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Water Resources Assessment of the Rito Peñas Negras

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Final Report

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Abstract

During the summer of 2011 students and faculty from the UNM Water Resources Program conducted an investigation of the Rito Peñas Negras in the Cuba District of the Santa Fe National Forest. The objective was to conduct an assessment of the stream and determine its characteristics, quality, and ability to meet its designated use of supporting high quality coldwater aquatic life. The Rito Peñas Negras is a small first order stream with a total length of 7.9 miles. It has one tributary, the Rito Café, which adds another 4 miles to its length. The watershed consists of 10,850 acres and ranges in elevation from approximately 8,500 ft to 9,000 ft. The lower reaches of the stream are the subject of a watershed restoration project by the WildEarth Guardians that consists of constructing animal exclosures and re-establishing riparian vegetation. The results of this study may serve as a baseline for future evaluation of the success of this restoration effort.

This project included a formal assessment of the stream at five locations along its length. These assessments included measurement of flow, water quality, stream geomorphology, and field identification of benthic macroinvertebrates. Additional measurements of flow and/or water quality were done at three other sites in watershed and three sites along the Rio de las Vacas. An intensive investigation of the stream was conducted during the second week of June, while a follow up study on August 15, 2011 was limited to flow measurements and collection of water quality samples at three locations.

Flow in the Rito Peñas Negras in June ranged from about 0.25 cfs in the upper reaches to 0.16 cfs in the lower reaches. Streamflow in August ranged from .52 to 1.04 cfs which was due to summer rains. Measurements of electrical conductivity and the stable isotopes deuterium and oxygen-18 suggest that the decrease in flow is the result of both evaporation and infiltration. During both sampling trips the stream was flowing well below bankfull conditions which was attributed to a dry winter, however, the lower reach showed evidence of a recent very high flow event due to a summer thunderstorm in August.

The water quality of the stream was found to be very high during the June study. Nutrient concentrations (nitrogen and phosphorous) were low and no measurable chlorophyll a was detected in the water, though small attached algal growth was noted on bottom sediments. Thermograph measurements over the preceding month exhibited a strong diurnal fluctuation superimposed on an increasing trend associated with on-set of summer. Field characterization of benthic macroinvertebrate populations also supported the conclusion of high quality water in the stream. Stream samples collected in August found moderate concentrations of nitrate which was attributed to cattle grazing that began about June 1.

The upper reaches of the watershed is steeper hence the stream was dominated by riffles and glide areas. The stream bed consisted mostly of sands and gravels and there was good canopy of riparian vegetation. Lower reaches were flatter and flow was primarily a mix of shallow pools and glide areas. Stream banks were generally stable with extensive undercut areas for fish refuge, however, there was virtually no woody riparian vegetation below FR 527. There was no sign of current beaver activity anywhere in the watershed.

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Preface

Water Resources 573, Field Problems, is one of three core class taught in the Water Resources Program at the University of New Mexico (http://www.unm.edu/~wrp). WR573 is taught each summer with the purpose of introducing students to methods used in water resources investigations. Included in the instruction are: the use of field equipment to measure hydrologic parameters, field and laboratory analysis of water samples to determine water quality characteristics, and methods of collecting and interpreting information on water resources management and policy in a particular watershed.

The class of 2011 studied the Rito Peñas Negras watershed in the Cuba Ranger District of the Santa Fe Forest in north central New Mexico. The class was taught by Dr. Bruce Thomson (Director, Water Resources Program) and Dr. Abdul-Mehdi Ali (Senior Research Scientist, Analytical Chemistry Laboratory Manager for the Department of Earth & Planetary Sciences). Questions regarding this report should be directed to Dr. Thomson (bthomson@unm.edu).

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This study would not have been possible without the assistance of Erica Nevins and Derrick Padilla with the Santa Fe National Forest. The project was suggested by Abraham Franklin with the Surface Water Quality Bureau of the NM. Nina Wells and Heidi Henderson, also with the Surface Water Quality Bureau provided insight, review and technical comment. Jim Matison with the WildEarth Guardians provided information on his organization's watershed restoration project.

Introduction

The Rito Peñas Negras is a small first order stream located in the Jemez Mountains of central NM, approximately 15 miles east of the Village of Cuba, NM (Figure 1). The Rito Peñas Negras is 7.9 miles long. It has one tributary, the Rito Café, which adds another 4 miles to the total length of the watershed. The Rito Peñas Negras is a minor tributary to the Rio de las Vacas which in turn flows into the Jemez River. The headwaters consist of a series of seepage springs at an elevation of approximately 9,000 ft. The elevation of the stream at its confluence with the Rio de las Vacas is at an elevation of just under 8,000 ft. The watershed consists of 10,850 acres and located within Sandoval and Rio Arriba Counties in the Santa Fe National Forest.

Previous studies of the Rito Peñas Negras by the New Mexico Environment Department and the U.S. Forest Service determined that the watershed was impaired and does not support its designated use as a high quality coldwater aquatic life. The probable causes of impairment listed by the New Mexico Environment Department (NMED, 2011) include high concentrations of nutrients, silt accumulation in bottom sediments, excessive temperatures, and elevated turbidity. The designated uses include: domestic water supply, fish culture, high quality coldwater aquatic life, irrigation, livestock watering, secondary contact, and wildlife habitat. Figure 2 shows the Rito Peñas Negras watershed.

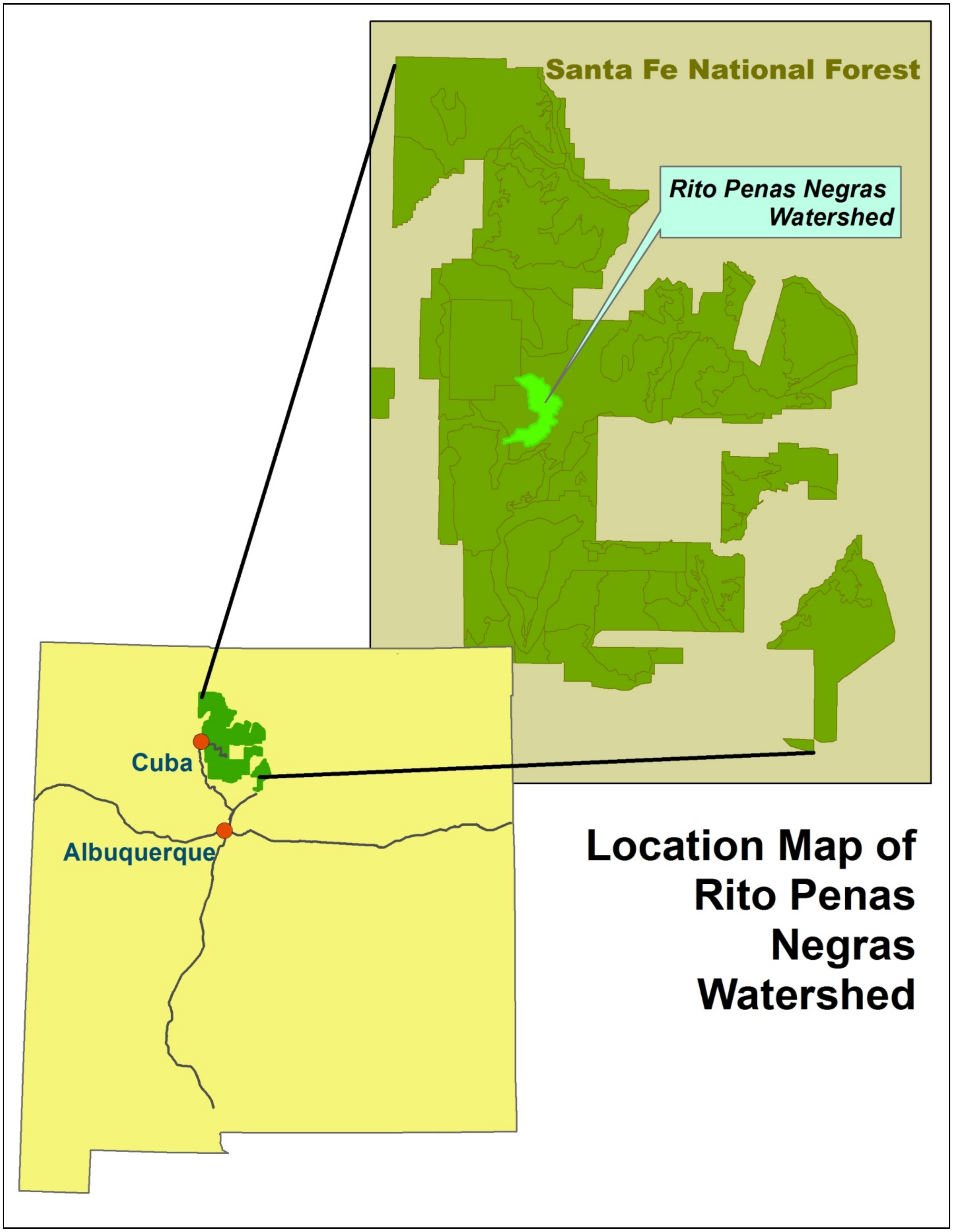

Figure 1. Location map of the Rito Peñas Negras watershed.

One of the objectives of this study was to evaluate the Rito Penas Negas to determine if the quality and quantity of the river is capable of sustaining a population of Rio Grande Cutthroat Trout (Oncorhynchus clarkia virginalis). The trout is a smaller species from the salmonidae famliy with an average adult size of 10 inches. The Trout has been extirpated from the Rito Penas Negas primarily due to deforestation, introduction of non-native species and over grazing. A 12 step observational study was preformed on the Rito Penas Negas constructed by Dr. Fleming to determine if the river was at an acceptable level to sustain a healthy cold water ecosystem. The primary habitat requirements were monitored including , temperature, pH, electrical conductivity, Dissolved Oxygen concentrations, stream morphology, and water quality characteristics.

The lower reaches of the Rito Peñas Negras watershed is presently the subject of, a watershed restoration program conducted by the WildEarth Guardians. The objective of the restoration efforts include: restoring riparian habitats and ecosystems, promoting watershed education, and monitoring restoration processes. The project area encompasses constructing riparian exclosure areas of approximately 50 acres over 1.8 miles of stream in a large meadow located approximately 1 mile upstream from the stream's confluence with the Rio de las Vacas.

The objective of the study described in this report was to conduct a comprehensive assessment of the Rito Peñas Negas watershed in order to establish baseline conditions for future assessments of watershed restoration activities. The results of this report are thus intended to serve in part as a quantitative and qualitative measure of baseline conditions of the watershed as existed in June, 2011.

Field work was conducted by graduate students and faculty of the University of New Mexico's Water Resources and Civil Engineering programs during the second week of June, 2011. The assessment serves as an opportunity for students to gain skills in field work, sampling, and laboratory methods that are commonly used in evaluating the health of a watershed.

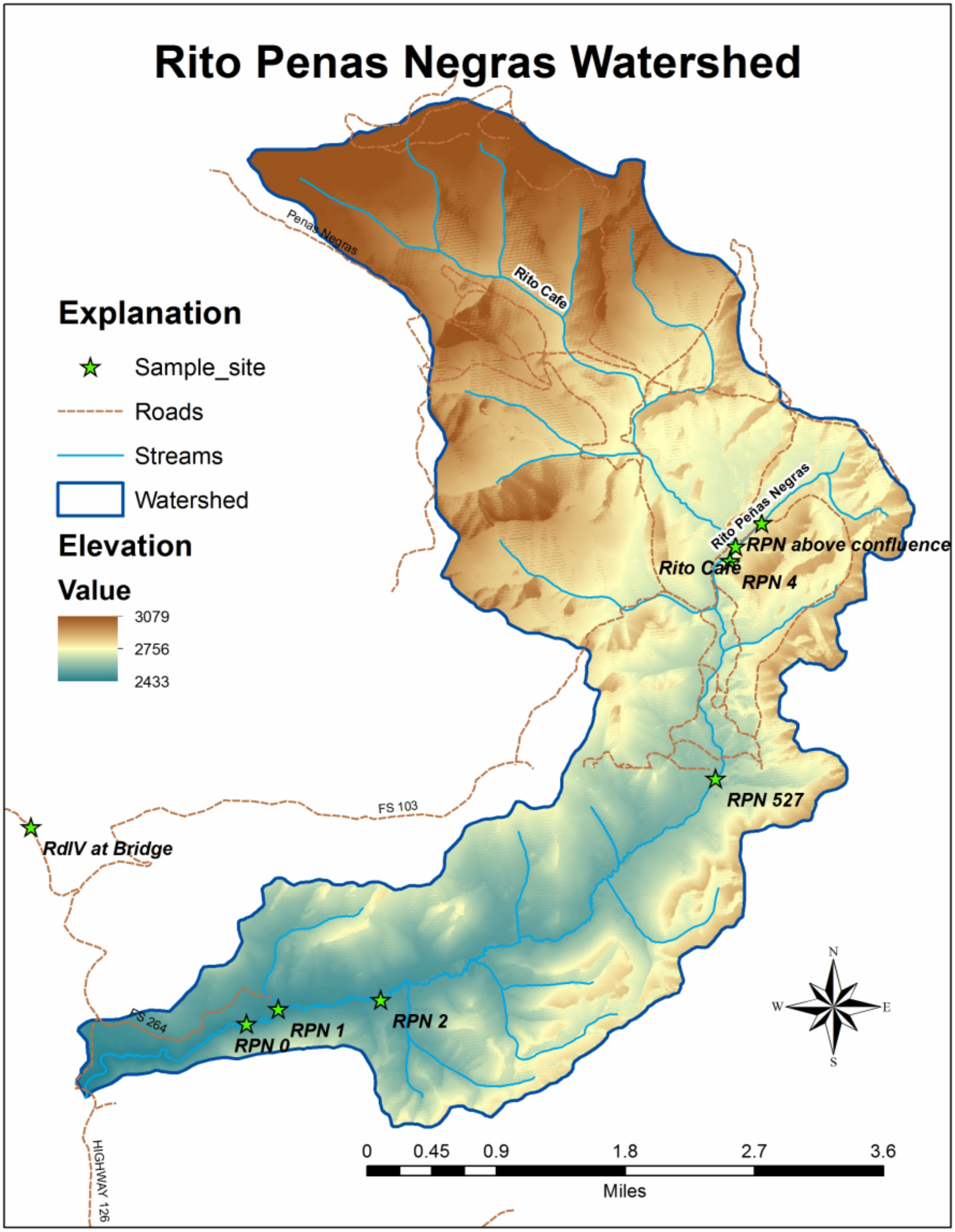

Figure 2. Map of the Rito Peñas Negras watershed showing assessment and sample sites (Rito Café, Pond, & springs).

Background

The investigation focused on the Rito Peñas Negras watershed on the eastern flank of the Jemez Mountains in north central New Mexico (Figure 1). The 10,850 acre basin is located near the headwaters of the Rio de las Vacas, a tributary to the Rio Guadalupe which in turn is a tributary to the Jemez River and ultimately the Rio Grande. Its hydraulic unit code (HUC) is 13020202. Ninety four percent of the watershed is under federal ownership, with a few small parcels of private property located within the study area. The Cuba Ranger District of the Santa Fe National Forest manages federal landholdings within the watershed.

The high altitude of the stream results in an alpine climate. Historic climate data is available for the nearby Wolf Canyon weather station (latitude 35•56'52", longitude 106°44'49"(NM 29982, Western Regional Climate Center). Average yearly temperatures at this site were 56.7 °F, with January maximum temperatures averaging 38.1 °F and maximum July temperatures averaging 76.7 °F. Average minimum temperatures range from 7.9°F in January to 42.4 ° F in July. Average yearly precipitation at this site is 22.7 inches, with summer monsoons providing the peak monthly (in August) precipitation average of 3.6 inches. Total average snowfall for this site is 120.6 inches, with the majority of the snowfall occurring from December through March. Monthly variations in temperature and precipitation are shown in Figure 3.

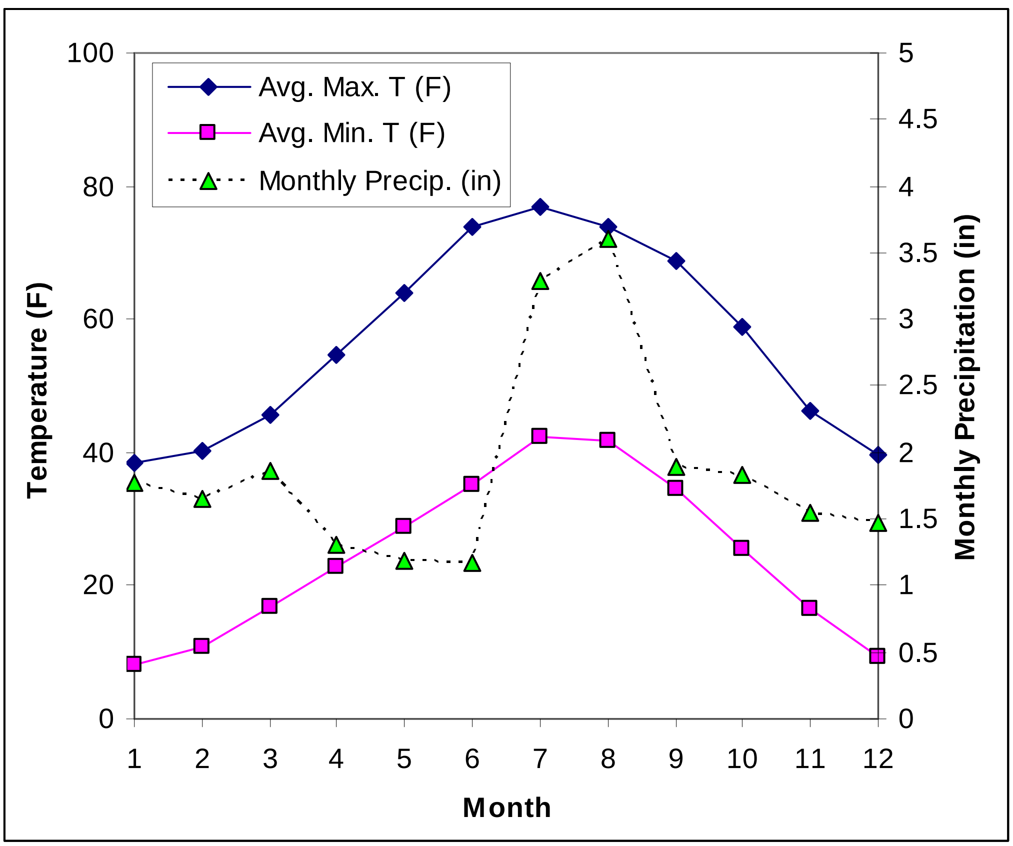

Figure 3. Average monthly temperatures and precipitation at Wolf Canyon (source: Western Regional Climate Center).

The Rito Peñas Negras and the Rio de las Vacas originate in Precambrian metamorphic and Permian sedimentary rocks. More specifically, the bedrock geology of the Peñas Negras are: Quaternary Bandelier Tuff, conglomeritic Tertiary Santa Fe, Permian Abo and Culter Formations, and fossiliferous Pennsylvanian Madera limestone. Surficial deposits in the Peñas Negras compose of colluvium material from weathering and erosion processes of associated bedrock, and contribute a fair amount of sedimentation in the watershed (Gore, 2006).

The watershed has been subject to various land uses including: timber harvesting, grazing, recreation, and copper mining. Human presence in the watershed has been limited, with the majority of impacts occurring from timber harvesting, historic farming, and ongoing grazing activities. The defunct Jarossa copper mine in the upper watershed is the only recorded mining presence in the watershed. It is estimated that 30% of the watershed was harvested for timber in the 1920's through the 1940's in part to provide lumber for a railroad along the Rio de las Vacas to transport timber to a sawmill in Gillman (Padilla, 2011).

Current land uses include recreation and grazing. The entire watershed is grazed with four grazing allotments managed by the Forest Service, and additional grazing on private lands. Overgrazing has damaged riparian areas which has resulted in the loss of riparian vegetation, increased erosion and consequential increases in water temperature and sediment impacts on the stream. The Forest Service reports that over 50% of the stream's banks are unstable due to overgrazing and destruction of the stream's banks by cattle (USFS, 2007). This contributes to elevated suspended solids loads in the stream, destruction of pools and undercut banks which provide fish habitat, and reduces shade which increases stream temperatures.

Eight recreation areas are located in the basin, with three used intensely. In order to discourage vehicular travel outside of designated roads, the Forest Service created the buck-n-pole fence program. The current road density of the study area exceeds Forest Service guidelines of 1.0 to 2.5 miles of road per square mile of watershed. ATV use has been curtailed to reduce erosion and promote riparian recovery (USFS, 2007).

A lack of Large Woody Debris (LWD) has been attributed to fuel wood harvesting, lack of available wood for recruitment, as well as past land management policies that led to removal of LWD in the Rio de las Vacas and perhaps in the Rito Peñas Negras as well (USFS, 2007).

The designated uses of the Rito Peñas Negras include: domestic water supply, fish culture, high quality coldwater aquatic life, irrigation, livestock watering, secondary contact, wildlife habitat, and to support high quality coldwater aquatic life (20.6.4.108 NMAC). All of the designated uses of the Rito Peñas Negras are fully supported except the high quality coldwater aquatic life (NMED, 2019). Probable sources of impairment include: high/road/bridge runoff, loss of riparian habitat, rangeland grazing, stream bank modifications/destabilization and unknown sources (NMED, 2010). Total Maximum Daily Loads (TMDLs) to address the causes of impairment have been developed for the probable causes of impairment as shown in Table 1.

Table 1. Probable causes of impairment and schedule for issuance of Total Maximum Daily Loads (TMDLs) (NMED, 2010).

Probable Causes of Impairment	TMDL Schedule
Temperature, water	2003
Sedimentation/siltation	2003
Nutriend/Eutrophication Biological Indicators	2009
Turbidity	2015

Historically, the Rito Peñas Negras provided habitat to the Rio Grande Cutthroat Trout (RGCT). Jemez mountain streams are considered a primary habitat for RGCT. In 1999 the US Fish & Wildlife Service identified the trout as a Sensitive Species and in May 2009 it was concluded the species was "warranted" for listing, but was precluded in favor of higher priority listings (USFS, 2007). Although the river does not currently support populations of RGCT the goal of restoration activities is to rehabilitate the stream so that it can support this species and prepare the stream for its future introduction.

The 1987 amendments to the Clean Water Act (CWA) established the Section 319 Nonpoint Source Management Program to provide federal leadership in the mitigation of nonpoint pollutants. WildEarth guardians were awarded a Section 319 grant by the Environmental Protection Agency (EPA), with additional funding from the New Mexico Environment Department's (NMED) River Ecosystem Restoration Initiative (RERI). Restoring ecosystem function includes the construction of enclosures to limit access to riparian areas by cattle and other grazing animals. Concurrent to limiting access to the stream, a variety of native riparian species are being planted along the riparian corridor to address high water temperatures. Restoring ecosystem function includes promoting beaver activity. Ultimately, WildEarth Guardians seeks to improve the habitat of Rito Peñas Negras to provide an adequate habitat for the RGCT. Riparian restoration methods established by WildEarth Guardians comprise the planting of numerous native riparian species totaling 20,000 willows, 600 forage species, and 2,000 cottonwood, aspen, and alders in fenced areas. Native species include Coyote Willow Western (*Salix exigua*), Narrow-Leaf Cottonwood (*Populus* angustifolia), Quaking Aspen (*Populus tremuloides*), Red-Osier Dogwood (*Cornus sericea*), Wax Currant (*Ribes cereum*), and American Plum (*Prunus armeniaca*) (Matison, 2011). Species are planted in relation to the stream bank, with willows closer to the channel, and cottonwoods and Aspens occupying secondary terraces. Woody riparian vegetation will provide forage, habitat, and encourage bank stabilization.

A desirable goal of the restoration activities is to create an environment that will support beaver activity (Matison, 2011). Beaver ponds trap sediment and promote channel aggradation, as well as provide fish habitat.

In the fall of 2005 a Santa Fe National Forest fisheries crew conducted a stream survey of the Rito Peñas Negras (USFS, 2007). The crew surveyed a total of 11.9 miles from the mouth of the stream to its head waters. The stream was divided into five reaches as shown in Figure 4 The objective of this survey was to collect historical information about the stream and watershed, to

determine the quality of habitat, determine fish species and determine if the Rito Peñas Negras is capable of sustaining a population of Rio Grande cutthroat trout. The fisheries crew found that the Rito Peñas Negras has been heavily over grazed. Riparian grazing should be eliminated or extremely reduced on the Rito Peñas Negras. Cattle trample and forage along the stream banks leaving little riparian vegetation, thus elevating stream temperature, creating sediment filled ponds and limiting fish habitat. The crew recommended limiting cattle grazing on the Rito Peñas Negras by practicing seasonal use, rest rotations, and riparian exclosure fencing.

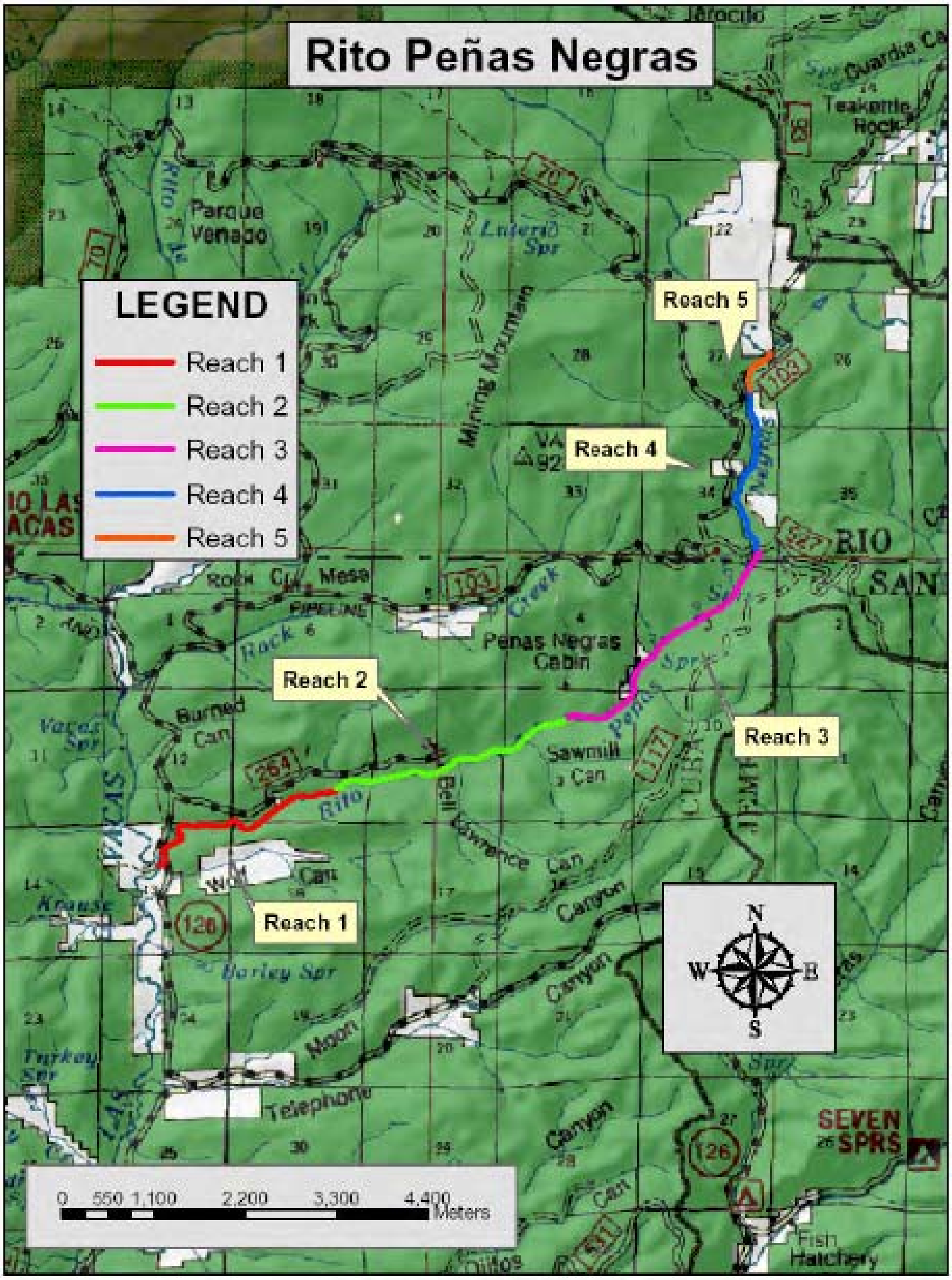

Figure 4. Map of the Rito Peñas Negras showing the five reaches identified by the Forest Service (USFS, 2007).

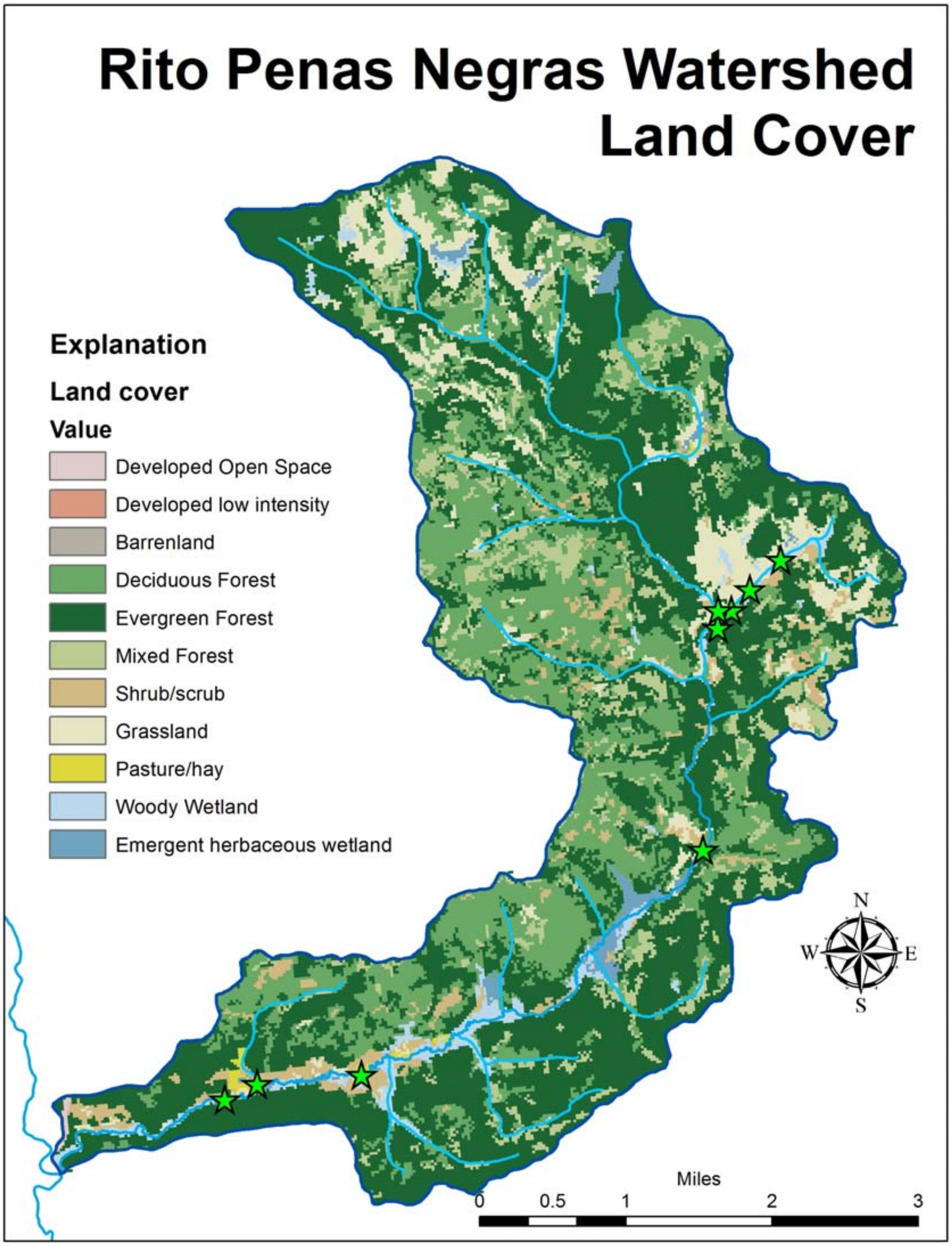

Figure 5. Land cover of the Rito Peñas Negras watershed. Stars identify flow measurement & water quality sampling sites.

Methods

The emphasis of the study described in this report was an assessment of the Rito Peñas Negras watershed based on its hydrologic, geomorphologic, biologic, and water quality characteristics. This section describes the methods that were used to collect and analyze data in the Rito Peñas Negras watershed.

Sampling methods were based on those described in the Environmental Protection Agency (EPA) Field Operations Manual for Wadeable Streams (EPA, 2003) and the Standard Operating Procedures developed by the Surface Water Quality Bureau of the New Mexico Environment Department (NMED, 2011).. These documents provide protocols for selecting assessment sites, measuring field parameters and collecting samples for laboratory analyses. All river sample sites were classified as wadeable meaning "the stream can be sampled with wadeable stream protocols, continuous water flow and greater than 50% of the sample reach is wadeable" (EPA, 2003). The assessment protocol published by EPA for a full evaluation recommends selecting a baseline river transect and five upstream and downstream transect locations for a total of 11 transect evaluations. However, due in part to the very small size of the stream only five transects were evaluated at each of five sites on the Rito Peñas Negras .

GPS, weather conditions, and photographs were taken at each site in order to provide a description and the relevant conditions at each site. Measurements and site descriptions were recorded on either NMED SWQB data sheets or in field notebooks. The assessment procedures used in this study are summarized below.

The watershed was subjected to intensive investigation during the second week of June 2011 which included full assessments at five locations along the Rito Peñas Negras as well as water quality sampling and flow measurements of the Rito Café, Rio de las Vacas, and Trail Creek, a tributary to the Rio de las Vacas. The watershed was revisited again on August 15, 2011 and water quality samples were collected and flow measurements were taken at each of the assessment sites. The principal purpose of the second visit was to determine the impacts of summer grazing on water quality.

Site Selection

For this study the Rito Peñas Negras was divided into five different reaches generally corresponding to the reaches described in a previous study by the U.S. Forest Service (USFS, 2007). Desirable characteristics for each assessment sites were based on criteria described by the EPA (2003):

- Segment of the river up and downstream is generally straight
- Depths mostly greater than 15 centimeters and velocities mostly less than 0.15 meters per second
- Flow is generally uniform with no obstructions, eddies, backwater or excessive turbulence

- A cross-section of the river bottom is U-shaped with a uniform streambed free of large debris (according to EMAP protocol, large rocks and debris may be removed *before* measurements.)

The sites selected for this study are identified in Table 2 and Figure 2. Five sites were selected along the stream at which a full assessment was conducted. These were selected to generally correspond to the five reaches identified by the Forest Service in their preliminary assessment of the stream (USFS, 2007). Three sites, RPN0, RPN1 and RPN2, were specifically selected to serve as a baseline to measure the effects of the watershed restoration activities of the WildEarth Guardians. RPN0 was downstream of the lowest exclosure, RPN1 was located near the downstream end of a large meadow between exclosures three and four, and RPN2 was located approximately 500 m upstream from the first exclosure.

Wide meadows predominate assessment sites RPN0, RPN1 and RPN2, and these sites appear to be characterized by significant stream degradation in which the stream is currently located one to two m below the meadow. The stream gradient is approximately 0.8% based on elevations from USGS topographic maps. The stream channel is incised and shallow throughout this section, with some incisions exceeding two m. With the exception of recently planted trees in the exclosures near RPN 1, no woody riparian vegetation was noted. Unlike the presence of abandoned beaver dams in the 2005 assessment, our assessment did not find any evidence of past beaver activity in RPN 0 or RPN1. Both assessment sites are characterized by a lack of woody riparian vegetation and the presence of cow paths to the stream suggests impacts on stream banks of grazing activities.

RPN 3 was located approximately 500 feet downstream of FR 527. Stream gradient in this section increases to 1.2% (USFS, 2007). The 2005 assessment noted the presence of thick clumps of Alder along the stream as well as several abandoned beaver ponds. One notable feature was that many of the Alder trees near the stream in this section were dead. Most of the beaver dams, however, were intact, though none showed evidence of any recent beaver activity whatsoever.

RPN4 is located just below the confluence of the Rito Peñas Negras and Rio Café. Whereas RPN0 through RPN3 are characterized by wide meadows, site RPN 4 is located within a narrow valley with significant woody riparian vegetation consisting of alders and willows.

Water quality measurements and samples and flow measurements were taken from the Rito Café, the only tributary to the Rito Peñas Negras, and water quality samples were collected from seep springs and a small pond at the headwaters of the Rito Peñas Negras.

Finally, water quality samples and flow measurements were taken from the Rio de las Vacas at the NM 126 bridge near the Rio de las Vacas campground and from a site approximately 1 km upstream from the entrance to the Girl Scout camp. A water quality sample and flow measurement was also taken from Trail Creek at its confluence with the Rio de las Vacas near the intersection of Forest Roads 152 and 20.

Table 2. Identification of sites sampled in this study.

Site ID	Description	Dist. from Confluence of Rito Peñas Negras (mi)	Type of Measurement
RPN0	Rito Peñas Negras below 1st exclosure	1.44	Full assessment
RPN1	RPN between 3rd & 4th exclosures	1.75	Full assessment, Flow & quality samples on 8/15/11
RPN2	RPN, ~.5 km above last exclosure	2.42	Full assessment
RPN3	RPN downstream from FR 527 culvert	5.53	Full assessment, Flow & quality samples on 8/15/11
RPN4	RPN below confluence with Rito Café	7.11	Full assessment, Flow & quality samples on 8/15/11
RPN Pond	Pond near headwaters of RPN	7.67	Water quality
RPN Spring	Springs at headwaters of Rito Peñas Negras	7.40	Water Quality
Rito Café	Rito Café above confluence with RPN	7.24	Flow & water quality
RPN abv Rito Café	RPN above confluence with Rito Café	7.30	Flow
RdlV @ Bridge	Rio de las Vacas at NM126 bridge by RdlV campground	2.59	Flow & water quality
RdlV @ GS	Rio de las Vacas ~1 km upstream from Girl Scout camp	-	Flow & water quality
Trail Creek	Trail Creek at confluence with Rio de las Vacas	-	Flow & water quality

Hydrology and Geomorphology

Flow and basic geomorphic characteristics were measured at five transects located 100 ft apart along the stream thalweg at each of the five assessment sites. Bankfull height at each transect was noted and the current water level depth below bankfull height was recorded as a semi-quantitative indication of the general flow conditions of the stream (EPA, 2003).

River discharge was measured using the velocity area procedure in which stream velocity and depth are measured at locations across the width of the stream, the flow is calculated as the produce of velocity times area for each increment, and then summed to give the total flow (EPA, 2003). Velocity was measured using a Marsh-McBirney Flo-Mate electromagnetic flow meter, while depth was measured using a surveyor's rod. The data was entered into a spreadsheet which calculated the volumetric flow for each increment of cross section and summed them to determine total flow. The Rito Peñas Negras is so small that at most sample sites velocities were only measured at each bank and at distances of 25%, 50% and 75% across the stream.

At each assessment site the thalweg depth was measured at 10 foot intervals for a distance of 200 ft upstream and downstream of the assessment site. The thalweg profile was measured using a surveyor's rod to locate the deepest path of the channel.

The stream geomorphology at each of the five transects was noted. Bank angle and undercut distances were determined at the left and right bank. Bank angles were recorded with respect to horizontal so that undercut banks had angles greater than 90 degrees. Stream bottom deposits or substrate size was estimated based on visual characteristics. At assessment sites along the RPN ach transect was analyzed at five points including left and right banks, and at distances of 25%, 50%, and 75% across the stream. This serves as an indicator of habitat for fish and macrointervertebrates and can provide information about erosion or other anthropogenic influences. Estimates of the average percentage of embeddedness of rocks were also recorded to estimate the impact that fine sediment deposition had on stream bottom materials at each transect.

Riparian Vegetation Cover and Human Influence

The presence of riparian vegetation was noted at each assessment site. These observations were qualitative and intended to ascertain evidence of human impacts (bridges, dams, culverts, irrigation diversion structures), presence of riparian vegetation (native and introduced), and impacts of land use (grazing, road construction, logging) at each study site. Historically, beaver have constructed dams in the stream so evidence of current and historic beaver activity was specifically noted. Photographs were taken at each site. Several students also hiked the full length of the Rito Peñas Negras and described human and animal activity and notable structures/woody debris in the watershed..

Benthic Macroinvertebrates

Benthic macroinvertebrates are widely used to indicate the quality of a water body because they live in the environment year round and thus provide an integrated assessment of aquatic

conditions. It is achieved by identifying the organisms present, quantifying the species diversity, and correlating the species present and their diversity to their sensitivity to water quality.

Benthic macroinvertabrates were identified using a taxonomic key published by the Hoosier River Watch, sponsored by the Indiana Department of Resources Division of Fish and Wildlife (IDNR, 2011). The Pollution Tolerant Index (PTI) characterizes macroinvertebrates into four groups, each group is given a Pollution Tolerant Index Rating (PTIR) based on the groups number of different taxa. Group 1 being the least tolerable and Group 4 being the most tolerable to pollution. The PTI is a quick semi-quantitative way to rate the health of the stream. PTIR values indicate the number macroinvertabrate species which are intolerant of pollution with a score of 23 or more is Excellent, 17 to 22 is Good, 11 to 16 is Fair, 10 or less is Poor.

A kick net was used to collect benthic macroinvertebrates at the five assessment sites along the RPN and are marked on the map on Figure 2. The kick net was placed in a stream riffle and the stream bottom materials were vigorously agitated for a distance of approximately one meter upstream from the net. The net was then washed into a sample tray and the captured organisms identified according to taxa and counted. The net was manufactured according to specifications listed in the Rapid Bioassessment Protocol (RBP). A key published by the Hoosier Riverwatch (IDNR, 2011) was used to identify the organisms.

Water Chemistry

Water samples were analyzed for pH, electrical conductivity (EC), temperature, dissolved oxygen (DO), turbidity, metals and anions by the field and laboratory methods identified in

Table 3.

Table 3. Summary of field and laboratory methods used to measure water quality.

Constituents	Analytical Method	ASTM Methods No.
Field Measurements		
pH	Glass electrode	ASTM 2310
Electrical conductivity	EC meter	ASTM 2510
Dissolved Oxygen	Membrane DO meter	ASTM 4500-O
Alkalinity	Alkalimetric titration	ASTM 2320
Laboratory Measurements		
Metals	ICP-OES	USEPA 200.7
Anions	Ion Chromatography	ASTM 4110
NH_4^+		U of AZ SOP No. 21
Chlorophyll A	Spectrophotometric	Sartory et al. 1984
Stable Isotope Ratios	WS-CRD	Gupta et al. 2009

Water samples were collected in acid-washed bottles flushed with 18MΩ water. The samples were filtered with ashless Whatman #41 qualitative filter paper for the anion samples, and filtered and acidified with HNO_3 (pH less than 2) for the metals analyses. Samples for non-metals analysis were filtered and refrigerated; no preservative was added. All samples were refrigerated at 4ºC until analyzed. Alkalinity was measured by acid titration method using standardized H_2SO_4 (normality of 0.02). pH, temperature and EC were measured with a Oakton

multi-probe meter that was calibrated daily with buffer solutions of pH 7 and 10 and conductivity standard solution respectively. Dissolved oxygen (DO) was measured with an Oakton DO meter that was calibrated by an air calibration technique that was adjusted for the elevation at each site.

All samples were kept on ice. Upon returning to UNM, samples were filtered through 0.45 μm membrane filters to remove suspended material prior to laboratory analysis for metals and non-metals. All laboratory analyses were conducted in the geochemistry laboratory of the Department of Earth and Planetary Sciences at the University of New Mexico.

Chlorophyll a

Chlorophyll a is the common chlorophyll found in planktonic algae and can be used to determine an estimate of total algal biomass (Standard Methods, 2005). The samples were cooled and placed in aluminum foil after being collected to ensure the chlorophyll amount accuracy. The samples were prepared using the method as described in Sartory et al. 1984. This method uses centrifugation to concentrate suspended solids, which is then followed by heated ethanol extraction to determine chlorophyll a. Absorbance was measured using a Hitachi U-2000 Spectrophotometer.

Stable Isotope Analyses

The isotope ratio of oxygen 18 to oxygen 16, both stable isotopes, in water molecules can identify evaporation in natural waters. When water evaporates it tends to remove the lighter water molecules containing oxygen 16. Therefore as the water travels from its headwaters to its confluence it should become more concentrated with water molecules containing oxygen 18 isotopes. A Picarro Wavelength Scanned Cavity Ring-Down Spectrometer was used to detect the amounts of both oxygen 16 and oxygen 18. There is little sample preparation for the spectrometer instrument other than allowing samples to settle. This facilitates rapid isotopic analysis.

Results

As described previously, complete assessments of the Rito Peñas Negras were conducted at five locations identified as RPN0 through RPN4. Additional measurements of flow and water quality were taken at sites summarize in Table 2 and shown on Figure 4. Photographs of each of the assessment sites and the sampling site on the Rito Café are presented in Figure 7 through Figure 12. This section describes the results obtained in this study.

Hydrology

A total of 9 flow measurements were collected; 6 in the Rito Peñas Negras watershed including the Rito Café, 2 flow measurements of the Rio de las Vacas, and measurement of the flows of Trail Creek, a small tributary to the Rio de las Vacas (Table 2). Field instruments were employed to measure pH, electrical conductivity (EC), dissolved oxygen (DO), water temperature, flow velocity, stream depth and width. Figure 2 shows the location of the sampling points in the Rito Peñas Negras watershed. A GPS receiver was used to measure latitude and longitude of each sample site.

Flow measurements were collected at the specific reaches along the Rito Peñas Negras, above the confluence with Rito Café; near the Forest Road 527 culvert; the second reach encompassing open meadows and livestock exclosures; and the first reach containing the mouth of the stream and fence exclosures. Flow measurements were also collected of the Rito Café, two locations on the Rio de las Vacas and of Trail Creek, a minor tributary to the Rio de las Vacas.

Streamflow Measurements

Table 4 lists the flows at sites within the RPN watershed and along the RdlV measured during this study. Flow in the upper reach, above the confluence with Rito Café, was measured on June 9, 2011 and measured 0.003 cfs (cubic feet per second). Flow originated from a series of seepage springs and was minimal at this location. Flow was higher below the beaver pond at 0.157 cfs. Flow downstream, in the third reach, below Forest Road 527 was 0.260 cfs. Flow measurements downstream in the second reach, in an open meadow area was 0.152 cfs. Flow collected in first reach at the mouth of the river was 0.126 cfs. Additional flow measurements were collected on the Rio Café at 0.320 cfs and the Rio de las Vacas ranging from 8.85 to 12.31 cfs. Flow was also measured as 0.04 at Trail Creek near the girl scout camp.

The variation of flow along the Rito Peñas Negras and Rito Café with respect to distance from the confluence with the Rio de las Vacas is shown graphically in Figure 6. The data show that the stream loses water as it flows from its confluence with the Rito Café to its confluence with the Rio de las Vacas. The largest flow was measured at RPN3 in the third reach below the Forest Road 527 culvert crossing.

The decreasing flow along the length of the RPN is indicative of a losing stream. The stream loss along its length is believed to be due to evaporation and infiltration to ground water. Losses to evaporation could be correlated with measurements of electrical conductivity in the stream and are discussed later.

Water surface elevations throughout the length of the stream were in the range of nine to 15 inches below bankfull height. This study was conducted in early June, hence flow should be near its peak values as a result of spring runoff. The fact that the water was substantially below bankfull depth is consistent with drought conditions and low winter snow pack. The Rio de las Vacas was also well below its bankfull depth at the two measurement and sampling sites visited during this study.

The difficulties associated with accurately measuring flows in very small streams are illustrated by the discrepancy between the measured flow in the Rito Café and that at RPN4. These two sites were less than 100 m apart and the flows should be identical. However, the flows reported at RPN4 are an average of three measurements whereas the flow in the Rito Café is a single measurement. In small streams the principal sources of error are irregularities in the depth measurements and measurement of water velocities. Maximum depths in the Rito Peñas Negras and the Rito Café were less than 0.5 ft at nearly all transects. Thus, if the channel bottom consisted of coarse gravel or small cobbles of .08 ft (1 in) diameter as occurred in the upper reaches of the watershed accurate measurement of depth was difficult. The second challenge is that the sensor on the FloMate flow meter has a diameter of about .13 ft (1.5 in) which, when inserted in a small stream alters the flow patterns thus changing the velocity. Five flow measurements were taken at each of the assessment sites (RPN0 through RPN4) and the relative standard deviation at each site average 25%. Thus, the flow in the Rito Café was the same as in the Rito Peñas Negras at the RPN4 site. More importantly, all of the flows in the Rito Peñas Negras were very small, especially in comparison to the flows in the Rio de las Vacas.

Table 4. Flow measurements at assessment and sampling locations during this study.

		Flows (cfs)	
Site ID	**Location**	**Jun-11**	**Aug-11**
RPN 0	Below 1st exclosure	0.126	
RPN 1	Between exclosure 3 & 4		0.630
RPN 2	Above last exclosure	0.152	
RPN 3	At FR 527 culvert	0.260	0.520
RPN 4	Below pond	0.250	1.040
RPN Abv Confluence	RPN abv confl. With Rito Café	0.003	
Rito Café	Trib to RPN above RPN 4	0.320	
RdlV @ Bridge	Rio de las Vacas at 126 bridge	8.85	
RdlV @ GS Camp	Upstream from GS camp	12.31	
Trail Creek	At confluence with RdlV	0.04	

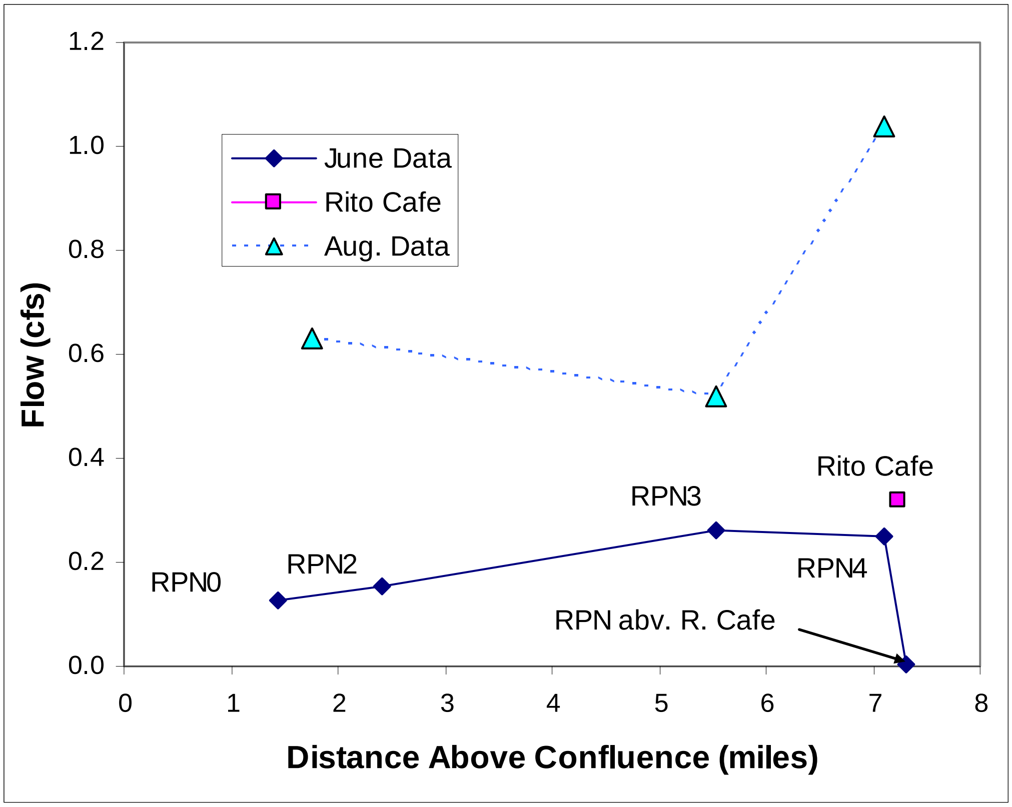

Figure 6. Variation of flow in the Rito Peñas Negras along its length. The Rito Café is the principal tributary to the stream near its headwaters.

Stream Morphology

Below the Forest Road 127 culvert the Rito Peñas Negras meanders across a wide valley floor and has developed incised channels banks with notable headcuts. The Forest Service reported typical channel meander with unstable banks and extensive utilization due to historic management practices causing the channel to degrade, shallow and widen (USFS, 2007). This field assessment noted meandering patterns and channel incision that has generally stabilized.

Thalweg profiles were taken at 5-ft intervals along reaches for each EMAP site, for a total of 400 feet. Depths were measured using a surveyor's rod. The Rito Peñas Negras and Rito Café thalweg profiles exhibited classic pool-and-riffle characteristics, although it is noted that the pools within the RPN3 site were significantly larger due to historic beaver activity along the reach.

The present study found that limited evidence of active erosion. Though head cuts were noted at some locations, stream banks at each of the five assessment sites were found to be in generally good condition with only limited damage noted due to cattle grazing. Each of the sites in the lower meadows, reaches two and three in Figure 4, had a good mixture of pool and riffle zones, and had extensive regions with undercut banks that will provide protection for fish. However, as noted before, there was virtually no riparian vegetation except grasses, and thus no shade or

woody debris in the stream. Further, the stream bottom was covered by a thin layer of silt at sites RPN0 through RPN2 (Figure 9).

On the August 15, 2011 trip to the site two geomorphologists accompanied the team, Drs. Les McFadden (soil geomorphologist) and Grant Meyer (fluvial geomorphologist). They were specifically interested in examining the channel incision in the lower meadows. They noted the presence of at least two and possibly three terraces at this location and little evidence of current active stream channel degradation. The presence of distinct A A/B and B soil horizons as well as charcoal particles embedded in the soil were noted which suggests that the soils are of late quaternary origin. Without more investigation it is not possible to determine when the incision occurred. However, based on their work in other watersheds in the Jemez Mountains Drs. McFadden and Meyer believe that the observed channel incision is not recent and may have occurred as long ago as 5,000 years. Furthermore, they believe it may not be the result of farming or grazing activities in the meadow.

Figure 7. Photograph of Rito Peñas Negras at assessment site RPN0.

Figure 8. Photograph of Rito Peñas Negras at assessment site RPN1.

Figure 9. Photograph of the Rito Peñas Negras at assessment site RPN2.

Figure 10. Photograph of inactive beaver pond on the Rito Peñas Negras just below assessment site RPN3.

Figure 11. Photograph of the Rito Peñas Negras at assessment site RPN4.

Figure 12. Photograph of the Rito Café just above confluence with the Rito Peñas Negras.

Stream conditions at assessment site RPN4 were significantly better with substantial woody riparian vegetation and little or no silt on the stream bottom (Figure 11).

At each transect bank angles and surface water widths were measured. Negative bank angles indicate undercut banks. Due to the small width of the Rito Peñas Negras bottom sediments were only characterized at the middle of the stream at each transect. Based on qualitative analysis of stream sediments, the Rito Peñas Negras exhibits varying degrees of sedimentation. For instance, at RPN4 below the historic beaver dams, there is relatively little sedimentation. This is somewhat intuitive, as deposition tends to occur upstream of dams. Downstream of dams, clear "sediment hungry" water tends to accumulate fine sediments in suspension. At other locations, notably RPN0 and RPN1, some evidence of channel aggradation is evident with larger cobbles exhibiting between 40-60% embeddedness.

Although some evidence of sedimentation is apparent, particularly in lower reaches, it appears that the general condition of Rito Peñas Negras is generally healthy with respect to suspended sediment and turbidity. It is noted, however, that grazing and other anthropogenic factors may reduce bank stability, thereby contributing to elevated sediment transport during high flow events. A summary of geomorphologic characteristics is shown below. This is consistent with

estimates of erosion potential published in the Terrestrial Ecosystem Survey of the Santa Fe National Forest (USDA, 1993).

Rainfall Runoff

To assess potential for erosion due to stormwater runoff, rainfall runoff potential in the Rito Peñas Negras watershed was estimated for 2- and 100-year rainfall events. The 1.5-year return period is generally accepted as a reasonable approximation of bank-full discharge. Stormwater runoff, including observed baseflow, was computed using the US Army Corps of Engineers HEC-HMS software. HEC-HMS software generates a runoff hydrograph for each sub-basin in the watershed based on precipitation depths, infiltration, time of concentration, and hydrograph attenuation due to routing. Hydrographs and routing for the project were generated using the methodologies in Table 5. Methods used to estimate storm runoff.

Table 5. Methods used to estimate storm runoff.

Calculation	Methodology
Rainfall Transform	SCS Unit Hydrograph
Routing	Muskingum-Cunge, with surveyed 8-pt cross sections
Loss/Infiltration	SCS Curve Number
Time of Concentration	Upland Method, converted to Lag

Point rainfall values were derived from National Oceanic and Atmospheric Administration (NOAA) Atlas 14, Volume IV, New Mexico, 2003. The New Mexico Type II-75 rainfall distribution was used for the 2- and 100-year, 24-hour events. Infiltration for each sub-basin is approximated by characterizing land cover, land use, and antecedent moisture conditions, which is then related to a curve number. Curve numbers range from 30 to 100, with higher numbers indicative of less infiltration. Curve numbers were estimated on the basis of field reconnaissance of site conditions and soil moisture estimates from data published in the *Terrestrial Ecosystem Survey*.

Time of concentration for each sub-basin was computed using the Upland method, as described in NMSHTD Drainage Manual Volume 1, Hydrology (NMDOT, 1995). Lag time, used in the SCS curve number method, is given by the relationship $t_L=0.7*t_c$. Peak discharges are routed through the watershed to various points of interests using Muskingum-Cunge methodology. Sub-basins, slopes, and reach lengths were delineated using ArcGIS software and USGS 7½" Quadrangle topographic mapping. Manning's 'n' values were estimated from site reconnaissance and *Guide for Selecting Roughness Coefficient "n" Values for Channels* (Faskin, 1963).

HEC-HMS Results

HEC-HMS model calculations indicate peak discharges of approximately 30 and 1,050 cfs for the 2- and 100-year events, respectively (Table 6). This prediction was checked by using Manning's equation to calculate the flow under bankfull conditions at assessment site RPN2, recognizing that bankfull flow represents flows that occur once every two years. Using slope of

0.8% and roughness coefficient (n) of 0.05, the calculated flow rates ranged between 20 and 30 cfs at three different cross sectional transects. These values are very close to those calculated for the two-year storm using HEC-HMS.

Table 6. Flows predicted by HEC-HMS for 2-year and 100-year storms in the Rito Peñas Negras watershed.

	Flow (cfs)	
Location	2-yr	100-yr
Rito Café	11	475
RPN4	12.6	531
RPN3	16.1	669
RPN2	21.2	846
RPN1	27.1	1,025
RPN0	28.3	1,050

During the August 15, 2011 site visit evidence was noted of a recent large storm event which caused flooding that topped the inner channel by at least one foot as shown by ash and floating debris deposited on the wire mesh of the WildEarth Guardians' exclosures and atop the stream banks. The storm was apparently highly localized as this evidence was confined to the lower mile of the meadow.

Temperature Modeling & Data

One of the water quality concerns about the Rito Peñas Negras is water temperature. One goal of this study is to establish a baseline condition for the watershed, which can be compared to future data to measure the effectiveness of watershed restoration activities. Stream temperature is a critical parameter, as the improvements are being used to restore riparian vegetation, thereby improving habitat conditions (i.e., lower temperatures) and possibly re-introducing native species.

The USGS Stream Segment Temperature Model (SSTEMP) was used to characterize temperature fluctuations in the existing stream. SSTEMP uses the physical features (e.g., riparian shade, topographic relief, ponding, etc.) of a watershed to balance heat gains and losses as water moves along a watercourse. Generally speaking, the software balances the effects of radiant heat sources and sinks within a stream segment in order to estimate mean and maximum daily water temperatures throughout the stream.

SSTEMP can calculate temperatures for a stream segment either independently (i.e., based only on local conditions for a particular segment) or as a system (i.e., based on both local conditions and heat contributions from upstream segments). For the Rito Peñas Negras watershed, three separate SSTEMP models were run:

1. Observed discharge, inherited temperature values
2. Observed discharge, independent temperature values
3. Predicted 2-year discharge, inherited temperature values

No model was run for a 2-year independent temperature value because no temperature data was collected for a 2-year, bankfull condition. Although the initial temperature for model 3 is also

estimated, an inherited temperature analysis is useful in assessing the "connectivity" of the stream system by comparing the relative effects for observed discharges versus bankfull discharges.

Results of the SSTEMP models are shown in Figure 13 and Figure 14. Under high flow bankfull conditions the stream is predicted to exhibit lower average and maximum temperatures than at low flow due to faster flow, deeper water and lower surface area-to-volume ratio. Conversely, the smaller volume of the observed discharge was more susceptible to heat transfer, as reflected in the higher temperatures for both average and maximum predicted temperatures. As might be expected, the inherited temperature models exhibit smoother average temperature curves, since they assume the inflow temperature for the downstream segment equals the outflow temperature from the upstream segment. The average temperature curve for the independent model is more discontinuous, however, it is noted that the discontinuity is largely governed by the time at which temperature measurements were taken. Future temperature measurements should be coordinated to ensure accurate assessment of the stream's temperature gradient. Ideally, measurements should be taken on the same discrete control volume as it moves downstream. For instance, if it takes 2 hours for a volume of water to travel from RPN3 to RPN2, the temperature measurement for RPN2 should be taken 2 hours after the temperature measurement for RPN3. If temperature measurements are coordinated correctly, the independent model should more closely resemble the inherited model, and any fluctuations in the independent model could be used to assess a segment's relative impact on heat transfer. In other words, if a data point in an independent model varies considerably from a properly calibrated inherited model, then it can be inferred that that segment is has a particularly great impact on the system as a whole. As such, this segment can be targeted in restoration efforts so that resources are dedicated where they will achieve the greatest impact.

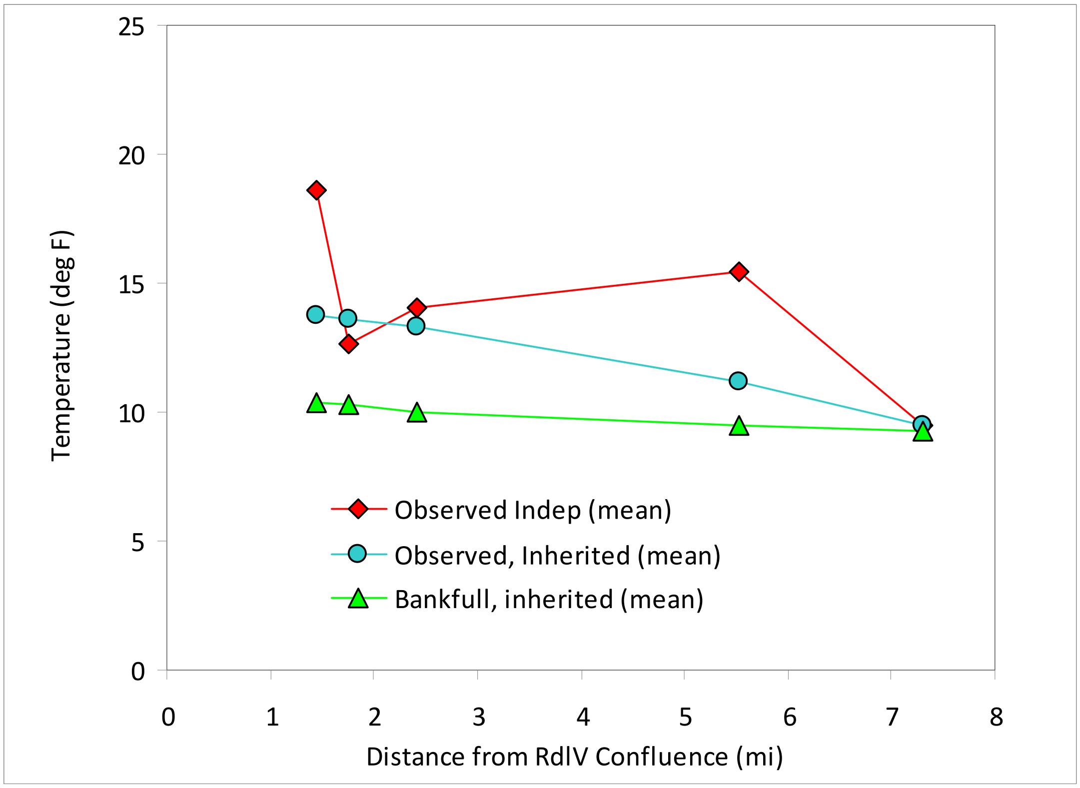

Figure 13. Mean water temperatures calculated by SSTemp model.

The predicted maximum stream temperatures all exhibit a pronounced drop at RPN3 as a result of the local ponding resulting from historic beaver dams. As discussed above, larger volumes of water are able to resist the transfer of heat. It is noted that neither the independent nor the inherited models predicted average temperatures that exceeded the predicted maximum temperature, even though the measured initial temperature was probably considerably lower than the average daily water temperature, which is specified in SSTEMP documentation as the proper input value.

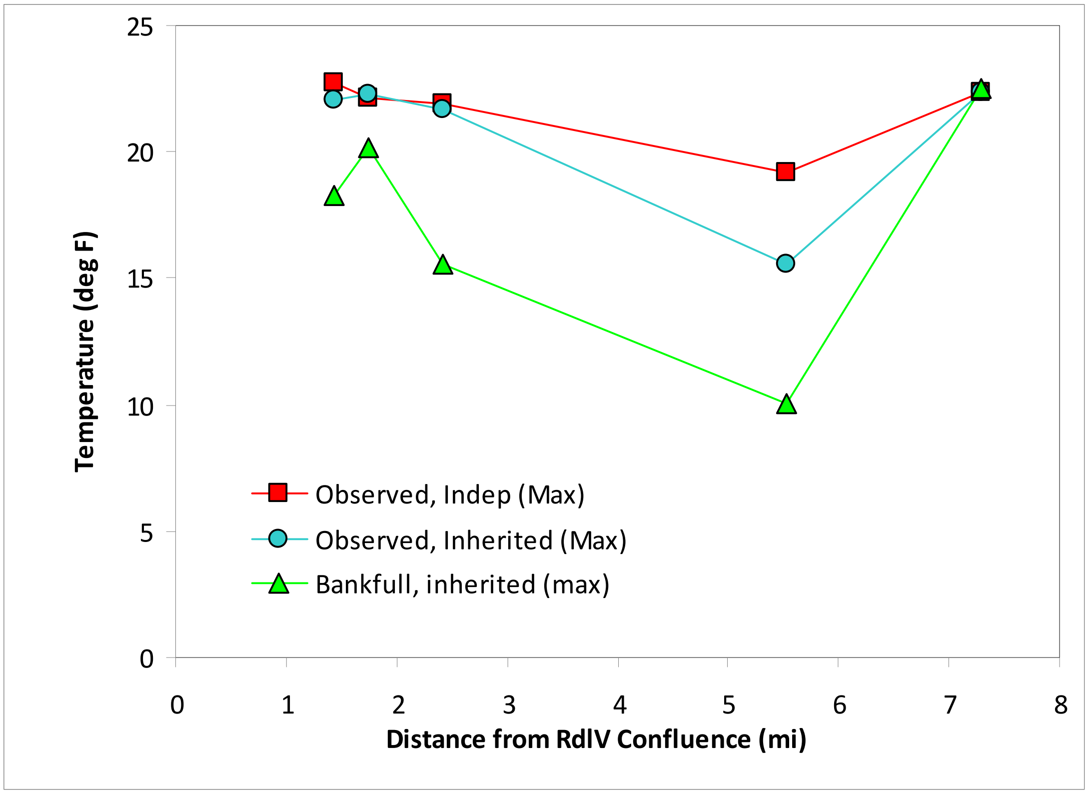

Figure 14. Maximum water temperatures calculated by SSTEMP model.

Although the SSTEMP model is based on actual physical parameters and has been validated against empirical data for a variety of watersheds, it is important to note that the results of the model are only estimates, and are contingent upon many different parameters. When using the results of this model the following should be considered

The Rito Café contributes substantially greater discharge (0.320 cfs) than the upper reaches of the Rito Peñas Negras (0.003 cfs), and is therefore likely to have a more significant impact on downstream temperatures. As such, the SSTEMP model was developed to consider the Rito Café as the upper segment of Rito Peñas Negras, while neglecting the Rito Peñas Negras above its confluence with the Rito Café. Because temperature impacts of the the upper Rito Peñas Negras are minimal, and for continuity with other rapid assessment/CMAP studies submitted to NMED Surface Water Bureau, it was determined that the USGS Stream Network Temperature Model (SNTEMP) – while it would effectively model temperature contributions from both streams – was not appropriate for this watershed.

Although there are several stock ponds on the Rito Peñas Negras near its headwaters and upstream of its confluence with the Rito Café, these ponds appear to retain all flow except when their spillways are overtopped by runoff and therefore do not impact daily temperature fluctuations. The ponds resulting from historic beaver activity downstream of Forest Service Road 527 do impact temperature, and their impact was included in the SSTEMP model.

The USFS installed two thermographs in the stream in mid-May, one near assessment site RPN1 and the other near RPN3. The temperature results are summarized in Figure 15 and show a trend of increasing average temperatures along with an increasing magnitude of diurnal variation.

The large maximum diurnal temperature difference is due in part to the lack of riparian vegetation, though the effect does not appear to be large. The average temperature difference for the period June 7 to June 16 at the upper thermograph was 12.5 C whereas the temperature difference for the lower thermograph was 13.1 C. Much of the Rito Peñas Negras above assessment site RPN3 has dense riparian vegetation. Using the Student's t-test this difference between the upper and lower sites is found to be significant at approximately an 85% confidence level. More data, especially later in the summer, could improve the confidence.

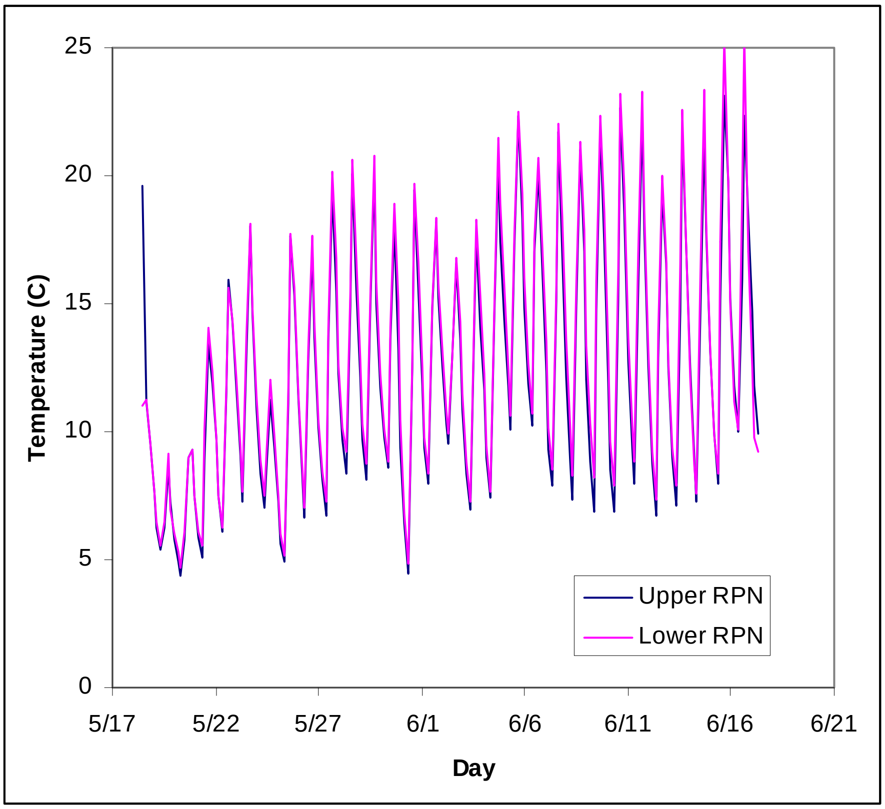

Figure 15. Temperature measurements of the Rito Peñas Negras collected by the USFS.

Another way of showing the difference between upstream and downstream temperatures for the month of June 2011 is plotted in Figure 16. A negative value indicates that the water temperature at the upper site is less than the water temperature at the lower site. Again, the data show a diurnal effect that increases as summer temperatures climb. This effect is exacerbated by the low flows in the stream and the lack of riparian vegetation in reaches 1, 2, and 3 of the stream.

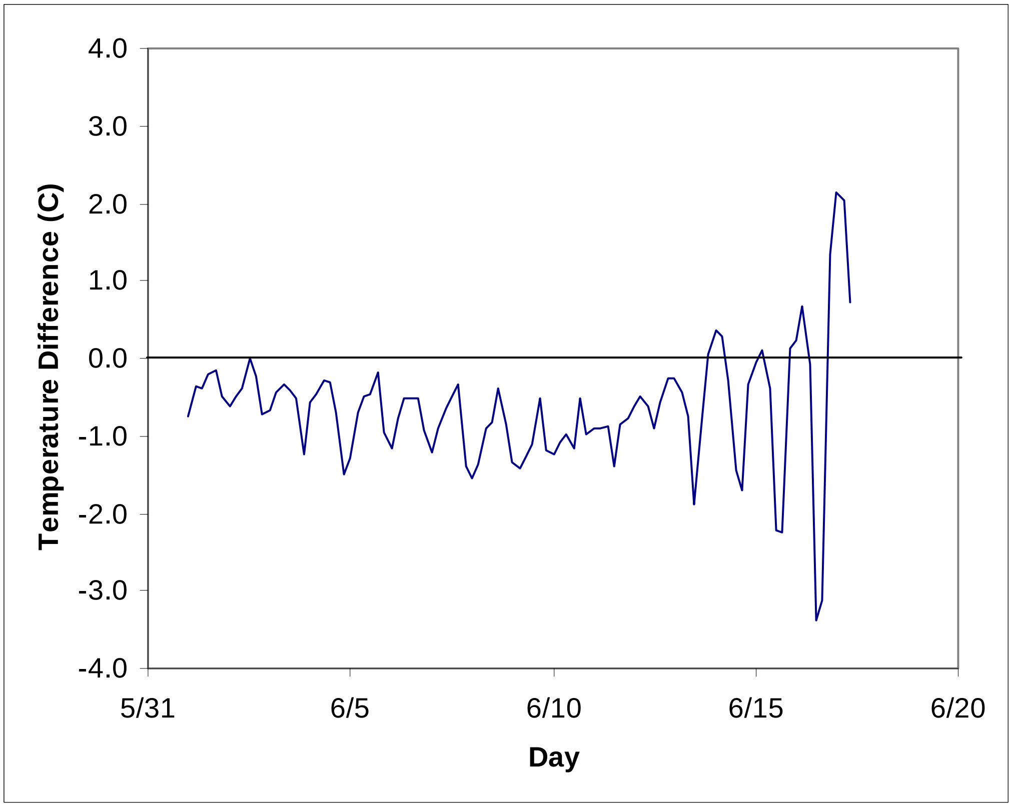

Figure 16. Plot of the temperature differences between the upper and lower reaches of the Rito Peñas Negras. Data collected by the USFS.

Water Quality

From June 6 through June 9, 2011, water samples at 11 locations were subjected to field and laboratory chemical analyses (Table 2 and Figure 2). The samples were collected from one of each of the five different reaches of the Rito Peñas Negras (labeled RPN0-RPN4, with the sample numbers increasing the closer to the headwaters the reach was), one from the Rito Café, two from the Rito Peñas Negras headwaters (Lake and Springs samples), two from the Rio de Las Vacas, and one from Trail Creek. Trail Creek and RPN are tributaries of the Rio de Las Vacas.

Field measurements were conducted for temperature, pH, dissolved oxygen and electrical conductivity. The list of analytes measured in the lab is presented in Table 3 and includes soluble metals, non-metals, nutrients (nitrogen species and phosphate), and chlorophyll A. The water quality results were compared to federal drinking water standards and New Mexico stream standards (20.6.4 NMAC).

Data for the field parameters are presented in Table 7. The pH values are within the narrow range of pH 7.9- 8.7. The alkalinity of the Rito Peñas Negras is quite high and is markedly different than that in the Rio de las Vacas. This is due to the presence of extensive limestone formations in the watershed. Similarly, the electrical conductivity of the Rito Peñas Negras is much higher than the Rio de las Vacas, and likely for the same reason.

Electrical conductivity in the Rito Peñas Negras ranged from 295 µS at the headwaters and increased slightly to 302 µS in the lowest reach of the stream. The pond near the stream's headwaters had the lowest value of 245 uS. Electrical conductivity is a surrogate parameter for salinity and the increase suggests increasing salinity concentration as a result of evaporation. However, the increase in electrical conductivity is very small compared to the decrease in stream flow (Figure 6) which suggests that most of the loss in flow is due to infiltration rather than evaporation.

An opposite trend of electrical conductivity was noted on the August 15, 2011 trip (Figure 17) in which the electrical conductivity was lower in the lower reaches. This was attributed to a recent large storm which diluted the stream with low conductivity rain water.

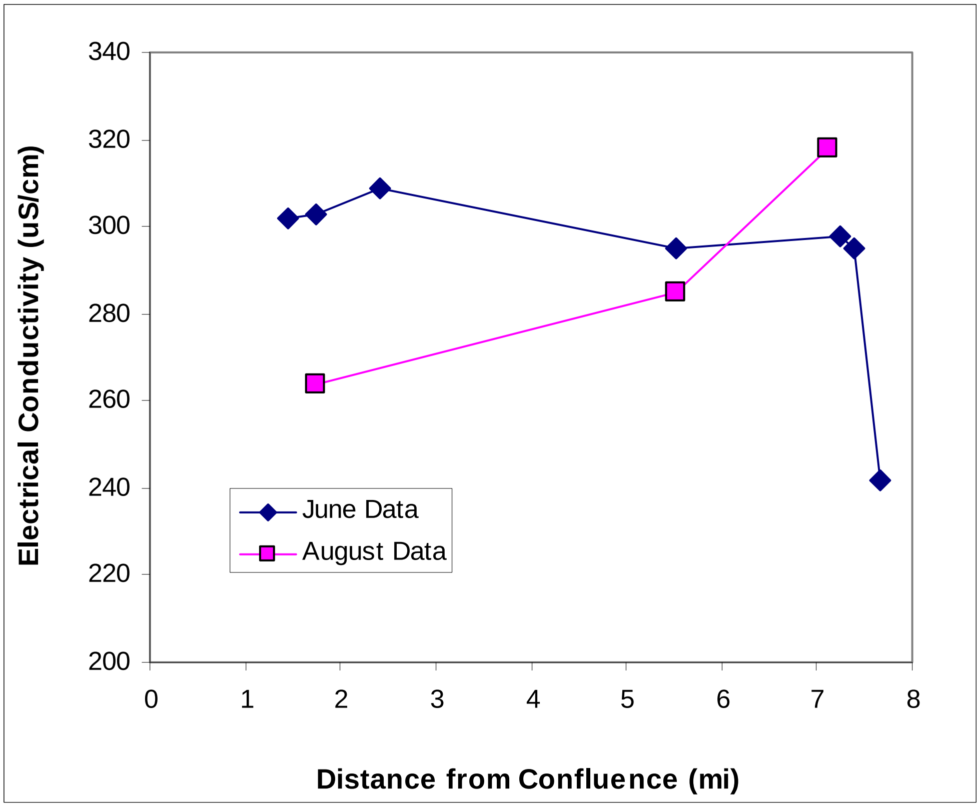

Figure 17. Plot of Electrical Conductivity in the Rito Peñas Negras vs distance from its confluence with the Rio de las Vacas.

Temperatures depended on the time of day and approach the upper limit established for cold water aquatic life. The range was 9.3°C in the Rito Café to 19.7°C in an afternoon sampling of a downstream reach of the Rito Peñas Negras. Maximum water temperature for salmonids to thrive is 19°C (66°F) (NMED, 2005)). Water temperatures at only one assessment site exceeded this value but elevated temperatures will likely become more of a problem later in the summer.

Table 7. Field measurements of water quality along the Rito Peñas Negras and Rio de las Vacas.

	June 2011 Data					August 2011 Data			
Sample ID	T (oC)	E.C. (uS/cm)	pH	DO (mg/L)	Total Alk	T (oC)	E.C. (uS/cm)	pH	Total Alk
RPN 0	19.7	302	8.7	11.22	169				
RPN 1	11.9	303	8.36	10.78	170	16.6	264	8.27	163
RPN 2	14.8	309	8.52	10.5	172				
RPN 3	12.8	295	7.9	12.5	161	19.1	285	8.58	179
RPN 4	16.5		8.61	9.32	161	17.6	318	8.5	193
Rito Cafe	9.3	298	8.16	12.23	174				
RPN Spring	16.3	295	8.19	9.55	191				
RPN Lake 1	21	242	8.6	10.35	136				
RdlV Bridge	15.5	41.9	8.18	9.77	19				
RdlV Rt. 20	18.8	107.5	8.13	12.23	52				
Trail Creek	16.3	264	9.92	9.92	152				

Total Alkalinity reported in units of mg $CaCO_3$/L.

The dissolved oxygen (DO) ranged between10.50 and 12.23 mg/L in the Rito Peñas Negras and Rito Café, and from 8.10 to 9.92 mg/L in the Rio de Las Vacas . In both streams DO levels are well above the 5.5 mg/L necessary to support a healthy trout population. The DO saturation increased to greater than 100% in most of the afternoon samples suggesting production of oxygen through photosynthesis by algae (virtually no aquatic macrophytes were noted in the stream).

Cations and anions present above detectable levels and their concentrations are included in Table 8 through Table 10. Table 11 lists the constituents that were not present at concentrations above the analytical method detection limit (MDL) in the water samples. The cations in the highest concentrations were calcium, sodium, and magnesium while bicarbonate was by far the anion in greatest concentration. High concentrations of calcium and bicarbonate are consistent with the presence of limestone in the Rito Peñas Negras watershed whereas the low alkalinity and calcium concentrations in the Rio de las Vacas samples indicate the absence of this mineral. The major ion composition of the water samples from the collected in this study is illustrated through use of a tri-linear diagram (Figure 18). This diagram shows remarkable consistency of the major ion composition of the Rito Peñas Negras along its length and including water from the Rito Café. The principle outlier is water sampled from the Rio de las Vacas at the Rio de las Vacas campground (collected under the State Road 126 bridge). But though its salinity remains low, the data show that the river picks up hardness and alkalinity as it flows downstream and the ionic ratios increasingly resemble those in the Rito Peñas Negras.

Table 8. Results of lab measurements of non-metals. All concentrations in units of mg/L.

	June 2011 Data - Concentrations (mg/L)						August 2011 Data - Concentrations (mg/L)					
Sample ID	F^-	Cl^-	NO_2^-	NO_3^-	PO_4^{3-}	SO_4^{2-}	F^-	Cl^-	NO_2^-	NO_3^-	PO_4^{3-}	SO_4^{2-}
RPN 0	0.11	1.91	ND	1.12	ND	5.02						
RPN 1	0.58	3.24	ND	0.36	ND	3.71	0.74	3.12	2.84	3.85	ND	6.08
RPN 2	0.26	1.99	ND	0.57	0.15	4.63						
RPN 3	0.18	2.31	ND	0.55	ND	4.81	0.92	3.02	ND	4.96	ND	6.50
RPN 4	0.21	2.27	ND	0.55	ND	5.15	0.84	2.75	ND	2.68	ND	6.33
Rito Cafe	0.15	1.62	ND	0.91	ND	5.29						
RPN Spring	0.06	2.95	ND	0.53	ND	7.45						
RPN Lake 1	0.16	3.95	ND	0.54	0.20	3.16						
RdlV Bridge	0.11	1.15	ND	0.79	ND	3.31						
RdlV Rt. 20	0.10	1.44	ND	0.65	ND	3.40						
Trail Creek	0.36	2.63	ND	0.68	ND	5.75						

ND = Not Detected at concentrations above Method Detection Limit (MDL)
NO_3^- and NH_3 reported in units of mg N/L

Table 9. Results of lab measurements of metals for June 2011 sampling. All concentrations in units of mg/L.

Sample ID	Ba	Ca	K	Li	Mg	Mn	Na	Si	Sr
RPN 0	0.399	60.2	1.69	5.78	4.01	ND	10.04	5.95	0.20
RPN 1 (Re	0.534	56.3	1.92	5.66	3.66	ND	10.69	5.68	0.18
RPN 2	0.178	50.4	1.27	5.00	3.32	ND	8.12	5.03	0.16
RPN 3	0.169	37.0	0.94	3.71	1.28	ND	3.07	4.97	0.07
RPN 4	0.167	52.3	1.47	5.24	1.66	ND	4.05	7.57	0.10
Rito Cafe	0.085	45.3	1.26	4.50	2.10	ND	4.07	8.74	0.10
RPN Sprin	0.545	46.9	1.26	4.64	4.54	0.03	5.99	4.71	0.17
RPN Lake	0.554	57.6	4.63	4.60	7.09	0.01	9.30	2.37	0.32
RdLV Bridg	0.023	5.8	0.64	0.56	0.23	ND	3.37	4.04	0.02
RdLV Rt. 2	0.057	30.9	0.95	3.08	1.11	ND	4.55	4.16	0.23
Trail Creek	0.078	34.7	1.62	3.39	3.33	ND	7.61	5.22	0.12
MDL	0.0065	0.05	0.25	0.25	0.0015	0.007	0.345	0.06	0.02

ND = Not Detected at concentration above Method Detection Limit (MDL)

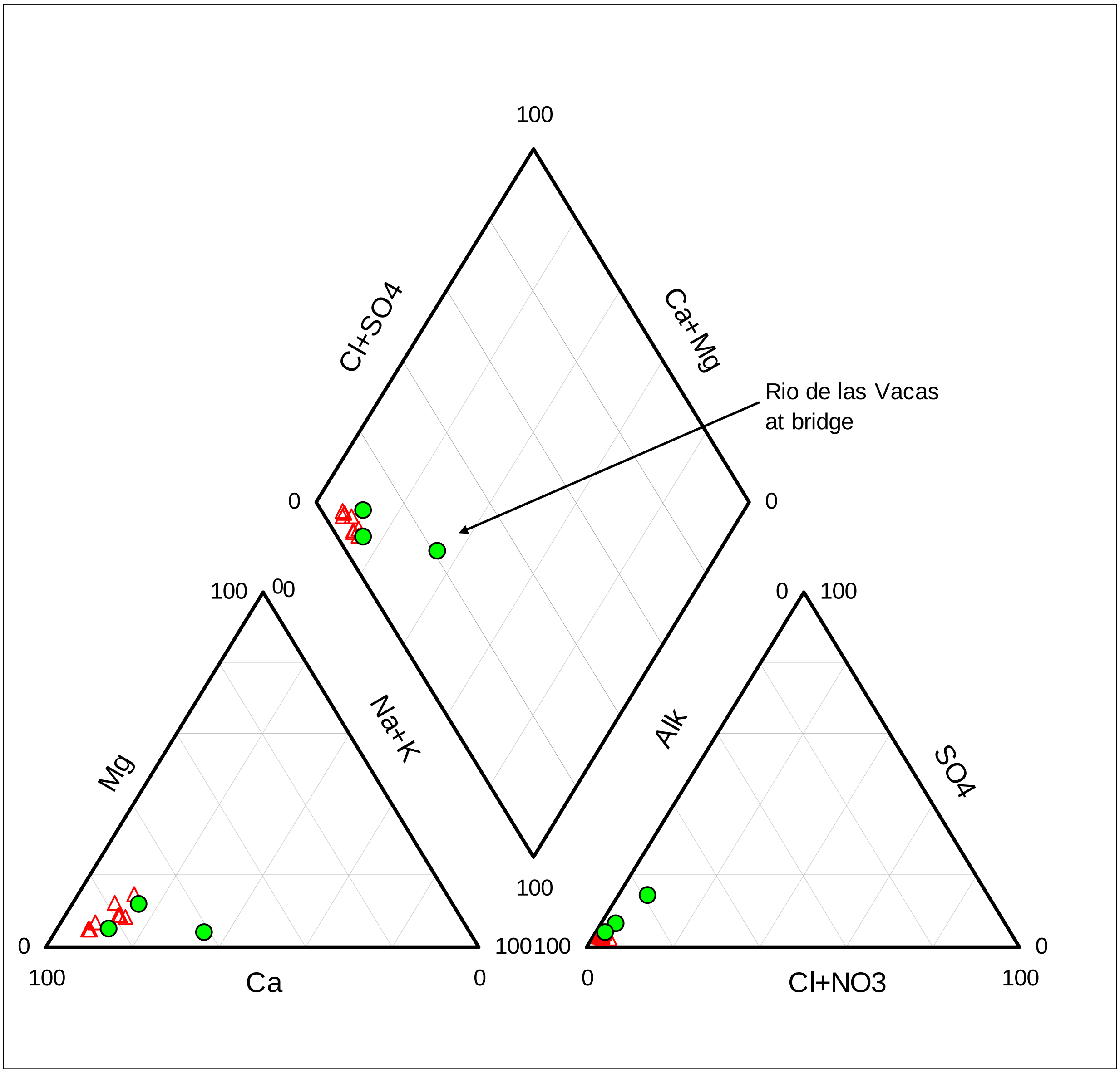

Figure 18. Trilinear diagram summarizing the major ion chemistry of the Rito Peñas Negras (triangles) and the Rio de las Vacas (circles).

Table 10. Results of lab measurements of metals for August 2011 sampling. All concentrations in units of mg/L.

Sample ID	Ba	Ca	K	Li	Mg	Na	Si	Sr
Data from 8/15	Ba 455.40	Ca 317.93	K 766.49	Li 610.36	Mg 280.27	Na 589.59	Si 251.61	Sr 421.55
RPN1	0.099	50.2	2.606	4.999	3.457	10.17	8.469	0.142
RPN3	0.097	58.91	2.12	5.836	2.528	6.956	9.747	0.11
RPN4	0.123	69.06	1.658	6.862	2.411	6.98	9.625	0.108

Table 11. Constituents not detected in water samples at concentrations above their Method Detection Limit (MDL). All concentrations in mg/L.

Element	MDL (mg/L)
Ag	0.065
Al	0.14
As	0.25
B	0.024
Be	0.0035
Cd	0.0135
Co	0.035
Cr	0.0355
Cu	0.027
Fe	0.031
Mo	0.0395
Ni	0.075
Pb	0.21
Se	0.375
V	0.032
Zn	0.1

Although it was not present at detectable levels in 0.45 um filtered samples, aluminum was detectable at concentrations ranging from 0.14 mg/L to .74 mg/L in samples filtered with qualitative filter paper then preserved with HNO_3. This is believed to be due to colloidal aluminum associated with clay sized particles in suspension as such particles will likely dissolve when preserved by HNO_3 addition to pH < 2.

As shown in Figure 17 the electrical conductivity of increased as the stream flows towards its confluence with the Rio de las Vacas. Most of the dissolved constituents showed either no discernible change or a slight increase in concentration similar to electrical conductivity as they became concentrated by the effects of evaporation. The two constituents that were markedly different were calcium and magnesium. Figure 19 shows a large increase calcium and magnesium in the lower reaches of the stream compared to sodium. This is attributed to dissolution of carbonate minerals in the watershed. The high concentrations of these elements in water samples from the upper reaches (the headwaters and pond) may be due to the influence of the seep springs; the very slow seepage provides time for dissolution of the minerals with resulting high concentrations of calcium and magnesium.

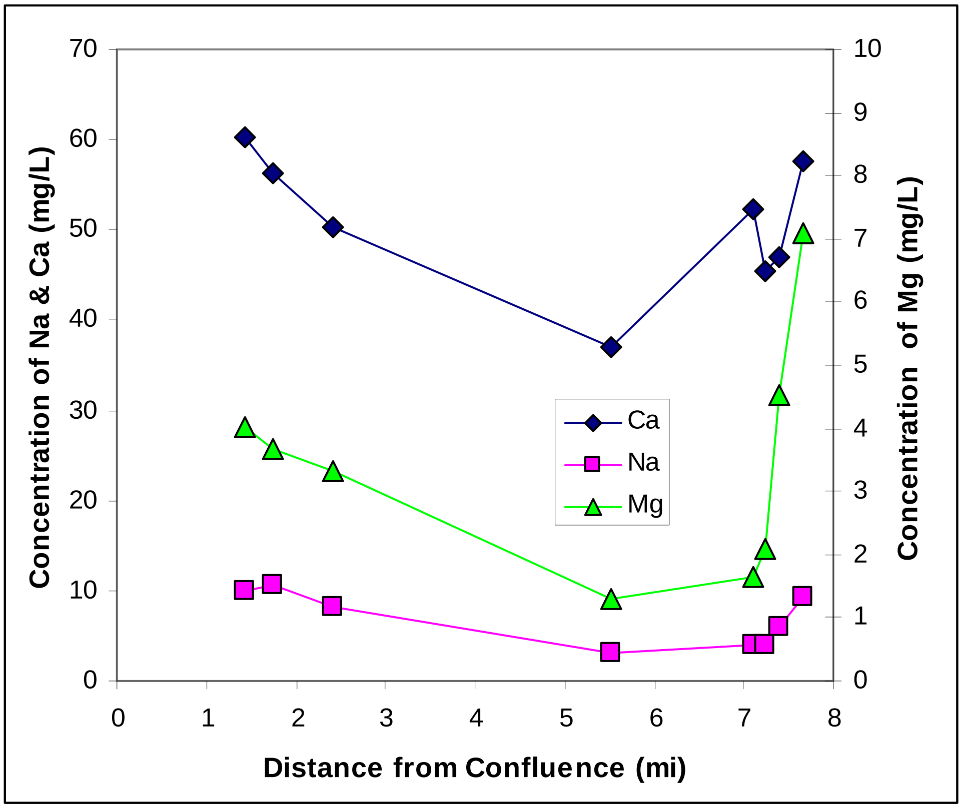

Figure 19. Concentrations of sodium (Na), calcium (Ca) and magnesium (Mg) along the Rito Peñas Negras, June 2011.

Nutrients were present at low concentrations during the June 2011 study. Nitrate was at concentrations ranging from 0.5 to 1.1 mg N/L present as NO_3^- and ammonia (NH_3) concentrations were all below 0.15 mg N/L present as NH_3. Phosphate was only detected in two of the samples, and at concentrations just slightly above the MDL. These are low concentrations and likely reflect the absence of cattle in the watershed during the winter. Cows were released to the range beginning about June 1 and their impact on nutrient concentrations in the stream is expected to increase during the summer. This was confirmed by the NO_2^- and NO_3^- concentrations measured in August 2011 (Table 8). The sum of these species increased by roughly an order of magnitude from < 0.5 mg/L in June to > 5 mg/L in August. This impacted the stream by stimulating growth of algae which was noted during the August visit.

Table 12. Relevant water quality standards for comparison of water quality results. All concentrations in units of mg/L unless noted.

Parameter	Drinking Water Standard[1]	NM Stream Standard for Aquatic Life[2]
Al	2.0[3]	1.37[4]
Ba	2.0	
Cl^-	250.[3]	
F^-	4.0	
Fe	0.3[3]	
Mn	0.05[3]	
NO_3^-	10.0	
$NH_{3(total)}$		5.62[5]
Dissolved Oxygen		≥6.0
T (°C)		≤23
pH	6.5-8.5[3]	6.6-8.8
EC (μS/cm)		300-1,500

Notes:
1 – Drinking water standards promulgated under the federal Safe Drinking Water Act
2 – NM Stream Standards are for high quality cold water aquatic life, 20.6.4.2 NMAC
3 – Secondary standard under the SDWA
4 – Chronic standard based on a water quality hardness of 100 mg/L as CaCO3
5 – Total NH3 at pH = 8.0

Chlorophyll A was measured in water samples at each of the 11 water samples by an extraction and UV absorbance method (Sartory et al. 1984). Note that these samples were collected from relatively quiescent pools and care was taken not to stir up bottom sediments. Thus, these measurements only reflect chlorophyll associated with suspended organisms, not organisms attached to bottom substrate. Chlorophyll A concentrations were found to be below detectable levels in all samples which indicate low concentration of suspended photosynthetic organisms. The low concentration is consistent with low nutrient concentrations in the water. However, the presence of afternoon DO concentrations above the saturation level does indicate photosynthetic activity. This is presumed to be due to growth of organisms on benthic substrates which, though minimal at the upper assessment sites (RPN3 and RPN4) was noticeable at the lower sites.

Stable Isotope Results

Measurements of the stable isotope ratios of oxygen (^{18}O:^{16}O) reported as $\delta^{18}O$ and hydrogen (^{2}H:^{1}H) reported as δD were conducted. The units are parts per thousand ($^{o}/_{oo}$). These measurements can be used to give comparative estimates of evaporation as water molecules composed of either oxygen-18 or deuterium are slightly heavier than molecules of the much more common oxygen-16 and hydrogen isotopes. Thus, their vapor pressure is slightly less, they evaporate more slowly, and they become slightly enriched as evaporation occurs.

Figure 20 plots the $\delta^{18}O$ and δD ratios that were measured along the Rito Peñas Negras. The data show a consistent increase in the ratio of heavier waters that is slightly greater than but very similar to the increase in electrical conductivity (Figure 17). The highest values were obtained for samples taken at a pond at the headwaters. Water samples from this pond were taken from the water surface right at the shoreline in the late afternoon (Figure 21) and it is believed that this result is due to concentration of the heavy water by evaporation.

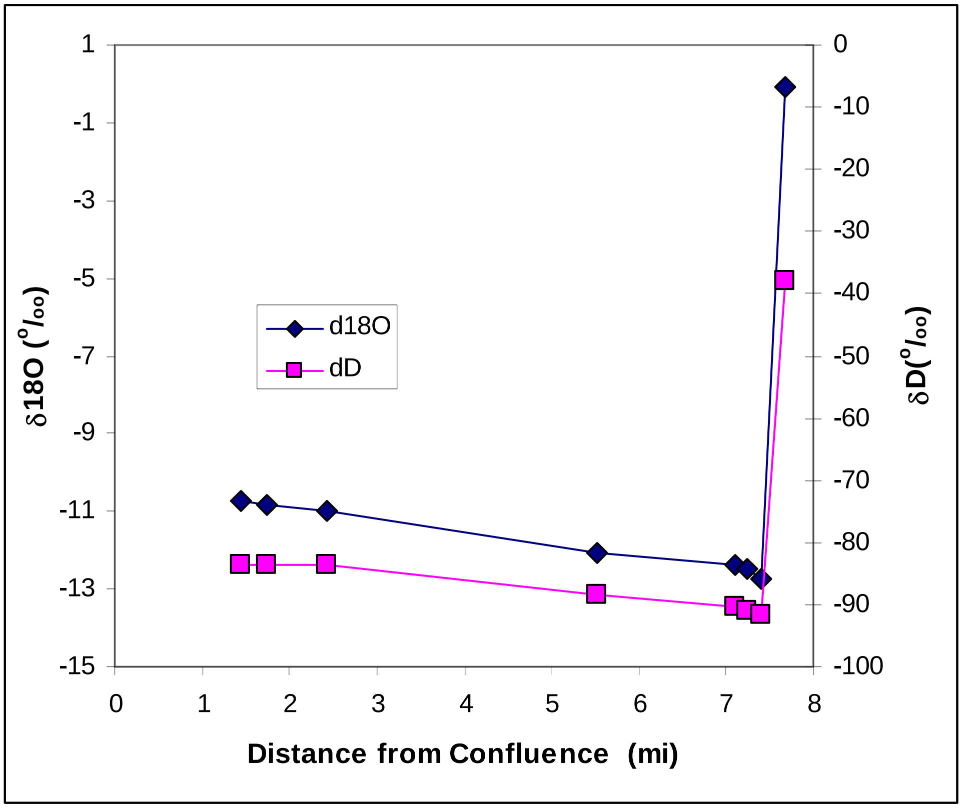

Figure 20. Plot of the stable isotope ratio for oxygen-18 ($\delta^{18}O$) and deuterium (δD) versus distance from confluence with the Rio de las Vacas.

Figure 21. Photograph of pond at the headwaters of the Rito Peñas Negras showing students measuring water quality parameters and collecting water samples for laboratory analysis.

Biological Characteristics

Benthic macroinvertebrates are frequently used to characterize the biological health of a stream as these organisms reflect the water quality characteristics over a much longer time than that of a grab sample. Benthic communities also are sensitive to wide range of constituents that are seldom measured in water quality samples (EPA, 2007). The orders in this study include Ephemeroptera, Mollusca, Plecoptera, Odontat and Trichoptera. Most of the species identified in these orders are intolerant of water pollution. Benthic macroinvertebrates were collected using kick nets and identified in the field at the five assessment sites. The relative numbers of species in each order was used to assess the quality of the stream.

The majority of the species observed in the RPN included the orders Ephemeroptera, Mollusca, Plecoptera, Odontat and Trichoptera and are located in group 1 and group 2 of the PTIR and require relatively high oxygen saturation (INDNR, 2011). The data are summarized in Table 13.

Table 13. Summary of field data for benthic macroinvertebrates at the five assessment sites along the Rito Peñas Negras.

Species	RPN 0	RPN 1	RPN 2	RPN 3	RPN 4
Caddis Fly larva	4				
Mayfly larva	3	12	6	5	5
Stonefly larva	25		3		3
segmented worms	1	2	3		3
leach					1
beatles	8				6
snails	10	4		20	4
Mosquito larva	1				6
Cranefly larva		4		5	
Dragonfly larva	4	3	6		
Damselfly larva	1				
Tubifex worm	5		1		
Midge larva			1		

The benthic macroinvertegrate data were used to calculate a pollution tolerance index (PTI) at each site (INDNR, 2011). The PTI ratings for the Rito Peñas Negras range from Fair to Excellent (Figure 22). The excellent rating was observed downstream of the new exclosures in the lower reaches of the stream. The fair ratings were collected from the three middle sample locations and a good index reading was recorded approximately a quarter mile downstream from the head waters. Because all of the other water quality parameters and descriptive characteristics were similar, it is believed that the lower PTI values in the middle reaches of the stream were due primarily to the low gradient and therefore lower velocities of the stream rather than the presence of any stressors. The stream at sites RPN1 through RPN2 had low velocities, less exposed gravel, and more silt than in the steeper reaches. These factors resulted in lower biological diversity.

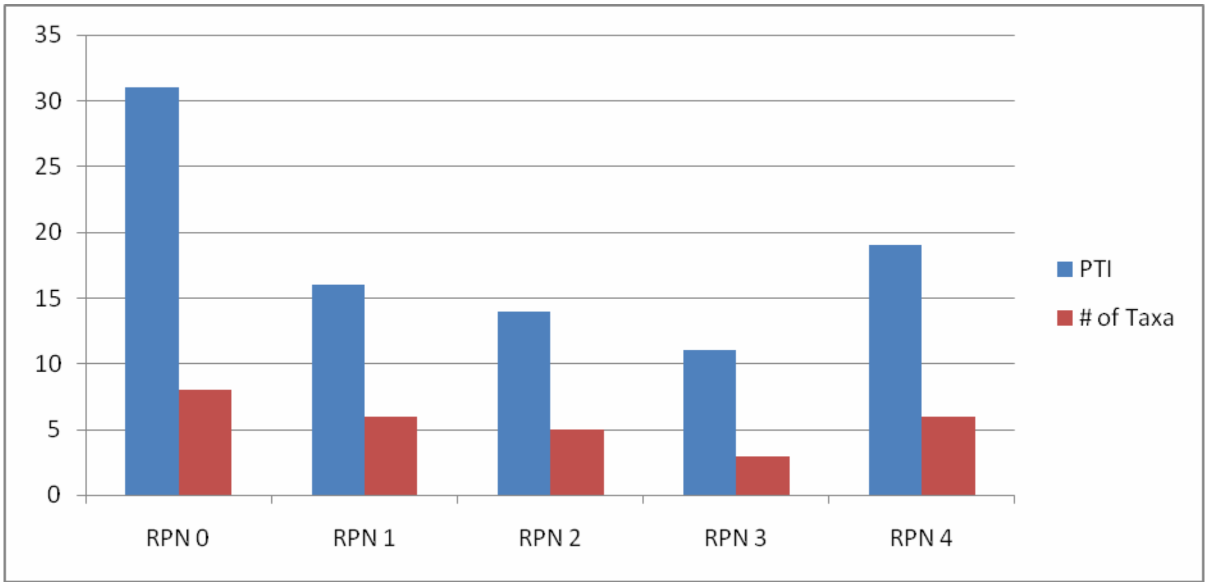

Figure 22. Pollution Tolerance Index (PTI) based on the population of benthic macroinvertebrates.

Vertebrate Organisms

No fish or other vertebrates were collected in this study, however, one member of the team had a degree in fish biology and the presence. Fish species observed in the stream included the native Rio Grande chub (*Gila Pandora*) and the introduced non-native species German brown trout (*Salmo trutta*). The Rio Grande chub was observed in the lower reaches of the stream. The German brown trout was observed throughout the Rito Peñas Negras with a density of approximately 1 trout every 40 meters.

The only reptile species observed in the RPN was the Western Terrestrial Garter Snake (*Thamnophis elegans*). This species was observed from the lower reaches to the head waters of the RPN. Amphibians were not observed during the assessment.

Riparian Vegetation

Less than 1% of the watershed vegetation along the Rito Peñas Negras is composed of woody riparian species (USDA-FS 2002). The integrity of riparian areas is crucial to providing a high quality cold water fishery. Removal of riparian vegetation is a significant contributor to stream impairment in the Jemez River watershed (Jemez Watershed Restoration Action Strategy, 2005). The USFS Respect the Rio project has constructed buck-n-pole fences to limit vehicle access to delicate riparian zones (USDA-FS, 2007). Downstream reaches of the stream are characterized by wide, grass-dominated valleys, and do not exhibit a significant amount of riparian vegetation. However, early 2011 installation of exclosures and plantings of native tree species in lower reaches of the RPN are intended to promote recovery of riparian vegetation and address stream impairments.

Alder species are more prevalent in upstream sections and remain common in areas dominated by pine and spruce species. The upper reach below the confluence of Rito Café and RPN consists

of a narrow valley with significant riparian vegetation. Riparian vegetation density decreases downstream and is virtually nonexistent in reaches below FR 527.

Notable Features

Students hiked the stream from the confluence of the Rito Peñas Negras and Rito Café to its confluence with the Rio de las Vacas (~5 miles) and performed a visual survey of notable features. A Geographical Positioning System (GPS) receiver was used to note coordinates and elevation of significant features. Notable changes in substrate were observed, with upper reaches dominated by colluvium and large boulders. Such channel substrate differences are consistent with mountain stream characteristics. Extensive thinning of trees was noted near the FR 527 culvert (36˚0.888' N, 106˚ 42.524' W).

The first evidence of channel incision was noted at 8583' (36˚ 1.265'N 106˚ 42.533'W). The channel had incised ~4 feet below the surface of the surrounding landscape and displayed features typical of the widespread channel degradation downstream from the FR 527 culvert. Notably, several stands of dead Alder were observed ~100 feet upstream of FR 527. Similar stands of dead alder were found downstream of FR 527. The soil around the cement encasing the culvert has eroded causing water to enter from the sides of the culvert and resulting in the buckling of the pipe, perhaps creating a barrier for fish migration. The FR 527 culvert needs to be rehabilitated to prevent its washing out during high flow events.

Abandoned beaver dams downstream of RPN's intersection with FR 527 constitute the only evidence of beaver activity. A series of 5 beaver ponds originate downstream from FR 527 (35˚ 59.881' N, 106˚ 12.568 W). No evidence of recent beaver activity (tracks, beaver slides, etc.) exists in the area.

One notable feature near FR 527 (assessment site RPN3) was that nearly all of the woody riparian vegetation was dead. Though there were large stands of alder, virtually all of it was dead. There were a number of fairly large beaver ponds immediately downstream of the FR 527 culvert, but all were abandoned as was previously noted by the Forest Service (USFS, 2007). There was no evidence that beaver were responsible for the demise of these alder stands. The region of dead alders also extended upstream from the FR 527 culvert for a distance of approximately 200 m.

Comparison of Study Results with Previous Studies

The Santa Fe National Forest conducted a stream survey on the Rito Peñas Negras during the fall of 2005 and released a report (Rito Peñas Negras Stream Inventory 2007) in 2007. The report noted a beaver dam complex of six small structures over 405 feet of stream length upstream from FR 527. The 2005 survey noted the presence of two beaver dams along the RPN. Our survey did not identify beaver activity along this reach, perhaps indicating beaver populations have abandoned the stream altogether. The same 2005 Forest Service assessment did not find any native amphibians including tiger salamanders, western toad, leopard frog, and chorus frog. Similarly, our survey did not identify any amphibians.

With the exception of the series of abandoned beaver dams, Large Woody Debris (LWD) was absent downstream of FR 527. LWD is integral to improving the fishery and habitat of the RPN. The 2005 assessment compared total LWD from a 1993 report, concluding such debris are decline in quantity. The habitat characteristics for a properly functioning stream aim for >30 pieces of >12" diameter LWD per mile in areas where recruitment for debris naturally occurs.

The Forest Service noted extensive areas of bank instability in the lower reaches of the Rito Peñas Negras. This was attributed to erosion caused by removal of riparian vegetation and bank damage caused by cattle grazing. Photographs of the stream were shown to a soil scientist/geomorphologist familiar with Jemez mountain soils and Quaternary stratigraphy who suggested an alternate explanation (McFadden, 2011). He stated that many of the meadows in this region and valleys elsewhere in mountainous regions in the southwest are characterized by late Holocene aggradation, a process that has been attributed to numerous causes besides grazing pressure (e.g., responses to fire, climate change, complex response behavior). Thus, recent deep incision noted in the lower reaches may reflect re-establishment of the stream conditions prior to such sediment deposition. This interpretation is very preliminary but suggests that further evaluation of the stream's geomorphic characteristics is needed.

Data Gaps and Information Needs

Perhaps the most significant shortcoming of the present study is that it involved one week of field work during the second week of June. The limitation is that this one time study gives only limited information regarding the seasonal variability of the hydrologic, chemical, and biological characteristics of the stream. All of these characteristics are expected to vary throughout the year. Of particular interest are the conditions of the stream and watershed in late summer-and early fall when stream flows are lowest, temperatures are highest, and riparian vegetation and water quality are most likely to be impacted by livestock grazing throughout the summer. The observed 10-fold increase in nitrite-plus-nitrate concentration is of concern because high nutrient concentrations stimulate algal growth which leads to eutrophication. Other impacts that may occur include: decreased flows, elevated temperatures, increased evaporative losses, and increased levels of nutrients and stream bottom sediments. At the same time, the influence of intense summer thunderstorms and associated large storm flows may cause erosion problems.

Another shortcoming of this study is that it did not include quantitative measurements of riparian cover. This is especially important for temperature modeling using the SSTemp model. A variety of methods have been used to obtain quantitative and qualitative information on riparian canopy including densiometers, clinometer, hemispherical photography, solar pathfinder, and photo documentation (OPSW, 1999). Riparian shade measurements using densiometers are frequently used in NM and are recommended for future studies of this watershed to be consistent with data collected in other watersheds. A longer period of record for thermograph data is also needed for calibration of a temperature model.

A careful analysis of the geomorphic characteristics of the lower reaches of the Rito Peñas Negras is needed. Examination of channel morphology in the lower meadows shows past evidence of significant erosion which appears to have nearly halted in recent years, however, much of the channel incision is believed to pre-date agricultural use of the valley. The restoration activities of the WildEarth Guardians is based in part on the desire to achieve bank stabilization and limit erosion. Further, it has been suggested that shallow bedrock formations have limited erosion which may affect growth of deep rooting riparian vegetation (Mattison, 2011). An investigation of the valley's geology and the stream's geomorphic characteristics would determine whether erosion is limited by shallow bedrock, and whether observed channel incision is recent and influenced by range management strategies, or reflects a return to stream conditions prior to historic aggradation processes. This knowledge would provide guidance for future stream restoration activities and range management programs.

Conclusions and Recommendations

This study evaluated the characteristics of the Rito Peñas Negras watershed during the second week of June 2011 and August 15, 2011. The initial study occurred approximately one month after peak spring runoff and shortly after the range was opened to cattle grazing. Thus, although stream flows were not high, they had not yet been strongly influenced by the remarkable drought conditions nor by the effects of heavy grazing. The WildEarth Guardians finished construction of several large animal exclosures shortly before this study and planted a mix of trees and shrubs to improve riparian conditions in the lower reach of the stream. One of the purposes of this study was to establish baseline conditions against which to compare the effects of these restoration activities.

Stream assessments using USEPA and NMED protocols were conducted at five sites (Figure 2). These assessments consisted of measuring flows and water quality characteristics, collecting water samples for measurement of quality, identifying benthic macroinvertebrates, and evaluating geomorphic characteristics. In addition, flows and water quality characteristics were measured at three other locations in the watershed, at two locations on the Rio de las Vacas, and at Trail Creek, a small tributary to the Rio de las Vacas.

Flows measured in the lower reaches of the stream averaged 0.14 cfs, well below the bankfull estimated flow of 20 to 30 cfs. Flows in the upper reaches (above FR 527) exceeded 0.25 cfs. The bankfull flow represents the peak flow with a recurrence interval of two years (i.e. a two-year storm). A hydrologic model analysis also predicts similar flows for a two-year storm. The low flows observed in this study in part reflects the limited spring runoff resulting from regional drought conditions. The decrease in flow over the lower reaches of the stream is due to evaporation and to infiltration. Measurement of electrical conductivity and deuterium and oxygen-18 isotopes suggest that evaporation is responsible for less than 20% of the decreased flow. August 2011 flows were higher than those in June due to summer monsoons.

This study found high water quality throughout the watershed and that all parameters measured met those established for the designated uses to support high quality coldwater aquatic life. In particular, the water contained low concentrations of nitrogen and phosphorous compounds which is due in part to lack of grazing during winter months. The second sampling event occurred after 2.5 months of grazing and found greatly increased concentrations of nitrite (NO_2^-) and nitrate (NO_3^-). This has stimulated algal growth in the stream. Thermograph measurements for the months of May and early June show a strong diurnal temperature variation. Although temperatures were below the maximum level for coldwater aquatic life, they were increasing and likely will exceed this criteria. The lack of shade from riparian vegetation contributes to warming of the water.

Benthic macroinvertebrates were sampled at each of the five assessment sites and their order identified. This information was used to determine the biological health of the stream by calculating a pollutant tolerance index (PTI) that ranged from Fair to Excellent. The PTI provides a semi-quantitative indication of the stream based on whether organisms present can

survive in contaminated water. The apparent inconsistency between the high quality of the water according to chemical analyses and the modest PTI values may in part be due to the fact that the stream was assessed early in the summer before establishment of large populations of organisms.

The geomorphic characteristics of the stream suggest that it has a stable alignment with limited evidence of recent erosion or bank cutting. In the upper reaches (above FR 527) steeper gradients result in faster flows dominated by riffles. Bottom sediments were dominated by sands and gravels. In the lower reaches the velocities slow and the channel consists of a mixture of shallow pools, glide areas, and riffles. A fine layer of silt covers the bottom sediments in this region. There is almost no woody riparian vegetation in the lower half of stream, however, stream banks are stable and much of the stream's banks are undercut which provide habitat for aquatic life. There are a few locations where animals have knocked down the banks to gain access to the stream, but this damage is limited.

One notable observation was the presence of extensive stands of dead alders along the stream immediately upstream and downstream from the FR 527 stream crossing. The cause is not known. Although several intact beaver ponds were observed near the FR 527 culvert, there was no indication that there had been any beaver activity in many years. This observation was noted in previous studies.

In summary, this study found the Rito Peñas Negras to be a high quality watershed at the time of this study as reflected by most of the criteria considered. It is likely that water temperatures will climb during the summer. Preliminary modeling suggests that lack of shade is a factor. However, water quality is high which is substantiated by macroinvertebrate populations and diversity. Grazing during the summer has increased the concentration of nitrogen species in the river which has in turn stimulated algal growth. Future study is needed to determine the effects of the newly constructed grazing animal exclosures on the stream after riparian vegetation have become established.

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