom000.1	Bottom of AU
38	American Creek above Rito de las Palomas	31Americ000.1	Sampled by SFNF
39	Clear Creek at NM 126	31ClearC002.3	Bottom of AU
40	Rio de las Vacas at NM 126	31RVacas023.7	Bottom of AU
41	Rio de las Vacas above FR 70	31RVacas026.5	SFNF site for grazing impacts from Nacimiento Plateau
42	Vallecito Creek above Ponderosa diversion	31RValle012.2	Bottom of AU
43	Vallecito Creek at Paliza Campground	31RValle015.5	Bottom of AU

<u>NOTES:</u> [H] Geothermal Spring
WWTP = Wastewater Treatment Plant, AU = Assessment Unit, USFS = U.S. Forest Service
USGS = U.S. Geological Survey, VCNP = Valles Caldera National Preserve, SFNF = Santa Fe National Forest

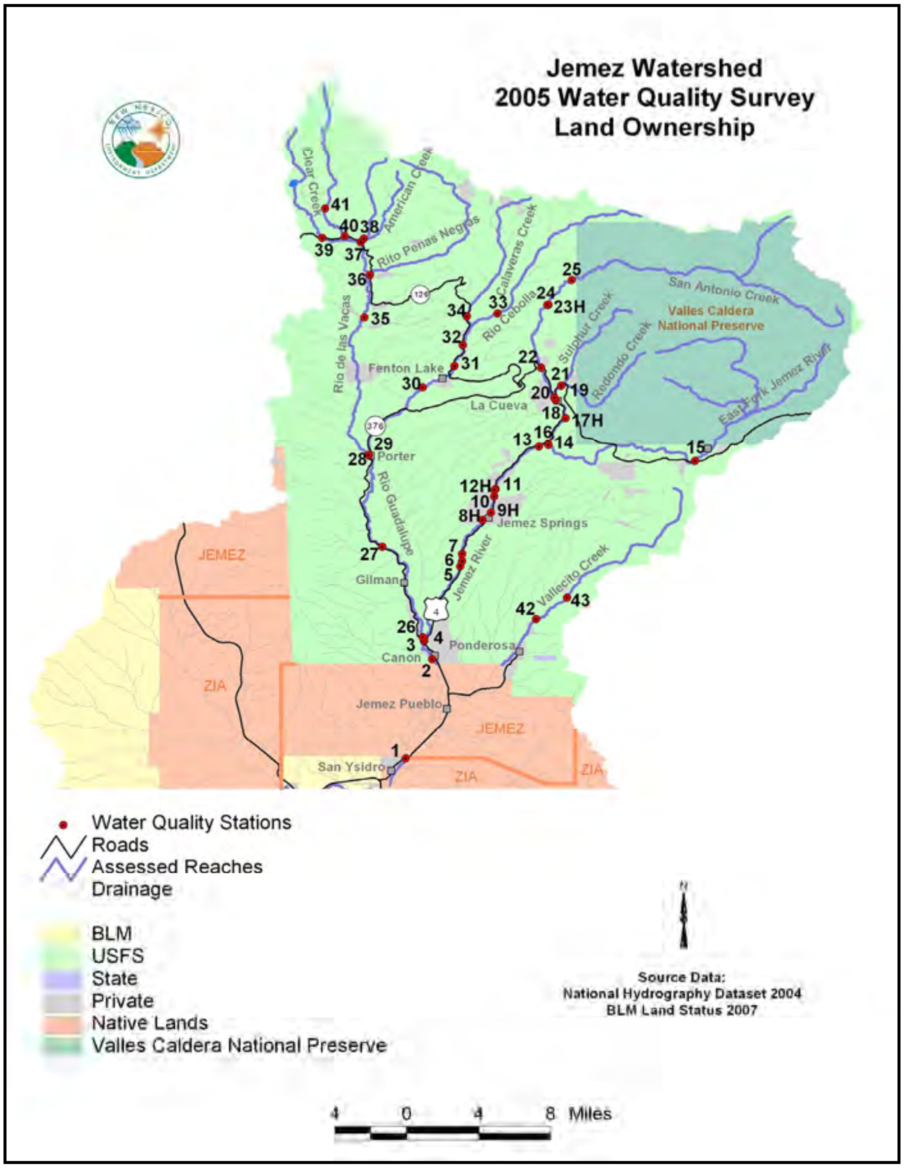


Figure 3. Jemez River Watershed 2005 Study Area and Sampling Stations

Table 3 summarizes data collected in each assessment unit and at each station. The number of times each parameter (or suite of parameters) was sampled is indicated (in the case of stream discharge, some of the data are retrieved from USGS gages). Field data include temperature, specific conductance, pH, DO, and turbidity.

Table 3. Sampling Summary; Jemez River Watershed Survey, 2005.

Assessment Unit / Station	Discharge	Field Data	Ions (full suite)	Ions (TDS/TSS/ Hardness)	Nutrients	Total Metals (full suite)	Total Hg/Se (only)	Dissolved Metals (full suite)	*E. coli*	Cyanide	Radionuclides	Thermograph	Sonde Deployment	Physical Habitat	Macroinvertebrate Community	Periphyton	Fish Community
American Creek (Rito de las Palomas to headwaters)																	
American Creek above Rio de las Palomas	Water Chemistry grab sampling conducted by SFNF. No other monitoring was conducted.																
Calaveras Creek (Rio Cebolla to headwaters)																	
Calaveras Creek on NM 126, above Rio Cebolla	5	11	4	3	8		4	4	1			X	X	X	X	X	
Clear Creek (Rio de las Vacas to San Gregorio Lake)																	
Clear Creek at NM 126	7	13	5	4	10		4	4	2			X		X	X	X	
Hot Springs																	
Giggling Springs Hot Spring		1	1		1		1	1			1						
Jemez Hot Spring		1	1		1		1	1			1						
Soda Dam Hot Spring		1	1		1		1	1			1						
Spence Hot Spring		1	1		1		1	1			1						
San Antonio Hot Spring		1	1		1		1	1			1						
Jemez River (Zia Pueblo boundary to Jemez Pueblo boundary)																	
Jemez River above San Ysidro at NM 4	2	8	3		3		3	3	5		1	X					
Jemez River (Jemez Pueblo boundary to Rio Guadalupe)																	
Jemez River near Canon, below municipal school	2	11	2	5	6		7	7	4			X	X	X	X	X	
Jemez River below Rio Guadalupe	3	11	4	5	10		12	12	3								
Jemez River (Rio Guadalupe to Soda Dam near Jemez Springs)																	
Jemez River above Rio Guadalupe	7												X	X	X	X	
Jemez River below Jemez Springs WWTP	2	8	3	5	10		9	9	3	2							
Jemez Springs WWTP		3	1	3	5		5	5									
Jemez River above Jemez Springs WWTP	1	9	3	4	8		8	8			1		X				
Jemez River at NM 4 by USFS station	6	10	3	5	8		8	8			1						
Jemez River (Soda Dam near Jemez Springs to East Fork)																	
Jemez River above Soda Dam	6	12	4	5	9		8	8	1	2		X	X	X	X	X	X
Jemez River at gage below Battleship Rock	6	10	3	6	9		9	9	1	2		X					
East Fork Jemez (San Antonio Creek to VCNP boundary)																	
East Fork Jemez River above San Antonio Creek	8	14	6	4	11	1	9	9	3	2	1	X	X	X	X	X	X
East Fork Jemez River below Las Conchas day use area		11	3	8	11		11	11	2	2		X					
Redondo Creek (Sulphur Creek to VCNP boundary)																	
Redondo Creek above Sulphur Creek		9										X					

Assessment Unit / Station	Discharge	Field Data	Ions (full suite)	Ions (TDS/TSS/ Hardness)	Nutrients	Total Metals (full suite)	Total Hg/Se (only)	Dissolved Metals (full suite)	*E. coli*	Cyanide	Radionuclides	Thermograph	Sonde Deployment	Physical Habitat	Macroinvertebrate Community	Periphyton	Fish Community
Rio Cebolla (Rio de las Vacas to Fenton Lake)																	
Rio Cebolla above Rio de las Vacas	7	13	6	4	11		4	4	2		1	X	X	X	X	X	X
Rio Cebolla below Fenton Lake		7			3				1	2		X					
Rio Cebolla (Fenton Lake to headwaters)																	
Rio Cebolla ~0.5 mile above Fenton Lake	6	13								2		X	X	X	X	X	X
Rio Cebolla at NM 126	2	9	3	3	7				2								
Rio Cebolla above 7 Springs	4	11	5	4	10		6	6	2			X		X	X	X	X
Rio de las Vacas (Clear Creek to headwaters)																	
Rio de Las Vacas at NM 126	7	12	4	3	8		4	4	2			X					
Rio de las Vacas above FR 70		2	2		4								X	X	X	X	X
Rio de las Vacas (Rio Cebolla to Clear Creek)																	
Rio de Las Vacas above Rio Cebolla	6	13	5	3	9		4	4	2	2	1	X	X	X	X	X	
Rio de las Vacas below inholdings at FR 20		2	1		1												
Rio Guadalupe (Jemez River to confluence with Rio Cebolla)																	
Rio Guadalupe above Jemez River	7	13	4	6	10		9	9	2	2	1	X	X	X	X	X	
Rio Guadalupe at Deer Creek Landing	6	8	4	5	9		8	8									
Rio Guadalupe at Porter Landing		6										X	X				
Rito de las Palomas (Rio de las Vacas to headwaters)																	
Rito de las Palomas at NM 126	7	13	5	3	9		4	4	1		1	X		X	X	X	
Rito Peñas Negras (Rio de las Vacas to headwaters)																	
Rito Peñas Negras at NM 126	6	12	4	4	9		4	4	2			X	X	X	X	X	
San Antonio Creek (East Fork Jemez to VCNP boundary)																	
San Antonio Creek above Jemez River	9	14	5	7	12		11	11	2	2	1	X	X	X	X	X	X
San Antonio Creek below La Cueva	1	10	3	6	9		1	1	3								
San Antonio Creek above NM 126	7	12	6	3	9		8	8	1			X	X	X	X	X	X
San Antonio Creek at VCNP boundary	Water Chemistry grab sampling conducted by SFNF. No other monitoring was conducted.																
San Antonio Creek above San Antonio hot spring												X					
Sulphur Creek (San Antonio Creek to Redondo Creek)																	
Sulphur Creek above San Antonio Creek	6	12	3	5	8		8	8	2		1		X				
Sulphur Creek (Redondo Creek to VCNP boundary)																	

Assessment Unit / Station	Discharge	Field Data	Ions (full suite)	Ions (TDS/TSS/ Hardness)	Nutrients	Total Metals (full suite)	Total Hg/Se (only)	Dissolved Metals (full suite)	*E. coli*	Cyanide	Radionuclides	Thermograph	Sonde Deployment	Physical Habitat	Macroinvertebrate Community	Periphyton	Fish Community
Sulphur Creek above Redondo Creek	1	7										X					
Vallecito Creek (Perennial Prt Div above Ponderosa to headwaters)																	
Vallecito Creek above Ponderosa diversion	4	13	5	3	9		9	9	2		1	X	X	X	X	X	X
Vallecito Creek at Paliza Campground	5	11	4	5	9		6	6				X	X	X	X	X	

5.0 WATER QUALITY ASSESSMENT FOR NUMERIC CRITERIA

For many water quality analytes, the State of New Mexico maintains numeric water quality standards. 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 2008). Determined physicochemical water quality criteria numeric exceedences are provided in **Table 4**, and details of assessment procedures are available in the *Assessment Protocol*. A complete data set can be obtained by contacting the water chemistry survey lead or calling the SWQB.

Table 4. Physiochemical Water Quality Standards Exceedences; Jemez Watershed, 2005.

Assessment Unit / Station	Temperature	pH	Aluminum, Acute	Aluminum, Chronic	Arsenic, DWS	Arsenic, HH	Arsenic, Irr.	Boron, Irr.	Long Term Temp. %	Long Term pH %	Long Term DO %
Jemez River (Zia Pueblo boundary to Jemez Pueblo boundary)											
Jemez River above San Ysidro at NM 4						3/3		2/3			
Jemez River (Jemez Pueblo boundary to Rio Guadalupe)											
Jemez River near Canon, below Municipal School				4/9		7/9		2/9			
Jemez River below Rio Guadalupe				2/7		5/7		2/7			
Jemez River (Rio Guadalupe to Soda Dam near Jemez Springs)											
Jemez River above Rio Guadalupe						8/9	2/9	4/9		13.1	14.3
Jemez River below Jemez Springs WWTP				4/8		7/8	2/8	5/8			
Jemez River above Jemez Springs WWTP				4/8		7/8	2/8	4/8			
Jemez River at NM 4 Bridge by SFNF Office				4/8		8/9	1/8	3/8			
Jemez River (Soda Dam near Jemez Springs to East Fork Jemez River)											
Jemez River above Soda Dam				4/8	7/8	5/8			65.6	98.6	
Jemez River at USGS gage below Battleship Rock				5/8	6/8	0/8			11.0		
East Fork Jemez (San Antonio Creek to VCNP boundary)											
East Fork Jemez River above San Antonio			2/9	7/9	6/9				15.6		
East Fork Jemez River below Las Conchas day use area			2/8	8/8					12.0		
San Antonio Creek (East Fork Jemez to VCNP boundary)											
San Antonio Creek above Jemez River				5/9	6/9					9.4	
San Antonio Creek below La Cueva				1/1							
San Antonio Creek above NM 126				3/8	1/8					15.3	
San Antonio Creek above San Antonio Hot Spring										29.4	
Sulphur Creek (San Antonio Creek to Redondo Creek)											
Sulphur Creek above San Antonio Creek		5/12	2/8	7/8						59.1	
Rio Guadalupe (Jemez River to confluence with Rio Cebolla)											
Rio Guadalupe above Jemez River				5/9						32.3	14.3
Rio Guadalupe at Deer Creek Landing				4/8							
Rio Guadalupe at Porter Landing										12.4	
Rio de las Vacas (Rio Cebolla to Clear Creek)											
Rio de Las Vacas above Rio Cebolla				1/4						23.5	
Rio de las Vacas below inholdings at FR 20										31.7	
Rito de las Palomas (Rio de las Vacas to headwaters)											
Rito de las Palomas at NM 126				1/4					19.4		
Rito Peñas Negras (Rio de las Vacas to headwaters)											
Rito Peñas Negras at NM 126									22.9		
Rio de las Vacas (Clear Creek to headwaters)											
Rio de Las Vacas at NM 126				2/4							
Rio Cebolla (Rio de las Vacas to Fenton Lake)											
Rio Cebolla above Rio de las Vacas	3/13										
Rio Cebolla below Fenton Lake	2/5								9.7		
Rio Cebolla (Fenton Lake to headwaters)											
Rio Cebolla ~0.5 mile above Fenton Lake									9.4		
Rio Cebolla at campground above Seven Springs hatchery				1/4							
Vallecito Creek (Perennial Prt Div above Ponderosa to headwaters)											
Vallecito Creek above Ponderosa diversion				3/8							
Vallecito Creek at Paliza Campground				1/4							

6.0 WATER QUALITY ASSESSMENT FOR NARRATIVE CRITERIA

Parameters that have only narrative water quality standards are assessed for designated use attainment status with the application of the assessment protocols. For further detail on any assessment for narrative criteria refer to 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 2008). Complete data sets are available by contacting the biology survey lead at the SWQB.

6.1 Physical Habitat Data Summary

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 biological 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 within a certain landscape. **Table 5** describes the watershed size, ecoregion, and elevation of each station within the biological survey of the Jemez River watershed. This is the minimal data necessary to categorize the sites by landscape, and the reference sites indicated were chosen as the least disturbed by the professional judgment of the biology team.

6.1.1 Geomorphology

Quantitatively identifying the current structure of a stream channel allows for a determination of the amount 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 land or the aquatic communities within the channel. Identifying areas of instability and loss of habitat variability within a stream may allow for restoration of the channel before damage to adjacent land and aquatic life occurs. **Table 6** displays physical habitat parameters related to stream channel stability calculated from this survey.

6.1.2 Riparian Health

The riparian area is the corridor of vegetation surrounding the stream and providing 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 stream 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 observational assessments combined with the quantitative canopy measurements (**Table 7**) provide an indication of riparian health.

Table 5. Landscape Characteristics of the Jemez Watershed Biological Survey Sites, 2005. Sites in bold are reference sites.

Category	Station Name *Bold indicates reference site	Watershed Area (mi.^{2})	Elevation (Feet)	Omernick Ecoregion	Station #
FOOTHILL WOODLAND & SHRUBLAND	Jemez R. near Canon, below Municipal school	470	5630	Southern Rockies	2
	Jemez R. above Rio Guadalupe	200.3	5663	Southern Rockies	4
	Rio Guadalupe above Jemez River	**265.0**	**5669**	**Southern Rockies**	**26**
MID ELEVATION VOLCANIC FOREST	Vallecitos Creek above Ponderosa Diversion	16.1	6332	Southern Rockies	42
	Jemez R. above Soda Dam	179.2	6352	Southern Rockies	11
	Vallecitos Creek at Paliza Campground	12.6	6765	Southern Rockies	43
	San Antonio above East Fork Jemez R.	97.0	6778	Southern Rockies	16
	East Fork Jemez R. above San Antonio Creek	**67.0**	**6785**	**Southern Rockies**	**14**
HIGH ELEVATION VOLCANIC FOREST	Rio de las Vacas above Rio Cebolla	121.0	7192	Southern Rockies	28
	Rio Cebolla above Rio de Las Vacas	65.4	7198	Southern Rockies	29
	Rio Cebolla above Fenton Lake	40.0	7703	Southern Rockies	31
	San Antonio above NM 126	**70.3**	**7775**	**Southern Rockies**	**22**
HIGH ELEVATION SEDIMENTARY FOREST	Calaveras Creek above Rio Cebolla at NM 126	16.1	7966	Southern Rockies	34
	Rito Peñas Negras at NM Hwy 126	17.1	7992	Southern Rockies	36
	Rio Cebolla above Seven Springs Hatchery	17.6	8038	Southern Rockies	32
	Rito de Los Palomas at NM 126	12.2	8110	Southern Rockies	37
	Clear Creek at NM 126	7.5	8366	Southern Rockies	39
	Rio de las Vacas above FR 70	**13.4**	**8989**	**Southern Rockies**	**41**

6.1.3 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 in sections at high elevation with smaller watershed size gradually decreasing to sand in low elevation streams with large watersheds (**Figure 4**). 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 as displayed in **Table 8**. Other metrics in **Table 8** describe the sizes classes found in the reach, the size of the median of the cumulative frequency distribution (D50), and the mean embeddedness, which is how much of the particles were surrounded by fines. Rito de Las Palomas at NM 126 had significant variation between riffles throughout the reach, so two riffles were sampled, although riffle 1 was used for assessment purposes.

Table 6. Geomorphic Data for Jemez River Watershed, 2005.

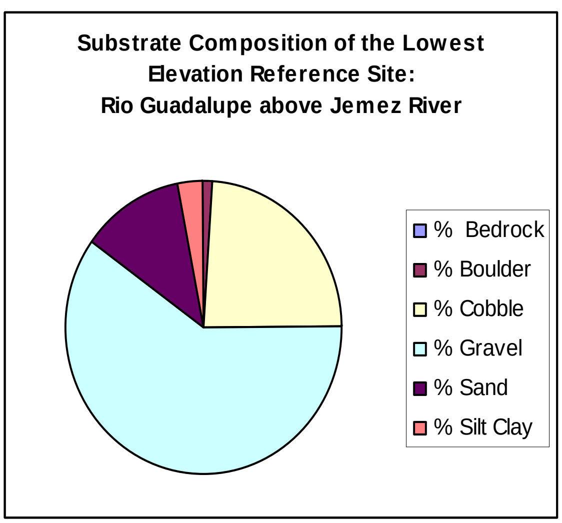
Station Name *Bold indicates reference site	Slope (%)	Mean Bank Stability[1] (4-22)	Bank Rating	Bankfull Width (ft)	Bankfull height (ft)	Width-Depth Ratio	Bankfull Cross Sectional Area (ft^2)
Jemez R. near Canon, below Municipal school	0.8	9.5	at risk	48.4	2.3	20.9	112.3
Jemez R. above Rio Guadalupe	1.0	10.5	at risk	31.0	1.8	17.2	55.8
Rio Guadalupe above Jemez River	**1.0**	**9.8**	**at risk**	**27.0**	**1.4**	**19.3**	**37.8**
Vallecitos Creek above Ponderosa Diversion	No Data	9.7	at risk	5.9	1.7	3.5	9.9
Jemez R. above Soda Dam	1.5	11.3	unstable	23.0	9.2	2.5	211.8
Vallecitos Creek at Paliza Campground	3.5	12.0	unstable	4.7	1.3	3.6	6.1
San Antonio above East Fork Jemez R.	2.5	10.5	at risk	12.5	0.6	22.3	7.0
East Fork Jemez R. above San Antonio Crk	**3.3**	**7.8**	**stable**	**11.6**	**0.7**	**17.1**	**7.9**
Rio de las Vacas above Rio Cebolla	No Data	11.5	unstable	10.3	5.5	1.9	56.6
Rio Cebolla above Rio de Las Vacas	2.0	7.6	stable	23.5	1.8	13.0	42.2
Rio Cebolla above Fenton Lake	1.5	12.2	unstable	27.1	5.5	4.9	148.5
San Antonio above NM Hwy 126	**2.0**	**10.0**	**at risk**	**6.2**	**0.4**	**16.8**	**2.3**
Calaveras Creek above Rio Cebolla at NM 126	1.3	11.2	unstable	5.3	0.9	5.8	4.9
Rito Peñas Negras at NM 126	0.5	11.0	unstable	4.6	0.6	7.4	2.8
Rio Cebolla above Seven Springs Hatchery	No Data	11.8	unstable	35.8	No Data	No Data	No Data
Rito de Los Palomas at NM Hwy 126	2.5	9.8	at risk	3.0	0.7	4.6	2.0
Clear Creek at NM 126	4.0	10.0	at risk	12.3	0.7	17.6	8.6
Rio de las Vacas above FR 70	**2.5**	**7.4**	**stable**	**No Data**	**No Data**	**No Data**	**No Data**

1 Bank stability is scored and rated based on measurement and observations of percent vegetative cover, substrate category, bank angle, and bank height (Fitzpatrick, 1998) Higher scores indicate more unstable banks.

Table 7. Riparian Cover and Qualitative Scores for the Jemez River Watershed, 2005. Sites in bold are reference sites.

Station Name *Bold indicates reference site	Riparian Canopy Cover (% cover)	RGA[1] Stability Score (0-36)	RHA[2] Habitat Score (0-200)
Jemez R. near Canon, below Municipal school	53	11.0	141
Jemez R. above Rio Guadalupe	22	6.0	152
Rio Guadalupe above Jemez River	**35**	**10.0**	**150**
Vallecitos Creek above Ponderosa Diversion	90	10.5	155
Jemez R. above Soda Dam	7	6.5	125
Vallecitos Creek at Paliza Campground	94	8.5	171
San Antonio above East Fork Jemez R.	65	10.5	138
East Fork Jemez R. above San Antonio Crk	**65**	**3.0**	**177**
Rio de las Vacas above Rio Cebolla	74	5.0	149
Rio Cebolla above Rio de Las Vacas	55	3.0	168
Rio Cebolla above Fenton Lake	32	11.0	155
San Antonio above NM 126	**53**	**7.0**	**167**
Calaveras Creek above Rio Cebolla at NM 126	2	14.0	147
Rito Peñas Negras at NM 126	94	18.5	120
Rio Cebolla above Seven Springs Hatchery	69	4.5	176
Rito de las Palomas at NM 126	19	15.0	114
Clear Creek at NM 126	28	16.0	104
Rio de las Vacas above FR 70	**71**	**No Data**	**No Data**

1. 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. Rapid Habit 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



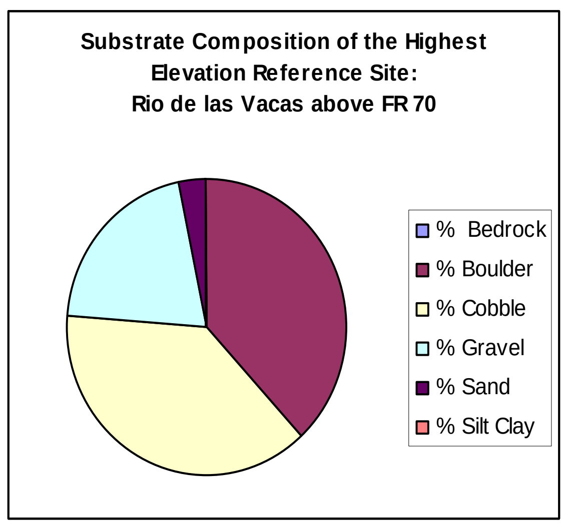


Figure 4. Variation of Substrate Composition within the Jemez River Watershed, 2005

Table 8. Substrate Composition Data from the Jemez River Watershed, 2005. Sites in bold are reference sites.

Station Name *Bold indicates reference site	D50 (mm)	% Bedrock	% Boulder	% Cobble	% Gravel	% Sand	% Silt Clay	Mean % Embeddedness
Jemez R. near Canon, below Municipal school	40	0	0	27	60	6	7	48
Jemez R. above Rio Guadalupe	77	0	2	58	23	0	17	62
Rio Guadalupe above Jemez River	**34**	**0**	**1**	**24**	**60**	**12**	**3**	**32**
Vallecitos Creek above Ponderosa Diversion	24	0	3	21	54	15	7	28
Jemez River above Soda Dam	131	0	23	42	17	9	10	49
Vallecitos Creek at Paliza Campground	26	0	0	13	79	7	1	32
San Antonio above East Fork Jemez R.	29	0	6	23	55	14	2	27
East Fork Jemez R. above San Antonio Creek	**114**	**0**	**18**	**49**	**27**	**3**	**3**	**20**
Rio de las Vacas above Rio Cebolla	80	0	9	55	29	7	0	24
Rio Cebolla above Rio de Las Vacas	13	33	0	11	33	16	7	23
Rio Cebolla above Fenton Lake	6	0	0	3	59	25	13	27
San Antonio above NM Hwy 126	**44**	**0**	**8**	**38**	**48**	**5**	**1**	**21**
Calaveras Creek above Rio Cebolla at NM 126	6	0	0	1	58	30	11	45
Rito Peñas Negras at NM 126	23	0	0	16	68	5	11	18
Rio Cebolla above Seven Springs Hatchery	13	0	0	3	72	17	8	28
Rito de Los Palomas at NM 126 (riffle 1)	16	0	10	11	55	0	24	NA
Rito de Los Palomas at NM 126 (riffle 2)	0.6	0	3	1	26	36	34	NA
Clear Creek at NM 126	43	0	0	37	46	15	2	24
Rio de las Vacas above FR 70	**185**	**0**	**38**	**38**	**21**	**3**	**0**	**18**

6.2 Macroinvertebrate Community and Sedimentation Assessment

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. Currently information is compiled on all identified species to create a stream condition index score (SCI) ranging from 0-100 (**Table 9**). This score expresses the amount of stress a macroinvertebrate community is encountering based on the diversity of species and the tolerance and feeding habitats of those taxa present in the stream reach. Table 9 also describes how that score translates into whether the designated aquatic life use (ALU) is supported through the macroinvertebrate community present in the stream. **Table 10** displays the metrics and calculated SCI score for the watershed.

Table 9. SCI Scoring and Support for Aquatic Life Use (ALU), Jemez Watershed, 2005.

	Supporting ALU		Not Supporting ALU		
	Very Good	Good	Fair	Poor	Very Poor
SCI Score	100-78.36	78.35-56.70	56.69-37.20	37.19-18.90	18.89 - 0

Table 10. Macroinvertebrate Data Metrics and SCI Scores from the Jemez River Watershed, 2005.

	Stations *Bold indicates reference site	Jemez R. near Canon, below Municipal school	Jemez R. above Rio Guadalupe	**Rio Guadalupe above Jemez River**	Vallecitos Creek above Ponderosa Diversion	Jemez R. above Soda Dam	Vallecitos Creek above Paliza Campground	San Antonio above East Fork Jemez R.	**East Fork Jemez R. above San Antonio Creek**	Rio de las Vacas above Rio Cebolla	Rio Cebolla above Rio de las Vacas	Rio Cebolla above Fenton Lake	**San Antonio Creek above NM 126**	Calaveras Creek above Rio Cebolla at NM 126	Rito Peñas Negras at NM 126	Rio Cebolla above Seven Springs Hatchery	Rito de Las Palomas at NM 126	Clear Creek at NM 126	**Rio de Las Vacas above FR 70**
Taxonomic composition	**Shannon Weiner**	2.15	1.8	**2.69**	2.94	3.10	3.08	2.79	**3.22**	3.73	3.96	2.11	**3.50**	4.36	No data	2.52	3.07	2.79	**3.25**
	Evenness	0.24	0.17	**0.31**	0.32	0.35	0.37	0.37	**0.39**	0.55	0.56	0.21	**0.42**	0.51	No data	0.31	0.41	0.30	**0.41**
	Percent Plecoptera	0.65	2.16	**11.70**	7.52	0	0	2.14	**3.32**	0.89	3.73	3.81	**7.59**	8.45	No data	0.36	1.67	7.39	**12.30**
Taxonomic Richness	**Number of Ephemoptera**	3	2	**6**	3	4	1	4	**5**	5	4	4	**2**	5	No data	2	4	5	**5**
	Number of Plecoptera	1	2	**3**	2	0	0	1	**3**	1	1	3	**3**	4	No data	1	1	2	**3**
Tolerance	**Percent EPT**	84.75	60.43	**83.02**	68.51	70.70	39.14	42.25	**68.44**	68.75	55.22	76.95	**63.92**	39.44	No data	41.07	14.44	22.60	**61.70**
	Percent Intolerance	3.27	2.52	**25.00**	34.06	12.10	17.74	11.23	**20.93**	48.21	20.90	8.76	**22.15**	20.00	No data	1.43	7.78	13.20	**51.06**
Habitat	**Clinger Richness**	10	5	**9**	10	12	8	11	**15**	10	12	8	**13**	12	No data	6	4	6	**11**
	Sprawler Richness	3	9	**7**	3	5	2	7	**4**	4	7	6	**6**	10	No data	3	8	8	**5**
	Swimmer Richness	1	1	**2**	2	2	1	2	**2**	2	2	2	**1**	4	No data	1	4	3	**3**
Functional Feeding Group	**Percent Scraper**	3.92	4.32	**7.55**	23.76	16.56	16.50	13.37	**13.29**	36.61	26.87	6.86	**25.32**	15.49	No data	13.57	22.22	52.10	**15.30**
	Scraper Richness	4	2	**5**	2	4	1	6	**7**	4	5	2	**5**	4	No data	2	3	2	**3**
	OVERALL SCI SCORE	42.68	36.90	**63.96**	54.23	54.95	34.68	53.67	**62.24**	68.00	64.53	48.90	**62.83**	70.96	No data	34.75	51.64	56.10	**68.98**

6.2.1 Sedimentation/Siltation Assessment

In order to assess for excess sedimentation, the SCI score and the percent fines in the stream reach are assessed independently for their support of the ALU. Reference sites are currently used to determine the amount of fines appropriate for each stream reach. When the macroinvertebrate community has an SCI score below 56.8 (ratings of fair, poor, or very poor), it can be concluded that there is stress on that community (**Table 9**). If a low score coincides with a percent fines that is 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 (**Table 11**). If only the SCI score is low, excess fine sediment is not indicated as a cause of impairment.

Table 11. Sedimentation Assessment for Jemez River Watershed, 2005.

Stations	SCI Rating	%Fines[+]	Reference Fines+28%*
Jemez R. near Canon, below Municipal school	Fair	13	19.2
Jemez R. above Rio Guadalupe	Poor	17	19.2
Rio Guadalupe above Jemez River	Good	15	Reference
Vallecitos Creek above Ponderosa Diversion	Fair	**22**	7.68
Jemez R. above Soda Dam	Fair	19	7.68
Vallecitos Creek above Paliza Campground	Poor	8	7.68
San Antonio above East Fork Jemez R.	Fair	16	7.68
East Fork Jemez R. above San Antonio Creek	Good	6	Reference
Rio de las Vacas above Rio Cebolla	Good	7	7.68
Rio Cebolla above Rio de las Vacas	Good	**23**	7.68
Rio Cebolla above Fenton Lake	Fair	**38**	7.68
San Antonio Creek above NM 126	Good	6	Reference
Calaveras Creek above Rio Cebolla at NM 126	Good	**41**	3.84
Rito Peñas Negras at NM 126	No Data	16	3.84
Rio Cebolla above Seven Springs Hatchery	Poor	**25**	3.84
Rito de Las Palomas at NM 126	Fair	**24**	3.84
Clear Creek at NM 126	Fair	17	3.84
Rio de Las Vacas above FR 70	Good	3	Reference

[+] A **bold** "% Fines" value indicates an exceedence of the 20% fines threshold value.
* All reference site values + 28% are less than the 20% fines threshold value thus 20% fines is used to assess for excess sedimentation.

6.3 Periphyton Community and Nutrient Assessment

The periphyton community is another biological indicator that can express system stress in ways that the macroinvertebrate or fish 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.

6.3.1 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, 2008). 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 the applicable criterion or threshold value to generate an exceedence ratio, or the number of exceedences divided by the total number of times the parameter was measured (**Table 12**). For total phosphorus, total nitrogen, and chlorophyll *a*, the threshold values are dependent on the ecoregion and designated aquatic life use.

Table 12. Nutrient Assessment Data from Jemez River Watershed, 2005. Shaded cells indicate an exceedence of the threshold value.

Assessment Unit Station ID	**Ecoregion**	**Designated Aquatic Life Use**	**DO & pH – long term datasets**	**DO %Sat. – grab** (# and % of exceedences)	**pH – grab** (# and % of exceedences)	**DO conc – grab** (# and % of exceedences)	**Total Nitrogen** (# and % of exceedences)	**Total Phosphorus** (# and % of exceedences)	**Chlorophyll *a* exceedence?**
Calaveras Creek (Rio Cebolla to headwaters) Calaveras Creek abv Rio Cebolla on NM 126	Southern Rockies	HQCWAL	support HQCWAL	0/11, 0%	0/11, 0%	0/11, 0%	5/6, 86%	0/11, 0%	No
Rio Cebolla (Fenton Lake to headwaters) Rio Cebolla ~0.5 mile above Fenton Lake	Southern Rockies	HQCWAL	support HQCWAL	2/33, 6%	0/33, 0%	0/33, 0%	15/20, 75%	7/20, 35%	No
Rio Cebolla (Rio de Las Vacas to Fenton Lake) Rio Cebolla above the Rio de las Vacas	Southern Rockies	HQCWAL	support HQCWAL	0/20, 0%	1/20, 5%	0/20, 0%	9/9, 100%	7/9, 78%	No
Clear Creek (Rio de Las Vacas to San Gregorio Lake) Clear Creek at NM 126	Southern Rockies	HQCWAL	support HQCWAL	0/13, 0%	0/13, 0%	0/13, 0%	5/8, 62%	2/8, 25%	No
East Fork Jemez (San Antonio Creek to VCNP bnd) East Fork Jemez above confluence with San Antonio Creek	Southern Rockies	HQCWAL	support HQCWAL	3/25, 12%	0/25, 0 %	0/25, 0%	13/14, 93%	6/14, 43%	No
Jemez River (Soda Dam nr Jemez Springs to East Fork) Jemez River abv Soda Dam	Southern Rockies	HQCWAL	**pH does NOT support HQCWAL	3/23, 13%	0/23, 0%	0/23, 0%	10/13, 77%	9/13, 69%	No
Jemez River (Jemez Pueblo bnd to Rio Guadalupe) Jemez River near Canon below municipal school	AZ/NM Plateau	CWAL	++support CWAL	5/21, 24%	0/21, 0%	0/21, 0%	9/14, 64%	10/14, 71%	No

Assessment Unit Station ID	**Ecoregion**	**Designated Aquatic Life Use**	**DO & pH – long term datasets**	**DO %Sat. – grab** (# and % of exceedences)	**pH – grab** (# and % of exceedences)	**DO conc – grab** (# and % of exceedences)	**Total Nitrogen** (# and % of exceedences)	**Total Phosphorus** (# and % of exceedences)	**Chlorophyll *a* exceedence?**
Jemez River (Rio Guadalupe to Soda Dam nr Jemez Springs) Jemez River abv Rio Guadalupe	Southern Rockies	CWAL	D.O. does NOT support CWAL	7/41, 17%	0/41, 0%	0/41, 0%	26/26, 100%	20/26, 77%	**Yes**
Rito de las Palomas (Rio de las Vacas to headwaters) Rito de las Palomas at NM Hwy 126	Southern Rockies	HQCWAL	N/A – sonde not deployed	2/13, 15%	0/13, 0%	0/13, 0%	6/7, 86%	1/7, 14%	No
Rio Guadalupe (Jemez River to confl with Rio Cebolla) Rio Guadalupe abv Jemez River	Southern Rockies	HQCWAL	support HQCWAL	1/27, 4%	0/27, 0%	0/27, 0%	13/14, 93%	13/14, 93%	No
Rito Peñas Negras (Rio de las Vacas to headwaters) Rito Penas Negras at NM 126	Southern Rockies	HQCWAL	support HQCWAL	5/12, 42%	0/12, 0%	0/12, 0%	6/7, 86%	5/7, 71%	**Yes**
San Antonio Creek (East Fork Jemez to VCNP bnd) San Antonio Creek abv Jemez River	Southern Rockies	HQCWAL	support HQCWAL	5/38, 13%	0/38, 0%	0/38, 0%	17/25, 68%	11/25, 44%	No
Rio de las Vacas (Clear Creek to headwaters) Rio de las Vacas abv FR 70	Southern Rockies	HQCWAL	support HQCWAL	1/14, 7%	0/14, 0%	0/14, 0%	7/10, 70%	1/10, 10%	No
Rio de las Vacas (Rio Cebolla to Clear Creek) Rio de las Vacas abv Rio Cebolla	Southern Rockies	HQCWAL	support HQCWAL	4/17, 24%	2/17, 12%	0/17, 0%	6/8, 75%	2/8, 25%	**Yes**
Vallecito Ck (Perennial Prt Div abv Ponderosa to headwaters) Vallecito Ck at Paliza CG Vallecito Ck abv diversion	Southern Rockies	CWAL	support CWAL	0/25, 0%	0/25, 0%	0/25, 0%	5/14, 36%	13/14, 93%	No

HQCWAL = High Quality Coldwater Aquatic Life
CWAL = Coldwater Aquatic Life
** = pH exceeds low pH criteria due to geothermal input so not counted as nutrient indicator
++ = DO probe failed; long-term pH dataset supports HQCWAL

6.4 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 bioassessment procedures. Once fish-based bioassessment procedures have been developed, fish community data will then be used as a basis for bioassessment.
- Development of biocriteria.
- To document and characterize a given water's fish community for comparison with future or past records.

The characteristics of fish species (**Table 13**) 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 14** provides the results of fish collection in the Jemez Watershed.

Table 13. Characteristics of Fish Species found in Jemez River Watershed, 2005.

Species	Common Name	Native	Temperature Tolerance	Spawning Habit/ Substrate	Reproductive Guild	Feeding Guild
Oncorhynchus clarki virginalis	Rio Grande cutthroat trout	Native	Cold	Gravel	Nonguarders, brood hiders	Insectivore Piscivore
Oncorhynchus mykiss	rainbow trout	Non-native	Cold	Redd in gravel	Nonguarders, brood hiders	Insectivore Piscivore
Salmo trutta	brown trout	Non-native	Cold	Sand and fine gravel	Nonguarders, brood hiders	Insectivore Piscivore
Rhinichthys cataractae	longnose dace	Native	Cool	Spawn in riffles over rocky and gravelly bottom	Nonguarders, open water/substratum egg scatterers	Insectivore
Catostomus (Pantosteus) plebeius	Rio Grande sucker	Native	Cool	Gravel	Nonguarders	Omnivore
Pimephales promelas	fathead minnow	Native	Warm	Underside of solid objects	Guarders, nesters	Omnivore

Table 14. Fish Community Data from the Jemez River Watershed, 2005.

Station			East Fork Jemez R. above San Antonio Creek	Jemez River above Soda Dam	Rio Cebolla above Rio de las Vacas	Rio Cebolla ~0.5 mile above Fenton Lake	Rio Cebolla above Seven Springs Hatchery	Rio de las Vacas above FR 70	San Antonio Creek above East Fork Jemez R.	San Antonio Creek above NM 126	Vallecitos Creek above Ponderosa diversion
Species	**Common Name**	**Temperature Tolerance**									
Oncorhynchus clarki virginalis	Rio Grande cutthroat trout	Cold						15			
Oncorhynchus mykiss	rainbow trout	Cold	24			3			3		
Salmo trutta	brown trout	Cold	29		12	79	110	82	17	44	5
Rhinichthys cataractae	longnose dace	Cool	32	21					13	39	
Catostomus (Pantosteus) plebeius	Rio Grande sucker	Cool	38	23	3				6	13	
Pimephales promelas	fathead minnow	Warm				1					
		Total No. of Ind.	123	44	15	83	110	97	39	96	5
		Total No. of Taxa	4	2	2	3	1	2	4	3	1
		% Native	57	100	20	1.20	0	15	49	54	0
		% Non-native	43	0	80	99	100	85	51	46	100
		% Cold water	43	0	80	99	100	100	51	46	100
		% Cool water	57	100	20	0	0	0	49	54	0
		% Warm water	0	0	0	1	0	0	0	0	0

7.0 DISCUSSION

Due to the large volume of data collected during this survey, it is not included with this report. To acquire specific data, contact the SWQB or search USEPA's STORET database. All of the monitoring that was conducted is summarized in **Table 3**. Those variables with numeric criteria that exceeded the State's Water Quality Standards are shown in **Table 4**. Narrative criteria assessments are detailed in **Tables 11 and 12**.

The most common water chemistry analyte causing findings of non-support was dissolved aluminum (chronic), with 12 assessment units across all three water quality segments not supporting their respective aquatic life uses. A previous survey conducted by the SWQB has determined that this aluminum is natural and related to the volcanic nature of the Valles Caldera (Appendix A). This finding is supported by data results showing higher aluminum concentrations during times of high flow and in areas with a prevalence of volcanic rock type. Three assessment units were found not to support their respective aquatic life uses because of exceedences of the acute aluminum criterion (750 µg/L). All three reaches are located in volcanic valleys and one (Sulphur Creek) exhibits very low pH.

After aluminum, the most common exceedences were caused by arsenic, boron and pH all of which appear to be related to natural geothermal waters (Trainer et al., 2000). The five hot springs sampled during the course of this survey cluster into two groups: those above Soda Spring (San Antonio Hot Spring and Spence Hot Spring), and those from Soda Hot Spring downstream (Soda, Giggling Springs, and the Municipal Spa). San Antonio Hot Spring and Spence Hot Spring exhibited relatively low concentrations of chemical constituents; often lower than their respective receiving waters. The remaining three, Soda Hot Spring, Giggling Springs, and the Municipal Spa, had higher concentrations of many constituents, with Soda Spring having by far the highest.

Arsenic concentrations indicated three findings of non-support in segment 20.6.4.108 [all three exceeded the domestic water supply use criterion (>2.3 µg/L) and one exceeded the human health criterion (>9.0 µg/L)] and three findings of non-support in segment 20.6.4.107 [three for human health criterion (>9.0 µg/L) and one for the irrigation use criterion (>100 µg /L)]. Given the lack of any other known source, and the finding that arsenic concentrations increased with decreasing surface flow, it appears that geothermal inputs from certain hot springs along these reaches, most notably Soda Spring, are responsible for the high levels of arsenic. Analysis of water from Soda Spring, the Municipal Spa, and Giggling Springs Spa, which yielded concentrations of 930 µg/L, 730 mg/L and 520 mg/L, respectively, for arsenic supports this interpretation.

Boron becomes elevated immediately below Soda Dam, with concentrations exceeding the irrigation use criterion (750 µg/L). Analysis of dissolved metals at Soda Spring, the Municipal Spa, and Giggling Springs Spa yielded values of 11,000 µg/L, 8,100 µg/L, and 7,000 mg/L, respectively, for boron, indicating that influent geothermal waters are likely the source of this contaminant.

Two AUs exhibited water quality impairments for the pH criterion. Of these, Sulphur Creek, which rises in acidic thermal springs, is naturally acidic throughout its length. The Jemez River

(Soda Dam near Jemez Springs to East Fork) intercepts acidic thermal waters in the vicinity of Soda Dam and is naturally acidic in that reach.

One AU, Jemez River (Rio Guadalupe to Soda Dam near Jemez Springs) violated the DO criterion. Examination of other data collected concurrently (Jemez Springs to Rio Guadalupe) indicates that the periods of low DO are associated with periods of precipitation. In this reach, runoff from NM 4, arroyos, and side canyons on the east side of the Cañon de San Diego is concentrated and channeled directly into the Jemez River, causing large inputs of warm, sediment laden water which can depress DO.

Stream bottom deposits were a common cause of non-support for the study area. A total of 6 sites survey were found to have fines greater than 20%. Of these four sites were also found to have stream condition index score (SCI), based on macroinvertebrate sampling, indicating fair or poor conditions (Table 11). SWQB staff observed evidence of road maintenance (or lack thereof) that appeared to contribute significant quantities of sediment to stream channels at bridges and arroyo crossings. Excessive sediment stresses aquatic communities and can contribute to stream bank destabilization. SWQB staff documented evidence of maintenance at the bridge over the Rito Peñas Negras. Spoils from grading operations have been pushed over the bridge abutments, eventually moving into the channel. The consequent increase in bedload impairs channel function, destabilizing the banks and adding even more sediment to the channel.

Figure 5. Road maintenance spoils in the Rito Peñas Negras

In addition to the immediate effects of sediment input to stream channels, the cumulative impacts can be far reaching. As sediment accumulates in channels, they become shallower and must increase their width to accommodate flow. This further increases sediment inputs, causes the channel to become wider and shallower (increased width/depth ratio), decreases sinuosity, and increases gradient, which then initiates down-cutting. Down-cutting advances downstream and upstream, eventually denying the stream access to its floodplain, lowering the water table below the root zone, and increasing the erosive power of high flows. The results of this cascade of events can be seen in many streams across New Mexico.

The total nitrogen and total phosphorus levels are generally higher in the Jemez River Watershed due in part to the volcanic nature of the Jemez Mountains. However, in general, the response variables did not exceed the threshold values, indicating that the nutrient levels were not present in concentrations that produced undesirable aquatic life or that resulted in the dominance of a nuisance species in these surface waters. In parts of the watershed where human activities have increased the rates of erosion and nutrient loading, such as the lower Jemez River, Rito Penas Negras, and lower Rio de las Vacas, nutrient levels were present in concentrations that produced undesirable aquatic life resulting in a impairment of four AUs for the narrative nutrient standard.

Fish collections yielded no previously undocumented species. The only species we expected to collect and did not was Rio Grande chub (*Gila pandora*). This species is historically common and well-documented in the Jemez basin and is considered by some to be in decline in all or parts of its range. The data collected in the Jemez watershed as well as elsewhere around the state will be used in the development of fish-based biocriteria or bioassessment procedures.

Figure 6. The Jemez River above Soda Dam

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APPENDIX A

GEOLOGY-BASED ANALYSIS OF ELEVATED ALUMINUM IN THE JEMEZ RIVER, NORTH-CENTRAL NEW MEXICO

The occurrence of elevated concentrations of total and dissolved aluminum in water quality samples from the majority of widely distributed sampling stations in the Jemez River watershed (NMED-SWQB, 1998) requires review in light of the element's exceedence of New Mexico State Standards. In general, increased metals in the water column can commonly be linked to sediment transport and accumulation, where the metals are a constituent part of the sediment. NMED's water sampling and sediment protocol does not identify a TSS exceedence or a sediment accumulation impact in the Jemez River, negating that relationship. High aluminum is especially characteristic of the spring snowmelt and runoff, and is not pronounced in other seasons' sampling runs which reflect baseflow, monsoon / flash flood regimes. In the absence of identifiable degraded uplands, poor streambank condition, or land use impact to explain the metals contribution, geochemical examination of the watershed area's bedrock and surface geology suggests a source of the increased aluminum values.

The Jemez volcanic field, including the Jemez and Pajarito Plateaus, is one of the most impressive and well studied volcano complexes on earth. It is composed of extremely thick accumulations of extrusive volcanic rocks, ranging in composition from tuffaceous ash to rhyolite, andesite, and basalts. Examination of the state's geologic map (1965) shows the Quaternary age Bandelier Tuff, dominantly composed of ashes, welded tuffs, and related rhyolite flows, are the most widespread units on the plateaus. To varying degrees the volcanic lithologies all share common constituent minerals from the feldspar/feldspathoid series of potassium-sodium-calcium aluminum silicates: $(K,Na,Ca)AlSi_{(2,3)}O_{(6,8)}$. For instance, the abundant rhyolite, a light-colored felsic lithology, is composed largely of quartz and alkaline feldspar (sanidine: $KAlSi_3O_8$). Rhyolite's average chemical composition is 71% SiO_2, and 14% aluminum oxide: Al_2O_3 (Travis, 1955). Andesite is an intermediate volcanic rock (52-66% SiO_2 and 17% Al_2O_3) with andesine as the feldspar mineral. Basalt is a mafic (sub-silicic, dominated by dark minerals) volcanic rock, composed of 16.8% Al_2O_3, derived from its plagioclase feldspar constituent ($CaAlSi_2O_8$). Geochemical studies of the full suite of Jemez volcanic rock types (Ellisor et.al.) indicate an average of 14.53% Al_2O_3, while more specific electron microprobe analysis of feldspar in the Bandelier Tuff was measured at an average of 23.6% Al_2O_3.

The above description serves to illustrate how abundantly available aluminum is in the bedrock stratigraphy of the Jemez River watershed. Mechanical and/or chemical processes must become active to free the metal and deliver it to streams where NMED's sampling program identifies it. Disintegration of the rocks and minerals, and delivery of detritus and metals in suspension or solution, is accomplished by: 1) weathering (in-place disintegration of bedrock and production of a regolith - loosely consolidated ground materials, including colluvium, alluvium or soils - via solution, freezing-thawing, pelting by rain, bioturbation, or vegetation and gravity effects); and 2) erosion (transportation and corrasion processes, chiefly accomplished by running water) (Gilbert, 1877). In the transport process, some materials, including soils (providing both dissolved and undissolved aluminum species) are quickly delivered overland into streams under slope runoff conditions, while a significant portion of the runoff may be absorbed into the earth. After underground circulation, that fraction reissues to charge the river, or is contributed by springs (chiefly introducing dissolved minerals). The overland delivery is credited as the larger and more frequent contributor of potential sediment, as well as total and dissolved minerals, although both of the processes are active in the Jemez watershed.

McDonald et. al. (1996) analyzed 175 soil profiles, distributed across the Pajarito Plateau, examining alluvial and colluvial settings. They reveal how aluminum and iron are the two most abundant metals in the Jemez soils (by full increased orders of magnitude). The aluminum is available for, and experiencing, redistribution or leaching from one soil horizon to the others. This study listed the element as highly bioavailable in its risk calculations. In addition, eolian dust is recognized as an important contributor to the soils of the Jemez region. In studies by Eberly et.al. (1996) aluminum is found to be enriched in all of the soil horizons examined in their study.

NMED's recent sampling results indicate the spring runoff period is the time when the largest aluminum standard exceedences occur. The Jemez climate plays a role here. Winter snow pack is, on the average, quite substantial. The slightly acidic condition of rain and snow accumulations act upon the disintegrating surface rocks, fragments, regolith and soils, providing the method and timing for peak transport of metals to occur during spring thaw. The "residence time factor", maximizing the frozen or melting snow's contact with the weathered fraction of the rock throughout the winter and early spring, develops into an effective spring pulse runoff, and is frequently observed to result in the highest concentrations of available metals from a given area. Other seasonal runoff events have more immediate instigation and completion, so the runoff, even if acidic, doesn't have as great an opportunity to take metals into solution and transport them to a receiving stream.

Since the watershed occupies a dormant volcanic field, there is a local abundance of active hot springs adding their contribution to the stream flow. The fractures and conduits the springs issue from may provide the opportunity for additional host rock alteration and mobilization of contained metals due to the action of slightly acidic, corrosive hot spring fluids. (The writer is unaware of any spring-specific water quality sampling to base further conclusions on.) Rocks with abundant feldspars, such as occur in the Jemez, are easily altered into secondary minerals and clays by the hot waters (example: formation of kaolinite, a hydrous aluminum silicate, $Al_2(Si_2O_5)(OH_4)$, from tuff and rhyolite parent materials). This alteration, combined with the springs' steady contribution to the streams, is another possible mode of introduction of excessive aluminum to the Jemez system.

In conclusion, it is recognized that the watershed draining the Jemez volcanic field has ample supply and opportunity to mobilize total and dissolved aluminum species. The active processes of local weathering and in-situ disintegration of the local rocks, eolian deposition and enrichment, winter/spring freeze-thaw runoff concentration, and diffuse delivery of aluminum to the network of local streams, are believed to be underway. Recognizing the metal contamination is apparently watershed wide, it is difficult-to-impossible to pinpoint a discrete source of contamination. The area-specific sampling results and the interpretation of causes presented here are limited to the Jemez watershed under consideration. These arguments are not intended to be applicable to every area of the state, absent of applicable geochemical and water quality studies, to explain the presence of metals, or to characterize New Mexico's large volcanic terrains in general.

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