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background of land use and management techniques collected from the Forest Service and a variety of other sources. Previous land use and management practices reflect on the current condition of environmental systems. Historical information helps explain the current condition of the river and is incorporated into this report.

Table 1. Matrix of factors and indicators of health condition for historic and currently occupied Rio Grande Cutthroat Trout **s**treams as related to R3 Stream Habitat Inventory.

FACTORS	INDICATORS	Properly Functioning	At Risk	Not Properly Functioning
Water Quality	***Temperature – State of New Mexico Standards***	<20°C (68°F) (3 day avg. max)	≥20°C (68°F) <23°C (73.4°F) (3 day avg. max)	≥23°C (73.4°F) (3 day avg. max)
	Temperature – Salmonid Development	≤17.8°C (64°F) (7 day avg. max)	>17.8º (64ºF) < 21.1º (70ºF) (7 day avg. max)	≥21.1ºC (70ºF) (7 day avg. max)
Habitat Characteristics	**Sediment**	<20% fines (sand, silt, clay) in riffle habitat. Fine sediment within range of expected natural streambed conditions		≥20% fines (sand, silt, clay) in riffle habitat. Fine sediment outside of expected natural streambed conditions.
	Large Woody Debris[1]	>30 pieces per mile, >12" diameter, >35 feet in length	20-30 pieces per mile, >12" diameter, >35 feet in length	<20 pieces per mile, >12" diameter, >35 feet in length
	Pool Development[2]	≥30% pool habitat by area[3]		<30% pool habitat by area[3]
	Pool Quality[4]	Average residual pool depth ≥1 foot		Average residual pool depth <1 foot
Channel Condition and Dynamics	**Width Depth Ratios by Channel Type** *(utilize Rosgen type and range given if applicable)*	Width/depth ratios and channel types within natural ranges and site potential		Width/depth ratios and channel types are well outside of historic ranges and/or site potential
		Expected range of bankfull width/depth ratios and channel type	***Rosgen Type*** A, E, G B, C, F D	***W/D Ratio*** <12 12-30 >40
	Streambank Condition[5]	<10% unstable banks (lineal streambank distance)	10-20% unstable banks (lineal streambank distance)	>20% unstable banks (lineal streambank distance)

[1] Large Woody Debris numeric are not applicable in meadow reaches. For this survey a meadow reach can be defined as an area where there is no local recruitment of LWD.
[2] Pool Development numeric are applicable to 3rd order or larger streams.
[3] Area is defined by habitat length.
[4] All pool habitats in the San Antonio Creek survey have a residual depth of greater than or equal to 1 foot. Exclusive quality pools are related to a surveyor error and this parameter is excluded from analysis.
[5] Streambank Condition numeric are not applicable in reaches with > 4% gradient

Once the historical analysis is completed, in-stream survey data is collected to provide an overview of the current condition of a stream. Survey data produces a "snapshot" in time of the stream's habitat condition and the factors that are affecting it. Survey information can be used to identify both degraded sections as well as ideal areas to be used as a reference or model for other similar sections of stream. Another goal of the survey information includes the identification of potential fish passage barrier sites to link isolated populations of native fish. By combining the historical and current information pertaining to a stream, management options can be more clearly identified, which is the goal of this document.

BASIN SUMMARY

Table 2. Stream Summary Table for San Antonio Creek.

LOCATION:		
County:	Sandoval	
Forest:	Santa Fe National Forest	
District:	Jemez Ranger District	
Drainage:	San Antonio Creek	
Tributary to:	Jemez River	
Mouth Location:	T19N, R3E, S32	
WATERSHED:		
HUC Code[1]:	1302020202	
Watershed Area:	67,452 acres	105 square miles
Stream Order:	5	
Stream Length:	161,568 feet[2]	30.6 miles[2]
AQUATIC BIOTA:		
Fish Species:	rainbow trout, brown trout, Rio Grande sucker, and longnose dace	
Amphibian Species:	tiger salamander, Jemez Mountain salamander, western toad, leopard frog, and chorus frog	

[1] Hydrologic Unit Code used to identify watersheds.
[2] Stream length includes both surveyed and un-surveyed private land.

EXECUTIVE SUMMARY

San Antonio Creek is a 5th order stream originating from springs in Valle Toledo of the (VCNP), on the Jemez Springs Ranger District of the Santa Fe National Forest (Forest) in Sandoval County. Fisheries populations are present from the mouth (T19N, R3E, Sec.32) at 6,755 feet to the headwaters at 8,760 feet. The San Antonio Creek drains the area between East Fork of the Jemez River and Rio Cebolla. The watershed contains 67,452 acres (105 square miles), with a variety of landowners including the Forest, VCNP, and a number of private individuals. From the mouth of San Antonio Creek up to the town of La Cueva is exclusively Forest land. Near La Cueva, several sections of private land are interspersed with the Forest land. From the end of the private land to the VCNP boundary is Forest land. From the boundary to the headwaters is VCNP land.

San Antonio Creek is divided into 11 reaches, each reach containing similar habitat characteristics. Reach divisions are based on stream and valley morphology, dramatic changes in stream flow, impoundments, land ownership boundaries, or other changes, which have significant impacts on stream habitat characteristics. Reaches are numbered from the mouth up in progressive order related to the movement of the survey (see Table 3).

The average gradient of San Antonio Creek is 1.3%. When evaluated reach by reach the gradient ranged from 0.1% in Reach 7 to 4.9% in the first reach (see Table 9).

Geologically, San Antonio Creek flows through areas associated with the Jemez Mountains' volcanic origin. Rock in this area is igneous and includes pumice and tuff, which are very soft and form highly erosive soils. Excessive fine sediment loads and high turbidity are encountered in San Antonio Creek, exacerbated by historic and current grazing practices, human disturbance related to recreation and historic timber

management, as well as road encroachment and runoff from highway, Forest and VCNP road systems.

Table 3. Description and length of reaches on San Antonio Creek.

Reach	River Miles	Landmark at Beginning and End	Land Owner
1	0.0 to 3.3	Mouth to NM Highway 4 crossing.	Forest
2	3.3 to 3.8	NM Highway 4 crossing to private land boundary at Hidden Valley Road	Forest and private land
3	3.8 to 3.9	Hidden Valley Road to pond at south end of Sheen Estates	Private land-Not Surveyed
4	3.9 to 5.4	Pond at south end of Sheen Estates to NM Highway 126 crossing	Santa Fe National Forest and private land
5	5.4 to 9.6	NM Highway 126 crossing to San Antonio Hot Springs	Santa Fe National Forest and private land
6	9.6 to 12.0	San Antonio Hot Springs to VCNP boundary	Santa Fe National Forest
7	12.0 to 13.4	VCNP boundary to unnamed tributary on left bank one straight line mile from west edge of VCNP	VCNP
8	13.4 to 25.4	Unnamed tributary on left bank to Confluence of Rito de los Indios	VCNP
9	25.4 to 26.6	Confluence of Rito de los Indios to Pipeline Road crossing in west end of Valle Toledo	VCNP
10	26.6 to 28.8	Pipeline Road crossing in west end of Valle Toledo to artesian well creating tributary 48	VCNP
11	28.8 to 30.5	Tributary 48 on left bank to end of water at east end of Valle Toledo	VCNP

Stream flow in San Antonio Creek fluctuates between the high flow events in the spring and late summer to low flow in the mid summer. Spring high flow events originate from snow runoff and vary with the previous winter's snow pack. The snow pack of 2002 was unusually low and related to drought conditions that reduced the intensity of the spring runoff. The late summer high flow events are related to monsoon weather patterns, which typically develop in July and August. The flow related to monsoon events is not as severe as the spring runoff.

Water diversions from San Antonio Creek include one (1) irrigation ditch and one (1) pond. The ditch near San Antonio Campground diverts approximately half of the stream flow to the left bank. The human constructed pond is constantly fed by a negligible quantity of water from San Antonio Creek in Reach 4 (La Cueva).

Water quality in San Antonio Creek has been monitored at two sites by NMED. The sites were located at the mouth of San Antonio Creek and just above San Antonio Campground. Monitoring occurred between April 20th, 1998 and March 25th, 1999. Water quality at the two sites was generally in accordance with standards. Both locations had the same results when compared to water quality standards. At both sites, turbidity exceeded standards twice during spring runoff and once in the fall. Total organic carbon (TOC) exceeded standards once in the fall at each site and could be attributed to decomposing deciduous vegetation (NMED 2001).

Habitat Characteristics

San Antonio Creek's 30.5 stream miles (161,004 feet) is divided into 492 Natural Sequence Order habitat units (NSOs). 135 pool habitats comprise 6.9% of San Antonio Creek's stream habitat. Riffles comprised of 208 habitat units, the majority of stream habitat (see Table 4). Tributaries are not considered stream habitat, since they are outside of the mainstem and are thus excluded from the stream habitat analysis.

A pool-to-riffle ratio provides information on the relative amount of habitat types. Several means can be utilized to calculate this ratio including number of habitats, length in feet, or volume in cubic feet. The pool:riffle ratio by number of habitats is 1:1.5, the same ratio by length of habitat is 1:13.0. When calculating volume, assumptions were made about the shape of riffle and pool habitats. Riffle habitats were estimated as rectangles and pool habitats as half-spheres. The pool to riffle volume ratio is 1:1.7. A higher volume to length ratio is found in pools due to habitat shape. In any representation, the riffle habitat is much greater than pool habitat.

Table 4. Stream survey summary for San Antonio Creek.

Habitat Type	Number of Habitats	Total Stream Habitat (ft)	Stream Length* (%)	Stream Habitat** (%)	Properly Functioning Indicators
Pool	135	11,464	7.2	6.9	>30%
Riffle	208	149,223	92.7	89.2	-
Culvert	4	235	0.1	0.1	-
Tributary	51	-	-	-	-
Falls	4	54	0	0	-
Side Channel	89	6,292	NA	3.8	-
Total	492	167,268	100.0	100.0	-

*Percent Stream Length calculated with only riffle, pool, culvert, and falls habitat types.
**Percent Stream Habitat calculated using all stream habitat types except tributary.

When compared to the matrix of factors and indicators of stream health condition for historic and occupied Rio Grande Cutthroat trout streams, San Antonio Creek contains **not properly functioning,** and **properly functioning** characteristics (see Table 5). The parameters that are **not properly functioning** include water temperature, relative sediment content in riffles, the density of large woody debris (LWD), and pool development, and width-to-depth ratio. **Properly functioning** characteristics include stream bank condition.

Water temperature is a crucial parameter for fish health and development. Five stream temperature stations were strategically placed along the length of San Antonio Creek. The stations recorded water temperatures every four hours between June 11th and November 24th, 2002. The water temperature data was compared to both Forest and NMED standards. The Forest standards classified San Antonio Creek as **not properly functioning** for salmonid development at all sites except station 5 located near the headwaters. The NMED standards classified two of the five sites as **not properly functioning** for water quality. Mitigating human-caused elevated stream temperatures should be a focus in the management of San Antonio Creek.

Table 5. Stream Conditions on San Antonio Creek

Factors	Indicators	San Antonio Creek Conditions
Water Quality	Temperature 3 Day Average	**Site 1) Battleship: At Risk**
		Site 2) La Cueva: Not Properly Functioning
		Site 3) Campground: At Risk
		Site 4) VCNP: Not Properly Functioning
		Site 5) Rito de los Indios: At Risk
Salmonid Development	Temperature 7 Day Average	**Sites 1-4: Not Properly Functioning**
		Site 5) Properly Functioning
Habitat Characteristics	Riffle Sediment	**Not Properly Functioning**
	Large Woody Debris	**Not Properly Functioning**
	Pool Development	**Not Properly Functioning**
	Pool Quality	**Not analyzed due to surveyor error**
Channel Condition and Dynamics	Stream Bank Condition	**Properly Functioning**
	Width-to-Depth Ratio	**Not Properly Functioning**

Red= Not Properly Functioning Yellow = At Risk

Riffle substrate content is important to the reproductive success of fish. The space between gravel in riffle habitat is crucial for spawning and fish development. Fine sediment fills in the space between gravel substrates and eliminates spawning habitat. The relative quantity of fine sediment in San Antonio Creek is **not properly functioning** by matrix standards. Riffle sediment content was 29.9% (see Table 6).

Table 6. Summary of Habitat and Substrate Percentages for Riffles in San Antonio Creek.

Riffle Habitat Summary						
	# of Riffles	Avg. Length	Avg. Width	Avg. Depth	Avg. Max. Depth	
Entire River	208	717.4	12.2	1.0	2.2	
Substrate Summary						
	Sand (%)	Gravel (%)	Cobble (%)	Boulder (%)	Bedrock (%)	Total (%)
Entire River	29.9	29.7	23.0	14.4	3.0	100.0
Properly Functioning Indicators	<20.0	-	-	-	-	-

Pool habitat is important over wintering, resting, and feeding habitat for fish. Pool habitat is evaluated by both quality (or residual depth) and area of pool habitat (by length). Pool quality in San Antonio Creek could not be analyzed due to surveyor error (surveyor's assumed the definition of a pool to be that a pool had to have a residual depth greater than 1.0'). While this did include lowering the number of overall pool volume calculated in the survey, pools with residual depth less than one foot are by nature filling in and would result in small volumes which would be negligible for the overall pool volume matrix. The relative pool habitat volume is **not properly functioning.** Pool habitat is 6.9%, well below the >30% standard (see Table 4).

Table 7. Summary of Pool Habitat and the related substrate in San Antonio Creek.

Pool Habitat Summary											
Area	Number of Pool Habitats	Avg. Length	Avg. Width	Avg. Max Depth	Avg. PTC	Avg. Residual Depth	Pools per Mile	Number of Pools w/ Residual Depth >1'	Pools w/ Residual Depth >1'/Mile	Number of Pools w/ Max. Depth >3'	Number of Pools w/ Max. Depth >3'/Mile
Entire River	135	84.9	19.6	3.1	0.7	2.4	4.4	135	4.4	24	0.8
Properly Functioning Indicators	-	-	-	-	-	≥1.0[1]	-	-	-	-	-

Substrate Summary							
	Area	Sand (%)	Gravel (%)	Cobble (%)	Boulder (%)	Bedrock (%)	Total (%)
	Entire River	56.3	17.6	10.7	12.2	3.2	100.0

[1]Pool quality properly functioning indicator not analyzed for San Antonio Creek due to surveyor error

Large woody debris has been related to habitat complexity and the health of fish populations in stream habitats (Fausch and Northcote 1992). Large woody debris density is **not properly functioning** in San Antonio Creek. The number of pieces of LWD per mile in non-meadow reaches is 0.2, far below the >30 pieces per mile standard (see Table 8). The total number of LWD in San Antonio creek is 105 pieces (medium [redacted] arge woody debris density should be a focus in the management [redacted] Increasing LWD would also improve other degraded factors in the stream habitat including pool development and sediment deposition in riffles.

Each reach is defined by Rosgen stream classifications. Each stream class has an expected natural bankfull width:depth ratio which is related to how the stream should react to its valley formation (Rosgen and Silvey 1998). The properly functioning [redacted] d by the reaches classification, so each reach is evaluated separately [redacted] :depth ratio. San Antonio Creek contains both **properly** [redacted] **properly functioning** reaches for width:depth ratio. Reaches 1, 6, 8 [redacted] **rly functioning**

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Reach by Reach Comparison

San Antonio Creek contains eleven reaches that expressed of variety of conditions based on local and upstream influences. The following attributes were **not properly functioning** in at least one reach: Pool habitat, LWD per mile, stream temperature, bankfull width:depth ratio and unstable banks. No surveyed reaches are properly functioning in all categories (see Table 9).

Photo 1. Reach 6, NSO 312, R125. Long riffle habitat and bank instability (5 Aug 2002).

The quantity of pool habitat is of concern in all reaches except Reach 2 (34.1%). The relative quantity of pool habitat in reaches that are **not properly functioning** in San Antonio Creek range from 0.4% in Reach 10 to 13.6% in Reach 7 (see Table 9). Reach 11 is excluded from analysis due to its small size. All reaches that are **not properly functioning** for quantity of pool habitat are far below the matrix standard.

Table 9. Reach characteristics summaries for San Antonio Creek.

Reach	Total Length (mi)	Gradient (%)	Rosgen Channel Type	Pool Habitat (%)	Riffle Habitat (%)	Side Channel Habitat (%)	Dominant Substrate in Pools	Dominant Substrate in Riffles	LWD Per Mile	Bankfull Width to Depth	Unstable Banks (%)
1	3.3	4.9	A2	8.5	81.8	9.3	Sand/Silt	Boulder	8.2	12:1	6.8[3]
2	0.5	0.8	C3	34.1	60.5	4.8	Sand/Silt	Cobble	0.0	21:1	2.8
3	0.1	1.8	Private Land Not Surveyed								
4	1.5	1.0	B3	6.9	89.2	3.8	Sand/Silt	Cobble	0.0	21.6:1	3.1
5	4.3	2.1	C3	9.3	81.5	9.1	Sand/Silt	Cobble	17.0	14.3:1	8.1
6	2.5	0.9	E5	7.5	92.5	0.0	Sand/Silt	Sand/Silt	1.6[1]	15:1	11.1
7	1.5	0.1	E4	13.6	84.8	1.6	Sand/Silt	Gravel	0.0[1]	4:1	5.8
8	12.0	0.3	E4	2.6	96.0	1.3	Sand/Silt	Gravel	0.1[1]	7:1	1.9
9	1.2	0.5	E5	5.0	94.3	0.3	Sand/Silt	Sand/Gravel	0.0[1]	8:1	5.3
10	2.2	0.5	E5	0.4	99.1	0.5	Sand/Silt	Sand/Silt	0.0[1]	6:1	10.2
11	1.7	1.4	E5	0.6[2]	99.0	0.2	Sand/Gravel	Sand/Silt	0.0[1]	1:1	7.4
Entire River	30.5	1.25	-	6.9	89.2	3.8	Sand/Silt	Sand/Gravel	0.2	10:1	5.0
Properly Functioning Indicators	-	-	-	>30	-	-	-	-	>30	A,E,G: <12 B,C,F: 12-30 D: >40	<10

Red= Not Properly Functioning Yellow = At Risk

[1] LWD/Mile criteria are not applicable in meadow reaches.

[2] Pool development is not applicable in stream segments smaller than 3rd order

[3] Streambank condition is not applicable in reaches with >4% gradient

In all reaches, except those classified as a meadow, LWD density is **not properly functioning**. Meadow reaches are defined as containing no local natural recruitment of

LWD and are excluded from density analysis. In non-meadow reaches, LWD density ranges from 0.0 pieces per mile in Reach 2 to 17.0 in Reach 5. All analyzed reaches are far below the greater than 30 pieces per mile standard.

The bankfull width:depth ratio is **not properly functioning** in Reach 6 and is **at risk** in Reach 1 (see Table 9). The bankfull width:depth ratio in each reach is compared to the expected range for its related Rosgen stream type. Reach 1 and 6 should be verified with further analysis to determine cause**.**

Two of the 10 surveyed reaches are **at risk** for length of unstable banks. Reach 6 (11.1%) and 10 (10.2%) are **at risk** (see Table 9). The remaining reaches are **properly functioning**.

Tributaries

Fifty (50) tributaries in the form of seep, spring, and stream habitats contributed surface flow to San Antonio Creek during the survey. USGS 1:24000 Quadrangle Maps (1977) identify four perennial tributaries to San Antonio Creek, of which three have official names: Sulphur Creek, San Luis Creek and Rito de los Indios. Of these mapped tributaries only Rito de los Indios contributed more than 5% to the flow of San Antonio Creek (Table 10). Nine tributaries contributed more than 5% of the flow at the time of the survey. Temperatures of the nine (9) major tributaries ranged from 46° F near the headwaters to 74°F in an artesian well in Valle Toledo.

Photo 2. Reach 8, NSO 388, T29. San Luis Creek entering San Antonio Creek on the left bank (13 Aug 2002).

Thirty-nine (39) tributaries contributed 5% flow or less and one the flow of one tributary was not identified (see Appendix A, Table 3). Temperatures of the thirty-nine tributaries ranged from 55° F in a spring in Reach 5 to 100° in a spring originating in San Antonio Hot Springs. Sulfur Creek contributed no flow at the time of survey, but was classified as a tributary due to pooled water upstream of the confluence with San Antonio Creek.

Table 10. Summary of tributaries contributing more than 5% to the flow of San Antonio Creek.

Location		Bank	Habitat Type	Name	Percent Flow*	Time	Tributary Temp (°F)	Stream Temp (°F)	Comments
Reach	Habitat Number								
1	T1	Right	NA	NA	15	1252	73	NA	NA
8	T33	Right	Stream	NA	5-10	NA	NA	NA	Stream flows out of Valle Santa Rosa
8	T37	Left	Stream	Rito de los Indios	15	1335	56	NA	Enters stream between Valle San Antonio and Valle Toledo
9	T41	Left	Spring	NA	10	1245	57	57	Springs flowing out of rock enter stream in an approx. 100 foot area
10	T44	Right	Spring	NA	10-15	NA	NA	NA	NA
10	T48	Left	NA	NA	65	1420	60	NA	Source is artesian Well in Valle Toledo
11	T49	Left	NA	NA	15	1440	74	70	Source is artesian well in Valle Toledo
11	T50	Right	NA	NA	15	1535	64	66	Source is artesian well
11	T51	Right	Spring	NA	40	1425	46	54	Enters stream 600 feet downstream from end of stream

*Percent flow is a visual estimate by the surveyors and therefore should not be considered an exact measurement.

Stream Flow

San Antonio Creek's headwaters in Valle Toledo are fed by numerous springs and artesian wells. Springs and artesian wells provide a constant water source and have a moderating effect on stream temperatures. Peak flows are governed by spring snowmelt, typically spiking between late May and early June. Smaller increases in flow occur after heavy precipitation events associated with the summer monsoon weather pattern (July through September). However, the past few years the region has experienced a drought, creating unusually low flows. The summer of 2002 was also unusually dry, leaving many rivers in the Jemez Mountains dry (FS files).

Flow was measured utilizing a Swoffer flow meter on July 11th 2002 in Reach 1, River Mile 0. The flow was taken at the mouth of San Antonio Creek in a straight section of riffle with as few flow restricting obstacles (boulders, logs, etc.) as possible. A transect was created and divided into 24 equally spaced sections. At each section flow was taken at 60% of the depth in twenty-second intervals. The average flow is recorded from each section and related to area to calculate stream flow. San Antonio Creek flow on July 11th was 11.08 cubic feet per second (CFS).

Stream flow at the mouth of San Antonio Creek was also collected by the United States Geological Survey. On December 16, 1997 the stream flow was 10 CFS. On April 23, 1998 the flow was 42 CFS almost four times the flow on June 26th, 2002 (FS Files).

One irrigation ditch located near San Antonio Campground diverts water from the creek. Approximately half the flow of a large side channel is diverted into the ditch off of the left bank. This ditch is not identifiable on Seven Springs quadrangle map (USGS) but is

used annually during irrigation season to water fields on private land in La Cueva.

A human constructed pond is constantly fed by negligible quantities of water from San Antonio Creek. This pond is on private land at the very beginning of Reach 4. Overflow from the pond runs out of a PVC tube and back into the stream.

Water Temperature

Water temperature is a key component of water quality in a stream environment. Combinations of multiple factors determine water temperature regimes in stream habitats. Solar radiation, air temperature, riparian vegetation cover, ground water, stream discharge, channel shape, stream orientation, and climate are some of the environmental factors that influence water temperature. Many chemical and biological processes depend on specific temperatures. Temperature can help determine the suitability of waters for aquatic species such as Rio Grande cutthroat trout (RGCT).

Photo 3. Reach 8. M. Andre in San Antonio Creek at mouth of Santa Rosa Creek (14 Aug 2002).

Fish growth, health, and reproduction are affected by water temperature. Fish are very sensitive to water temperature due to temperature specific enzymes. As water temperature increases, so does fish performance. Although fish have increased performance with temperature, they also approach a lethal limit. No lethal temperature information is currently available for RGCT. Another high elevation, arid cutthroat subspecies Lahontan cutthroat trout (*Oncorhynchus clarki henshawi)* indicated an upper limit for growth and long-term survival is somewhere between 71.6 and 73.4 °F. These temperature limits were based on optimal conditions with high food availability and good water quality, not taking into account the other stressors that may exist in stream environments. It is possible that the actual lethal limits are lower due to water chemistry and other environmental factors (Dunham 1999).

Cutthroat trout reproduction is affected by temperature. Smith et al (1983) compared egg quality of cutthroat trout in a variety of water temperatures. Eggs in cold water were expelled easily and were in good condition. In warm water the eggs were expelled with

difficulty, were cloudy or opaque and often broken. Eggs spawned from two-year-old adults exhibited 74% viability in coldwater while in warm water only 6.9%.

Forest standards (noted as SFNF in Figure 2) are based on seven-day average maximum temperatures and are stricter than the NMED standards. While it is stricter, the Forest standard is more in line with approaches taken by U.S. Fish and Wildlife Service and NOAA Fisheries across the western United States. It also allows the SFNF to be more pro-active in improving watershed conditions for native fish as well as ameliorating impairments to water quality before a stream is listed as impaired on the 303(d) list.

NMED standards are based on three-day average maximum temperatures (see Table 11). Forest temperature standards are derived from research done on inland cutthroat trout and salmonid development. NMED standards are based on the Clean Water Act and Total Maximum Daily Loads mandate for water quality standards but are defined by needs for a successful coldwater fishery. Data between June 1st and September 30th is used for maximum water temperature standards analysis to identify high temperatures that occur in summer months (see Appendix A, Figure 1).

Water temperature in San Antonio Creek was monitored between June 11th and November 24th, 2002. Tidbit thermographs, small temperature recording devices, were strategically placed at five locations in San Antonio Creek. Thermographs recorded temperatures at four-hour intervals for the duration of their time in the creek. Data collected by thermographs was exported to Microsoft Excel 2000 for analysis and comparison to water quality standards.

Table 11: SFNF and NMED Water Quality Temperature Standards.

Water Temperature Standards	Properly Functioning	At Risk	Not Properly Functioning
SFNF 7-Day Average Max.	≤ 64 °F	64 to 70 °F	> 70° F
NMED 3-Day Average Max.	≤ 68 °F	68 to < 73.4 °F	≥ 73.4 °F

Five (5) temperature monitoring stations were established on San Antonio Creek. The stations were not moved for the duration of the monitoring period. The first station was placed at the mouth, just above the confluence with East Fork Jemez River (Reach 1, River Mile 0.0). Upstream, La Cueva Station is located behind La Cueva Lodge near the junction of Highway 4 and 126 (Reach 2, River Mile 3.8). La Cueva Station was placed immediately downstream from a section of private land that encompasses San Antonio Creek. The third station, Campground, was located at San Antonio Campground off Highway 126 (Reach 4, River Mile 5.3). Station four, VCNP Boundary, was located at the Valles Caldera National Preserve boundary (Reach 7, River Mile 12.1). The final station, Rito de los Indios, was placed immediately downstream of Rito de los Indios confluence near the headwaters of San Antonio Creek (Reach 8, River Mile 25.3).

Data collected from the five (5) thermograph stations is compared to Forest and New Mexico Environment Department (NMED) Water Quality Standards for temperature. Both standards classify water temperature as **properly functioning (PF)**, **at risk**, or **not properly functioning (NPF),** but with different requirements (see Table 11).

When Forest standards are applied, four out of the five stations were **NPF**. Rito de los Indios station was the only section functioning **at risk**. The VCNP Boundary station had the most NPF days, indicating significant warming occurred above this site in the Valles Caldera National Preserve (VCNP). NPF days then decreased to the Campground station

as the river passed through Forest land. Temperatures again increase at the La Cueva Station as the river passes through private land. Finally, temperatures decrease at the Battleship station, again on Forest land (see Figure 2). All of the stations with days exceeding the NPF standard must be mitigated for survival of coldwater fish populations.

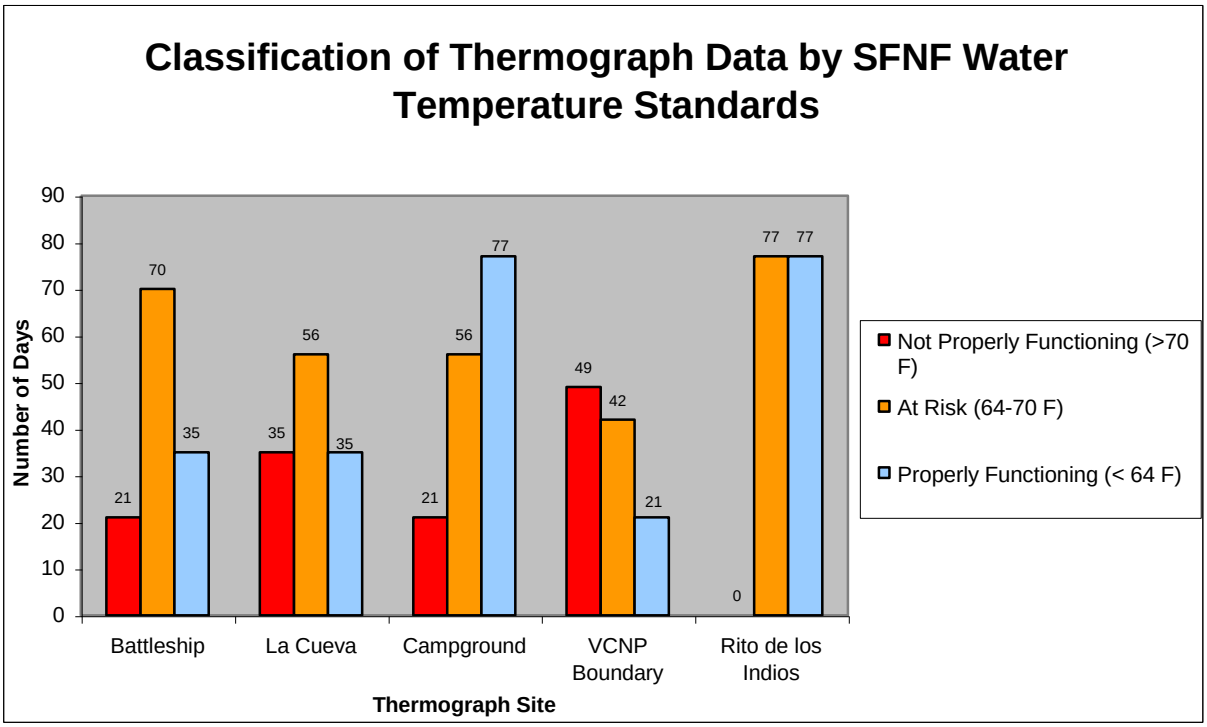


Figure 2. A comparison of **not properly functioning, at risk**, and **properly functioning** days at five thermograph sites in San Antonio Creek between June 11th and September 30th, 2002. Water temperature categories defined by SFNF Water Quality Temperature Standards are based on a seven-day average maximum.

Two stations recorded **NPF** days when classified by NMED standards: VCNP Boundary and La Cueva. (see Figure 3). Under both Forest and NMED standards, the VCNP Boundary and La Cueva stations exceeded NPF standards the most of the five stations. Factors creating the elevated temperatures at these stations must be mitigated to insure the viability of coldwater fish populations.

Two main factors influence temperatures at the Rito de los Indios site. The station is located near the headwaters with little time for solar warming. Fifteen tributaries enter San Antonio Creek between the headwaters and Rito de los Indios. Many of these tributaries are springs, which moderate stream temperatures during hot summer months.

Factors affecting the increasing temperatures between Rito de los Indios and the VCNP Boundary stations are solar warming, stream widening caused by bank instability, valley morphology and tributaries. The highly sinuous and low gradient wide valley morphology between Rito de los Indios creates an opportunity for solar warming. Solar warming is compounded by the lack of shade provided by riparian vegetation, collapsing undercut banks, and a wide and shallow channel shape. Several road crossings decrease stream depth and increase wetted width, exacerbating solar warming. Fifteen tributaries enter San Antonio Creek between the two stations. Two tributaries contribute more than an estimated 5% of the main channel flow and had properly functioning temperatures at the time of survey. Other tributaries ranged between PF and NPF temperatures with one hot spring. The hot spring contributed less than 5% of the flow at 100°F (8/13/2002 at 12:30) (see Appendix A, Table 3).

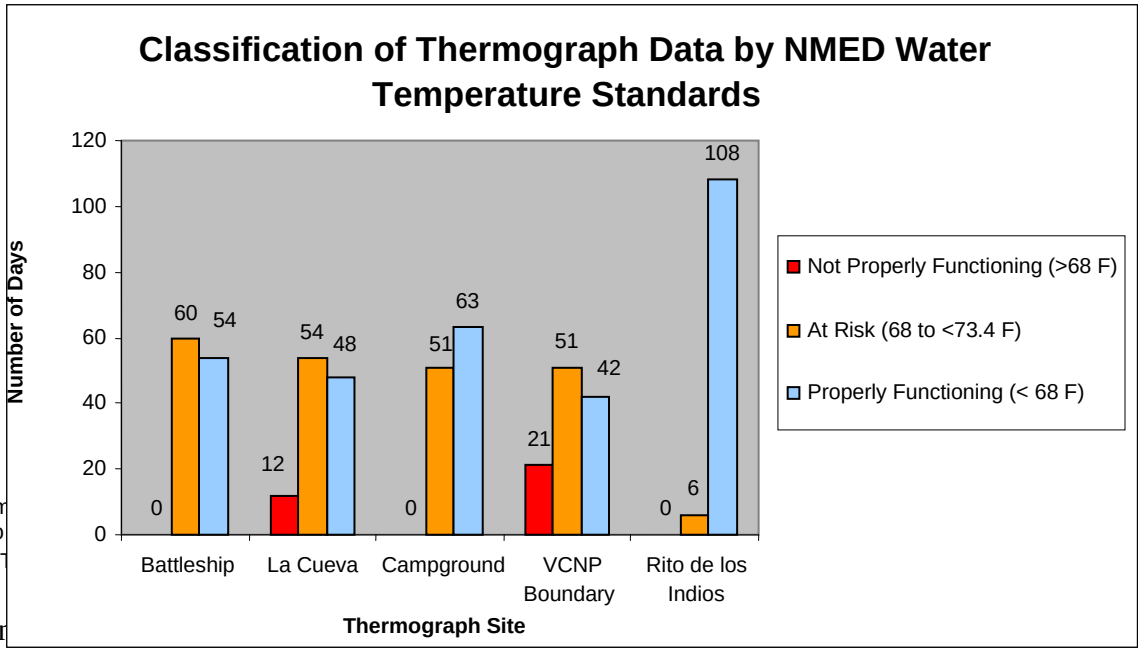


Figure 3: Com
in San Antonio
Water Quality T

Properly fu
under both the Forest and NMED standards (see Figures 2 and 3), but still remains **not properly functioning** under the Forest standard. Several factors contribute to the temperature decrease at the Campground station including a change in valley morphology, gradient and riparian vegetation. The valley morphology between the VCNP Boundary Station and the Campground Station becomes more confined allowing less solar contact. The riparian community shifts to include shade-providing vegetation and further decreases the sun's contact with San Antonio Creek. Although temperatures generally decrease through this section, several natural and human-caused warming factors influence water temperatures between the VCNP Boundary and the Campground. Factors that increase water temperatures and affect this section of stream include San Antonio Hot Springs, high human use and its impacts, grazing and previous anthropogenic stream modifications. San Antonio Hot Springs increased local San Antonio Creek's water temperatures by 2°F as determined by grab temperature samples collected at the time of survey. Heavy recreational use in this area and at San Antonio Campground increase erosion and sediment inputs to San Antonio Creek, which also lead to increased water temperatures. Areas of stock grazing, which contribute to decreased bank stability, had collapsed undercut banks and decreased riparian vegetation. Aside from these warming influences, the overall stream temperature decreases between VCNP Boundary and the Campground stations.

Only 1.5 miles separate the La Cueva and Campground stations, but there is a significant increase in temperature, listing this section as **not properly functioning** for both standards. This section of river is entirely private except for a few hundred feet managed by Forest Service. Visual observations of land use and habitat measurements of San Antonio Creek noted heavy grazing, stream modifications, loss of woody vegetation, and unstable banks. Excessive grazing can have degrading effects on stream habitat resulting in increased stream temperatures. Stream modifications, unless performed properly, can also degrade stream habitat and increase temperatures.

Stream temperatures decrease over the last four miles to Battleship. The valley morphology becomes confined, minimizing solar radiation. There is some natural influence related to Spence Hot Springs. Stream temperatures would likely improve if upstream conditions were improved.

To exemplify the temperature exchange over varying management regimes and valley forms, temperatures on July 19th from the headwaters down to the mouth were analyzed. Generally, temperatures show an increasing trend when progressing downstream with a peak at the La Cueva and VCNP Boundary stations. The peak at the La Cueva station is by far the most significant with a 3.5°F increase in 1.5 miles (see Figure 4).

Figure 4. Max temperatures at the five thermograph stations in San Antonio Creek, on July 19th, 2002. Stations are listed from left (Rito de los Indios) to right (Battleship) and demonstrate stream temperature changes with distance between stations.

Diurnal or daily high and low temperature fluctuations are analyzed from the thermograph stations. On July 19th, 2002, a particularly warm day, diurnal fluctuations ranged from 13.1°F at the Battleship station to 18.4°F at La Cueva.

Riparian Vegetation

Riparian vegetation is located on both banks of streams and rivers. Riparian areas serve many important functions including water purification, storage, erosion reduction and more. Riparian vegetation removes toxins from the water column and improves water quality. Riparian vegetation also stores water in the stream banks increasing available water and stream flow duration. Stream side vegetation also improves stream bank stability and reduces erosion and its associated fined sediment inputs (Brodie 1996). Riparian vegetation is important in maintaining a healthy fish population in San Antonio Creek.

The riparian vegetation is not consistent for the entire length of the stream. Three distinct riparian environments exist between the mouth and headwaters of San Antonio Creek. Reach 1 has a unique riparian habitat with high diversity. Alder, willow, locust and dogwood are the primary woody streamside vegetation, while water hemlock, grasses, and sedges dominate the herbaceous vegetation. From Reach 2 through 5 the diversity of vegetation decreases. Streamside woody vegetation is primarily comprised of alder and willow, while the herbaceous vegetation is mostly grasses, sedges, horsetail, and rushes (though overall quantity of herbaceous vegetation are severely decreased). From Reach 6 through 11, woody vegetation dramatically decreases, while herbaceous riparian

vegetation diversity increases. The only woody vegetation is an occasional patch of cinquefoil. The majority of streamside herbaceous vegetation is sedges, rushes, grasses, buttercups, sorrel, flea bane, dandelion, yarrow, thistle, horsetail (in wetter areas), hair bell, heal all, clover, spearmint, sunflowers, and scarlet Gila. Aquatic vegetation – potomogeten, elodea, coontail, and algae – were present in the entire stream, but increases in the upper reaches.

Photo 4. Stream surveyor in Reach 8 with the high concentration of aquatic vegetation typical of the upper reaches of San Antonio Creek (12 August 2002).

Beaver Activity

Beaver activity is heavy through San Antonio Creek's middle reaches. Beaver dams along San Antonio Creek are constructed from streamside alder and willow. Many effective dams back up the creek, creating large pools. The largest pools expand river width enough to drown upstream woody vegetation, which are eventually added to the dam. Beaver activity along the San Antonio is currently limited to Reaches 2, 4 and 5, with the highest density of beaver complexes being in Reach 4. These reaches are all prime beaver habitat due to their relatively low gradient and large amounts of woody riparian vegetation (willow and alder).

Some evidence suggests that historically beaver activity extended farther than its current range. The valleys within the VCNP currently lack woody riparian vegetation, a feature required for beaver occupation (Olson 1994). It continues to be debated whether VCNP historically contained woody riparian vegetation. The current lack of woody riparian vegetation could be a natural feature of the valleys or a result of intensive grazing. During the survey, a beaver skull was discovered near the river in a valley of the VCNP, providing evidence of their possible historic range. In 2001, the National Riparian Team found a small Bebb's willow plant in a neighboring valley within the caldera, Valle

Jaramillo. Beaver's dependence on woody vegetation within 100 feet of the stream (Allen 1983, Belovsky 1984) creates the possibility that at some point woody riparian vegetation did exist in the valleys.

Photo 5. S. Adams with a beaver dam creating pool habitat in Reach 2 (17 July 2002).

While the beaver's role in a watershed has been misunderstood by the public, land managers and biologists, studies over the last few decades conclude that beaver are a critical component to increasing stream integrity as well as biotic productivity within the stream and floodplain. Beaver dams were methodically removed from streams on public land until recently (FS Files).

Beavers have many influences on stream systems, surrounding riparian vegetation, and fisheries populations. Beaver caused stream impacts are considered to be generally beneficial to trout habitat and an asset to stream systems.

Beaver activity and its associated ponds have many affects on stream water quality, most of which are considered beneficial to trout habitat. The decreased stream velocity that occurs in pool habitat, such as beaver dams, decreases the waters ability to carry sediment suspended in the water column. Suspended sediment tends to settle into a pond's substrate, creating a sink for stream sediment and reducing turbidity. Sediment transport has been reduced by as much as ninety percent in studied streams (Olson 1994). Nitrogen and phosphorus containing sediments also settle, making beaver ponds a nutrient sink for a stream system. The storage of nutrient laden soil in sediment reduces eutrophication in nutrient rich systems. In low nutrient systems, such as headwater streams, the nutrient storage in pond sediment creates a time-release system increasing productivity. After the beaver leaves an area and the pond drains, the nutrient rich soil is utilized by riparian vegetation to produce dense riparian areas.

Decreased water velocity caused by beaver ponds alters the carbon cycle of streams. Reduced water velocity combined with increased water temperatures allows macroinvertebrates and bacteria to break down organic matter (leaves and wood) at a faster rate, creating dense macroinvertebrate populations. The breakdown converts organic matter to sediment and in some cases methane gas. The increased bacterial action reduces dissolved oxygen levels within the ponds and immediately downstream. The decreased velocity combined with increased width and overall surface area of the beaver ponds increases stream temperatures. The reduced concentration of dissolved

oxygen and increased temperatures usually does not reach levels of concern for trout in Rocky Mountain streams (Olson 1994).

Beaver activity also has an affect on the riparian vegetation within proximity of the ponds, as well as the water table. Beaver activity increases the surface area of ponds by several hundred times, which is highly influential on the surrounding riparian vegetation (see Photo 6). The increased surface area allows for storage of water in the banks and floodplain. The storage of water in the soil and floodplain increases the water table and stores water for times of low flow. During late summer low flow conditions, water stored in the banks provides cool water to moderate flow and extreme temperatures (Parker et al. 1985).

Photo 6. The effects of a beaver dam in Reach 4 on the wetted width and riparian vegetation of San Antonio Creek (18 July 2002).

While storing water, beaver dams also reduce extreme flows and related disturbance. The dams moderate flow during flood periods. This moderation reduces bank erosion related to flood events, improving bank stability in downstream areas (Olson 1994).

Beavers consume large quantities of riparian vegetation or woody supplies in their diet, as well as for the construction and maintenance of their habitat. Consumption rates for beaver populations are higher than the regeneration rates of riparian vegetation. Beaver tend to occupy an area until the surrounding supplies are consumed and then move on to a new section of river within or outside of the watershed. Once a beaver leaves, high nutrient content in the area allows for fast regeneration of consumed riparian vegetation. Over time, the area will regenerate and be ready for a beaver to return in future years (DeByle 1985).

Beavers generally improve trout habitat. Cutthroat trout in Rocky Mountain streams tend to be most abundant in streams with beaver ponds and are generally absent in streams with only abandoned ponds. Beavers do several things for fisheries habitat: provide a food source, moderate stream temperatures, as well as increase habitat volume and over wintering habitat. Trout biomass and individual size increases with the presence of beaver dams. One possible explanation is high density of macroinvertebrates involved in the decomposition of organic matter and consumption of bacteria. Macroinvertebrates are a key food source for many trout, including RGCT. Increased pool volume, a vital

habitat feature for trout, could also contribute to the correlation of healthy fish populations and beaver ponds. Over wintering habitat is also provided by the deep pools created by some ponds. The deeper pools become a refuge for fish when riffle habitat is frozen and can determine the carrying capacity of a stream. Flow and water temperature, moderating affects that are caused by increased water tables, provide cool water to the stream during low flow conditions. This could further increase the fish population carrying capacity of the stream (Olson 1994).

Forest Service projects over the last 20 years attempted to extricate species that caused undesirable impacts on fish habitat. In San Antonio Creek, projects focused on the removal of beaver dams through the use of dynamite (T. Moseley, personal communication 2001). Beavers have diverse effects on stream environments and the extreme nature of these impacts was thought to disrupt the stability of stream systems. Luckily, the projects focused on the removal of beavers were not completely successful and a beaver population still exists in San Antonio Creek.

Fisheries

Fish species native to San Antonio Creek drainage include Rio Grande cutthroat trout (*Oncorhynchus clarki virginalis*) (RGCT), Rio Grande sucker *(Catastomus plebius)*, Rio Grande chub *(Gila pandora)*, and longnose dace *(Rhinichthys cataractae)*. RGCT is the only native species not currently found in San Antonio Creek. While white sucker (*Catostomus commersoni)* is native to New Mexico, it is not native to Jemez Headwaters Watershed. White suckers have expanded their range in recent years due to habitat degradation and predation on native species as well as stocking practices in private ponds, all of which has assisted in decreasing native sucker populations. Further studies need to be conducted to determine if this new finding of white sucker is valid. Due to extensive stocking, German brown trout *(Salmo trutta)* and rainbow trout (*Oncorhynchus mykiss)* now take the place of native trout in San Antonio Creek (see Table 12).

Table 12. Fish Distribution in San Antonio Creek determined by evaluation of four snorkel sections (comprising 2800 meters of stream) in 2001 and 2002 and visual observations during stream survey. Snorkel sections were set up in Reaches 4, 5, 7, 8 and 9.

Fish Species	Native/Non-Native	Distribution by Reach
German brown trout	Non-Native	1 through 11
Rainbow trout	Non-Native	1 through 5*
Long-nosed dace	Native	1 through 11
Rio Grande sucker	Native	1 through 5*
[redacted]hite sucker	Invasive	1 through 4

Photo 7. Native Rio Grande cutthroat trout, a FS sensitive species.

Rainbow trout will freely hybridize with RGCT and threaten genetic purity of native populations (Sublette et al. 1990). Conflicts with exotic trout species are one factor that has defined RGCT as a sensitive species on the Forest Service's sensitive species list.

New Mexico Game & Fish (NMGF) stocks San Antonio Creek with between 500 and 700 rainbow trout twice a month from May to October. The two stocking locations are near La Cueva and San Antonio Hot Springs. German brown trout have not been stocked for years, but remain the dominant fish species. Between 1984 and 1987 the Forest Service completed a "Standing Crop" fish survey at four locations in San Antonio Creek (including one on the Baca Ranch). Rainbow trout were only present in the very lowest reaches and brown trout were present throughout. Brown trout dominated the middle and upper reaches of San Antonio Creek (USDA, "Unit Seven Standing Crops"). Snorkel surveys conducted by the Forest in 2001 and 2002 concur with these survey results (see Photo 7). Rainbow trout were observed in reaches 4 and 5, but no further upstream. Brown trout were observed throughout, with increasing population sizes farther upstream (Reaches 7-9). It has been proposed by the Forest to restore the population of RGCT to the entire length of San Antonio Creek (Ferrell 2002) in partnership with NMGF and VCNP. US Fish and Wildlife Service support this effort and believe that it is "an extremely valuable" effort to recover the species (FWS 2003).

Photo 8. Snorkeler surveying fish populations in Reach 5 (2002).

Native populations of Rio Grande sucker, Rio Grande chub and longnose dace are present in San Antonio Creek. One white sucker was observed in snorkeling surveys conducted in Reach 4. Further studies need to determine if white suckers have invaded San Antonio Creek (a private pond in Reach 2 has been stocked with "suckers" in past years (Ric Martin, personal communication, 2002)). Sucker and chub populations are limited to lower reaches. A possible barrier below San Antonio Hot Springs (located at the end of Reach 5) may maintain these population boundaries (a snorkel survey below and above the barrier would give more definitive understanding of population boundaries and barriers). Longnose dace are present throughout the length of the creek, but populations dramatically increase in the upper reaches.

Wildlife Species

San Antonio Watershed shelters a diverse array of wildlife including elk, black bear, coyotes, water shrews, grouse, migrating bald eagles, and wild turkeys. As well as these commonly found animals, the watershed also harbors federally-listed species. Northern goshawk (*Accipiter gentiles*), New Mexico meadow jumping mouse (*Zapus hudsonius luteus*), and Peregrine falcon (*Falco peregrinus*) are all "sensitive" species that live within the watershed. A documented sighting of the mouse occurred 3 miles upstream from San Antonio Campground. The only threatened species present in San Antonio Watershed is the Mexican Spotted Owl (*Strix occidentalis lucida*). Southwestern Willow Flycatcher (*Empidonax tralilii extimus*) is the only endangered species believed to have potential to reside in the watershed. Flycatcher presence has not been confirmed by an actual sighting, though suitable habitat does exist in the lower Jemez River watershed. Presence of these fragile populations demands vigilant watershed management (Wargo 2002).

Amphibian and Reptile Species

Rattlesnakes, garter snakes, and green snakes are present within San Antonio Watershed. One notable and rare amphibian species resides in the watershed. Jemez Mountain salamander, *Plethodon neomexicanus* (see Photo 9), is considered a sensitive species by the federal government and a threatened species by the State of New Mexico (Wargo 2002). No reptiles or amphibians were observed during the 2002 survey.

Photo 9. Jemez Mountain Salamander is found only in the Jemez Mountains, NM (David M. Dennis, enature.com).

Stream Improvements

Several attempts have been made to improve fisheries habitat in San Antonio Creek. Improvements were documented as early as the 60's with the last project implemented in the 1980's (FS files). These improvements include pool-forming features, bank stabilization, trash collectors and removal of migration barriers. Although stream modifications were intended to improve fish habitat, few projects succeeded and many actually degraded San Antonio Creek habitat.

Modifications intended to form pool type habitat include fixed log structures and debris anchors. The fixed log structures were anchored in place, either straight across or in a "V" shape spanning the river channel. The logs created a drop in the channel and eventually a scour pool. While initially quality habitat was formed, most of the structures were not successful in creating long-term pool habitat. Nearly all of the anchored log structures caused the stream's width to increase or forced the stream to move around the structure (see Photo 10). Due to the anchored and unbending nature of the modifications, many ended up breaking due to the extreme force imposed by the current, leaving only pieces of evidence of their existence. Both the log and anchor structures can be found in Reaches 1, 5, and 6.

In the 1960's, trash collectors were installed by the Forest and Girl Scouts in an effort to reduce the cost of log type structures (FS files). The trash collectors comprised of fence posts or other anchors placed in the substrate across the channel. Fencing was strung between fence posts to create a debris catching net. These structures were unsuccessful in creating pool habitat at the time of the survey. Fence posts remain, many bent and hard to see. These structures present a hazard to recreationists.

Photo 10. Stream survey crew with an anchored "V" shaped log structure that has failed in Reach 6. Notice the change in channel shape to bypass the stream improvement, rendering it ineffective, and causing stream widening and shallowing (30 July 2003).

Bank stabilization projects include the installation of gabion and riprap type structures. Gabion structures are comprised of broken rock anchored by fencing (similar to chicken wire) in areas where there is erosion potential. Riprap is piled and placed boulders, most often angular, to stabilize exposed banks often around road crossings or places of road encroachment. In San Antonio Creek bank stabilization projects were used to mitigate erosion and potential sediment inputs in proximity to high use areas. During the 2002 survey most of these structures were still intact. Unfortunately, by unnaturally hardening stream banks, water is forced to destabilize other areas downstream or upstream from this point in order to find equilibrium.

Previous stream modification projects include the removal of woody debris and logjams from San Antonio Creek. Logjams were perceived as fish migration barriers, separating fish populations from upstream habitat. Logjams were also believed to have negative impacts on fish habitat by decreasing the stability of the stream channel and causing erosion problems. These projects were implemented in the Jemez Mountains to remove woody debris and log jams from streams accessible by road in the 60's and 70's (FS files). Since much of this work was not specific in documentation, it is unclear if this occurred in San Antonio Creek. It is likely given its accessibility and fishing importance.

It is now understood that the changes that woody debris create in stream systems is a crucial aspect to their dynamic nature and beneficial to fish populations. In the study of a small British Columbia stream, sections of river that had previously been cleaned of woody debris were compared to sections that had been left undisturbed for at least 40 years. The sections of river that had been cleaned of woody debris contained simple habitat that was less sinuous, wider, and shallower and contained less pool volume and overhead cover. Populations of cutthroat trout were significantly greater in the more complex sections where woody debris was not removed (Fausch and Northcote 1992). Overall, large woody debris is beneficial to fish providing critical and dynamic habitat, cover, thermal protection and food.

LAND USE

Cultural Resources

Note: Many thanks to Chris Jenkins and Connie Constan, Jemez Ranger District archaeologists, for their historical interpretation of the Jemez area.

Archeologists have not surveyed most of the watershed due to the large percentage that is on the VCNP, which only recently became public land. Thirty-eight sites, at least 50 years old, have been identified on Forest Service land (Jenkins 2002). This figure is not necessarily representative of the total number of archeological sites that exist. Most mesa tops in this area, where early Puebloan people often lived, have not been surveyed. A large-scale cultural survey effort began on the VCNP in 2001, which has reaped extensive findings of[illegible] (a. S [illegible] aŒ, pei [illegible] nal [illegible] bicadi [illegible] 2002).

Land Grant was made in 1798, with major settlement near the confluence of the Jemez and Guadalupe Rivers. In 1821 Mexico gained independence from Spain and assumed control over New Mexico until the war of 1846 with the United States. After the treaty of Guadalupe Hidalgo in 1848, the United States assumed control over most of New Mexico, and the Anglo presence in the Jemez area became much greater.

Hispanic and Anglo use of the Jemez Mountains has focused on stock grazing, logging, mining, and hunting. The original Jemez Forest Reserve was created in 1905, while the Santa Fe National Forest was created in 1915 with the combination of the Jemez and Pecos Forest Reserves. Commercial logging of the area began in 1922 with formation of the White Pine Lumber Company and construction of a lumber mill and logging railroad from Bernalillo up the Jemez and Guadalupe Rivers (Glover 1989). Important railroad logging towns included Porter on the Rio Cebolla and O'Neil Landing on the Rio de las Vacas. The railroad line was abandoned in 1941 following a damaging flood. Use of the sawmill at Gilman, however, continued into the 1970's.

During the 1930's President Franklin D. Roosevelt created the Civilian Conservation Corps to provide work for unemployed males during the Depression and to cope with national conservation needs. CCC personal involved in a variety of conservation activities on the forest, including building fences and cattle guards for grazing management, constructing dams and erosion control along streams and drainages, and constructing roads, trails, campgrounds, and picnic areas for recreation purposes.

Some areas within the watershed were highly developed. Sulphur Springs (a San Antonio tributary) was mined extensively for sulphur at the turn of the 19th century (Baca Location Report 1993). This area still shows the signs of its past use with old equipment and pools of stagnant sulphur water. Recollections exist of a water-powered sawmill at Battleship Rock in the late 1800's (Sandoval 1981), but no obvious signs remain.

Roads:

Fish habitat degradation can result from poorly planned, designed, located, constructed, or maintained roads (Furniss et. al 1991). Even in good condition, roads introduce large quantities of sediment to streams (Grayson et al. 1993). The increased fine stream sediment concentrations that result from high road densities has been associated to decreased fry emergence, decreased juvenile densities, loss of winter carrying capacity, and increased predation of fishes. The introduction of fine sediment has also been related to the reproductive degradation in salmonids. Survival of incubating salmonids from embryos to emergent fry has been inversely related to the proportion of fine sediment in spawning gravels (USDA Forest Service 2000).

San Antonio Creek Watershed has an extensive road system, many of which are degraded and in need of maintenance. Between 5.6 and 10.7 miles of road per square mile exist in the San Antonio Creek Watershed. The highest road densities occur within the VCNP. The road densities are well above what is recommended for watersheds occupied by salmonids, less than 2.5 miles road per square mile (USFWS Matrix of Factors and Indicators of Bull Trout; NMFS Matrix of Factors and Indicators of Steelhead). Many of the roads in the VCNP are not currently maintained or used and should be considered for decommissioning or improvement. Some of these may be part of road improvements slated for 2003.

The high density of roads, many within proximity to San Antonio Creek and its tributaries, contribute to sedimentation and fish habitat degradation. During a rain event the impervious surface of a dirt road transports fine sediments, and if located near a river the sediment ends up in the water. Once in the water the fine sediments have several negative effects on fisheries habitat. Fine sediments decrease reproduction habitat by filling in fine gravels where fish spawn. Sediments also become suspended in the water column, clogging and decreasing the effectiveness of gills. Increased difficulty of oxygen extraction stresses and decreases the health of fish populations. The suspended sediments settle out of the water column in areas of decreased energy, like pools. Settling sediments end up filling in and decreasing pool habitat, reducing crucial fisheries habitat. In low gradient systems, suspended sediments also settle into riffle habitat filling in gravel substrates and degrading reproductive habitat.

The road system on the VCNP is a major concern and cause of fisheries habitat degradation. Many of the current roads are poorly designed, as most roads are constructed below grade causing rain water to collect on the roads, increasing erosion (USFS Report on Watershed Concerns Summer of 2001). None of the VCNP roads run parallel within proximity to San Antonio Creek, but do cross the stream in a perpendicular fashion. The road crossings increase the wetted width of San Antonio Creek. Due to distancing from the stream, sediment runoff and washed out roads have less of an effect on the stream when compared to the multiple road crossings. Most of the bridges that once allowed vehicles to pass over the stream have long since been washed out or collapsed. In their place are vehicle fords, which widen the stream, introduce fine sediments and degrade fish habitat. Arch culvert crossings are scheduled for implementation in 2003 in most if not all crossings on the VCNP.

A road management plan for San Antonio Creek Watershed is recommended. Seasonal closures should be explored along with unneeded roads being decommissioned and re-contoured. Roads that are crucial and cross San Antonio Creek should be outfitted with either bridges or bottomless arch culverts designed to handle 100-year flood events.

Many roads in the San Antonio Creek Watershed are located outside of the VCNP, including FS Roads 132 and 376 and State Highways 4 and 126. State Highway 126 had the largest impact on the stream, due to its proximity to the left bank for the entire first reach (3.3 miles). During rain events, it is noted that the clear waters of San Antonio Creek turn clay red. Sean Ferrell has investigated these events and observed that the highway road cut has induced slumping which once it rains pulses exorbitant amounts of clay sediments into the system. The key source area to be over a half-mile stretch around Spence Hot Springs, both up and down stream from this tributary (see Photos 11-13).

FS Road 376 is a low-maintenance, heavily-used road with difficult multiple-use management considerations. The road leads to an unmaintained parking area and hazardous administrative bridge crossing related to San Antonio Hot Springs. This highly visited area has serious issues that are discussed in the Recreation section and Reach Summaries. The road has drainage conditions that directly deliver sediments into San Antonio Creek and currently allows heavy four-wheel drive vehicle traffic to further expand resource damage. The Jemez Ranger District is exploring the possibility of a vehicle closure of the road at least one mile back from its current terminus while still allowing foot traffic to the hot springs area. The Fisheries Program would support this option as long as the road surface was rehabilitated to eliminate further resource damage.

Effects of slump caused by Highway 4 roadcut

Photo 11. San Antonio (entering on left) merges with East Fork Jemez River. Both drainages received heavy rain with San Antonio only showing effects (8 Aug 2001).

Photo 12. San Antonio Creek downstream from major slump after same rain event. Photo is taken from Highway 4.

Photo 13. Major slump below Highway 4 roadcut, downstream from Spence Hot Springs.

Timber Harvest:

Forested areas of the San Antonio Creek Watershed consist primarily of ponderosa pine (*Pinus ponderosa)*. However, higher elevations produce white fir (*Abies concolor*) and a mix of spruce (*Picea spp*.), quaking aspen (*Populus tremuloides)*, and Douglas-fir *(Pseudotsuga menziesii)*. Jemez Ranger District records date back to the late 1980's, but timber harvesting has occurred in the San Antonio Watershed since people have inhabited the area. Local history notes a timber sale in Mushroom Basin, which lies on Forest Service land, within the San Antonio Watershed. The notes of the Mushroom Basin timber sale leave no indication of the extent of the harvest. Forest thinning of the drainages in the vicinity of the western boundary of the Valles Caldera (on Forest Service Land) occurred around 1977.

Two major timber sales, Barley and Banco, occurred in the San Antonio Watershed within the last decade. The Barley Sale occurred between 1993 and 1998 and most of the sale took place outside of the watershed. The area within the watershed was located between FR 144 and 376. The Banco Timber Sale, located in both the East Fork Jemez and San Antonio Creek Watersheds, was completed in 1991. The sale covered a total of 193 acres and removed approximately 1.24 million board feet of timber (MMBF) between both watersheds. Approximately two thirds of the sale was located in the San Antonio Creek watershed (128.7 acres and 0.83 MMBF).

In addition to the major sales two small sales were active at the time of this report. The Ridge sale is a fuel-break/fuel-wood project in the Thompson Ridge area. This project involves thinning trees less than or equal to 9" diameter breast height within a 127 acre (300 foot wide, 3.5 mile long) corridor surrounding the privately owned Thompson Ridge Estates. In 1999 a proposal was made to remove some larger trees to create the minimum 15 to 20 ft. spacing between tree crowns for an effective firebreak. The purpose of this project was to reduce the threat of wildfire to the residents and improve firefighter safety in the event of a wildfire.

High quantities of timber harvesting occurred on the VCNP, which equated to over 60% of the forested acreage within the last 70 years (Baca Location Report, 1993; see Table 13). The Report on the Study of the Baca Location #1 states that timber harvesting is still an attractive management option. The forests that were logged in the past were replanted with young trees and might need thinning management in the future.

Table 13. Logging occurrences on the Baca Ranch between 1935 and 1993 (Baca Location Report, 1993).

Years	Acreage Logged
1935-1963	25,640
1963-1972	10,598
1972-1980	None
1980-1993	2,739
Total Number of Years:	Total Acreage:
58	38,977

Other timber-related management includes pest mitigation. In 1963 a pesticide was utilized in reaction to an outbreak of the tortricid moth larve, spruce budworm (*Choristoneura fumiferana)*. In reaction to the outbreak, the Forest applied *para-dichloro-diphenyl-trichloroethene* or DDT to the Jemez Ranger District. In an attempt of reduce the drift of the helicopter applied pesticide to non-target areas, low flight

patterns were established (USFS Fisheries Files). Later DDT was discovered to be toxic to humans and animals and banned in 1972 for most uses. Stations were established to monitor the effects of DDT on local fauna. No detrimental effects were identified in the study areas.

For aquatic resource and floodplain protection, future recommendations for timber management in San Antonio Watershed should be to manage riparian, floodplain and adjacent slopes as potential sources of LWD and to protect natural soil conditions. Harvesting of timber within 300' of live water should meet this objective. While this is a general statement, there are site-specific opportunities to conduct riparian thinning inside this buffer. In order to achieve this objective and assure large woody debris remains in the floodplain, firewood collection should be excluded from within this buffer.

Fires:

Historically, fire has played an important role in the forests of northern New Mexico. The forests adapted to a natural fire regime, which played an important role in the ecology of these systems. The historic fire regime consisted of smaller, more frequent fires that burned at a lower temperature than the current fires. Historic burns reduced the density of trees and shrubs, the amount of dead wood and kept forest fire fuels low. However, human intervention has dramatically altered the historic fire regime. Fire frequency in the Jemez Mountains has declined since the 1750's, possibly due to intensive grazing and shrub removal (Touchan et al. 1994). Over a century of fire suppression further reduced the fire regime frequency creating an abundance of fuel and increasing the potential for catastrophic fires similar to the 2000 Cerro Grande Fire. Catastrophic fires create larger and hotter burns, dramatically altering the ecosystem.

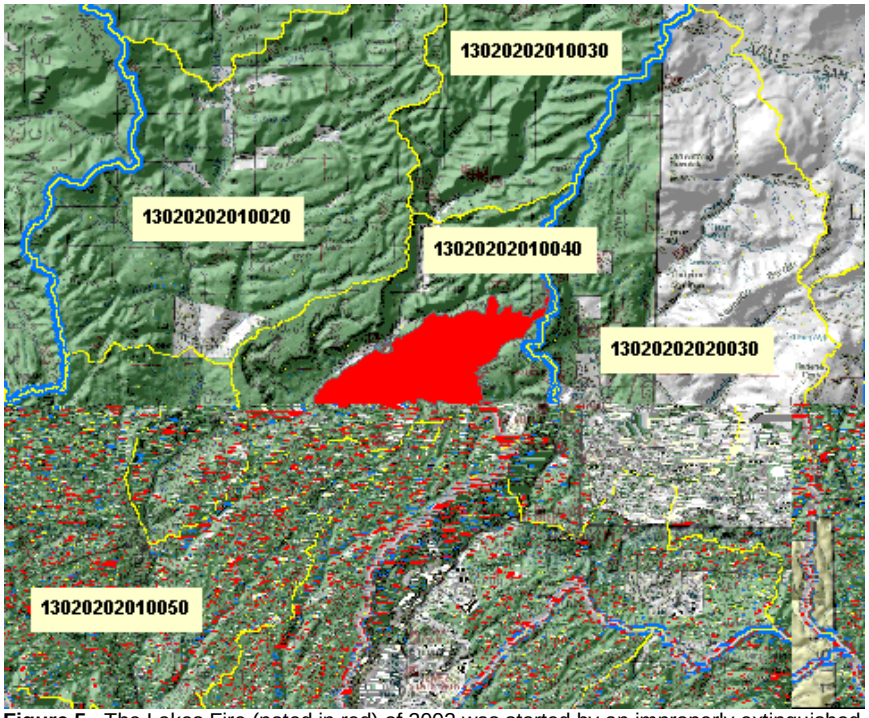


Figure 5. The Lakes Fire (noted in red) of 2002 was started by an improperly extinguished campfire and burned over 4000 acres. The yellow lines are 6th code watershed boundaries (or sub-watersheds) and the blue lines indicate the larger 5th code watersheds (San Antonio Creek falls within 130202020030).

No major fires or prescribed burns have occurred within the San Antonio Creek Watershed in the last 20 years. Two large fires that began in the neighboring Rio Cebolla Watershed slopped over into San Antonio in the 1970's. The Porter Fire, approximately
32

September. Only 711 animal units of cattle utilized this permitting period, but did not reach Valle San Antonio until two weeks after the completion of the survey. This is significant as the findings of the survey establish baseline after three years of rest prior to the VCNP establishing the beginning of its grazing program in Valle San Antonio.

The impacts of previous grazing practices are evident in San Antonio Creek within the VCNP. Many collapsed undercut banks and high riffle sediment content could be attributed to grazing practices. The collapsed undercut banks and other bank instability found in the VCNP showed signs of recovery. New vegetation is growing on the areas of erosion and beginning to stabilize the banks. The recovering state of bank instability could be attributed to the lack of grazing between 1999 and 2002.

Recreation:

The Forest has established seven (7) recreation areas along the creek. The majority of the recreation areas lie within Reach 1, accessible from State Highway 4. The Reach 1 recreation sites are day use only and include Battleship Rock, Rincon, Dark Canyon, Spence Hot Springs, and La Cueva Picnic area. With the exception of Spence Hot Springs, all of these sites are developed with paved parking and fishing areas. La Cueva and Battleship are open to vehicle access as weather permits but the public accesses these areas year-round. San Antonio Campground is a large developed camping area in Reach 4, accessible from State Highway 126. The campground has a host and opens from mid-spring to mid-fall, weather depending. San Antonio Creek Campground is slated for renovation in 2005 (Ferrell 2002). San Antonio Hot Springs is the uppermost vehicle access area on the Forest, accessible from FS Road 376. Located in Reach 6, it was turned from an overnight dispersed camping area to a day use area in the summer of 2002. The 4-mile access road is in substandard condition, and closed during winter months.

Federally acquired in 1999, the VNCP is temporarily closed to the public. Therefore, no recreation sites exist on this land (Reaches 7 through 11). However, there is a user trail that follows the river from San Antonio Hot Springs into the Valles Caldera. During our survey, one trespasser was observed camping about a half mile into the preserve land.

Forest recreation sites along San Antonio Creek are heavily used and have some amount of negative impacts to the river. Dispersed trails and campsites create bank instability, adding fine sediment to the stream. Recreation should be managed to increase riparian zone vegetation and stream integrity.

A watershed restoration and education program, entitled Respect the Rio, has been established on the Jemez Ranger District. This program can be used to promote and implement better user stewardship in the watershed.

Suggested practices to improve management through the Respect the Rio program include:

1) Modify and rehabilitate dispersed campsites and trails along San Antonio Creek by moving vehicle camping at least 100' away from the stream.
2) Either maintaining San Antonio Hot Springs as a "Day Use Only" area to protect natural and cultural resources or close the road at least one mile from its current terminus and allow walk-in camping. Dispersed campsites could be defined and hardened, established outside of the active floodplain.
3) Replant and re-establish riparian vegetation to restore the functions of the riparian ecosystem.
4) Place educational signs at trailheads and campsites to stress habits of river-friendly camping and/or day use.
5) Patrol the FS Road 376 corridor intensively, informing the public about the benefits and proper practices necessary for low-impact recreation, and/or establish a site host near the Hot Springs Area.
6) Establish a designated trail system in high use corridors, specifically from San Antonio Campground to San Antonio Hot Springs. Currently there are multiple dispersed trails reaching the same goal but causing exponential resource damage.

RECOMMENDATION SUMMARY

Education

Objective:
To educate forest users regarding the effects of their activities on the natural resources, inform them of ways of minimizing impacts and promote better use of the resource.

Concerns:
Public education is one of the most important tools to make management of these areas successful. Without education impacting activities will continue along with the associated damage. Rehabilitation programs spend millions of dollars repairing damage, but if the public isn't properly informed about a project, the money will have been spent needlessly.

Implementation methods:

1) Create a contact ranger program. A team of educators will contact forest users during intensive use times (summer), informing them of river-friendly camping, fishing, and other recreational practices. The team will also inform users of restoration and regulation changes occurring in the area.
2) Members of the public, including local and state decision makers, will be invited to join Santa Fe National Forest fisheries staff in seminars focused on stream integrity, including snorkeling seminars. Special seminars will also be offered to teachers and university courses.
3) Development and implementation of K-12 classroom educational programs. Several schools are either currently or becoming interested in water quality and riparian monitoring on forest water bodies.

Riparian

Objective:
To simulate riparian vegetation previous to anthropogenic impacts, promoting the San Antonio Creek Watershed integrity and function.

Concerns:
Currently, riparian vegetation is degraded in San Antonio Creek. Land use practices including, but not limited to, dispersed camping, riparian zone grazing are causing significant impacts on the riparian zone. Reduction of riparian zone species and decreased density are examples of the current degradation. The integrity of the riparian zone is crucial to stream function and coldwater fish habitat. The current riparian vegetation should be improved to resemble an undisturbed community.

Implementation methods include:

1) Augment current riparian area density by planting native species.
2) Grazing practices should be managed to provided additional protection for the riparian area between Highway 126 and the VCNP Boundary Fence.

3) Reduce the number and limit the use of dispersed trails and campsites within the riparian zone. This may include establishing hardened sites in the Hot Springs Area if walk-in camping is started.

Large Woody Debris

Objective:
To increase Large woody debris (LWD) densities to within the historic scope, improving coldwater fisheries habitat and stream integrity.

Concerns:
LWD in San Antonio Creek is below the estimated historic densities in forested reaches.

Implementation methods:

1) Arrange LWD in the floodplain and stream in strategic locations, increasing habitat complexity and fish habitat. These projects would utilize the best available science for LWD implementation.
2) Remove failed historic LWD projects to eliminate further stream and floodplain degradation caused by these failures.

Native fish populations

Objective:
To restore and protect populations of Rio Grande cutthroat trout, Rio Grande chub, Rio Grande sucker, and longnose dace in their historic range.

Concerns:
Populations of RGCT, which have been extirpated from San Antonio Creek, should be reintroduced.

Implementation methods:

1) Working in partnership with VCNP, NMGF and associated partners, develop and implement a native fish restoration plan.
2) In order to prevent upstream migration of non-native trout, waterfall areas could be enhanced, in such locations as below San Antonio Hot Springs (Reach 5) and around Dark Canyon (Reach 1).
3) If the restoration activities include the La Cueva area, work in partnership with community to assure their needs and concerns are met.

REACH SUMMARIES

Photo 14. Reach 1, NSO 100, R43. A typical riffle (3 July 2002).

Reach 1: Battleship Rock to NM Highway 4 crossing

Reach 1 begins at the mouth of San Antonio Creek, at Battleship Rock where the creek merges with East Fork Jemez River to form the Jemez River (T19N, R3E, Sec. 32, 6755' elev.). The survey progresses to the upstream side of the culvert under State Highway 4, below La Cueva (T19N, R3E, Sec. 20, elev. 7610'). The mapped length is 3.1 miles and the surveyed distance is 3.3 miles (includes stream sinuosity), with a gradient of 4.9%. Reach 1 is classified as an A2, moderately high gradient, confined with boulder as the dominant substrate.

The stream is paralleled on the left bank (looking upstream) by Highway 4 and the right bank by a steep canyon wall. The stream is marginally confined from Battleship to just north of Spence Hot Springs. This reach contains cobble and boulder dominant substrate. From Dark Canyon to the south end of the La Cueva Picnic Area, the stream became considerably confined and the gradient increased. The dominant substrate size increases to boulders and bedrock (boulder braiding and step pools were common habitat features).

This section had two waterfalls, as well as a number of shorter fall-like sections, which could be altered for the creation of a fish passage barrier (see Photo 15). Around the La Cueva Picnic Area, the valley floor widened considerably and the stream gradient decreased and the substrate is again dominated by cobble and gravel. This reach is characterized as an A2 stream by the Rosgen stream classifications. The reach ends with an increase of valley width and decreased gradient.

Photo 15. Reach 1, NSO 102, F2. S. Ferrell with cascade habitat and left bank erosion in Reach 1 (3 July 2002).

Numerous day use areas are dispersed through the reach, all of which displayed increased anthropogenic instability. Much of the instability is caused by recreational use and dispersed campsites (found at Rincon, and in an area between Rincon and Dark Canyon) and trails. Working from the mouth upstream, the high use areas are Battleship Rock

(see Photo 16), Rincon, Spence Hot Springs (undeveloped), Dark Canyon, a dispersed campsite between Rincon and Dark Canyon (minimal use), and La Cueva Picnic Area. Gabion structures, riprap, and concrete walls (for handicap fishing access) have been installed to increase bank stability in these areas. In high use areas, especially Spence Hot Springs, anthropogenic erosion are sources of stream sediment. Pools contained thick layers of sediment build up, and after storms the entire stream's water clarity decreased significantly, possibly influenced by the erosion in high use areas.

Photo 16. Reach 1, NSO 6, R3. Battleship Picnic Area encroaches on function of floodplain with boulder/mortar walls (26 June 2002).

Seven (7) tributaries fed San Antonio in Reach 1. The most significant tributary contributed an estimated 15%, with the rest contributing 5% or less of the main channel flow. Two (2) tributaries at Spence Hot Springs fed warm water (78° to 82°F) into San Antonio. This area also had an extensive amount of poison ivy.

Large woody debris (LWD) density or the number of pieces of wood per mile is low in Reach 1. Most of the LWD is located just upstream of Dark Canyon. The only logjam (minimum of three pieces, each greater than minimum size requirements) is located near the end of the reach, in La Cueva Picnic Area. Some woody debris show signs of beaver

B

and sediment to San Antonio Creek. Signs of high flow events include scoured and downcut channels leading from the culverts with exposed soil and no vegetation.

Most of the herbaceous streamside vegetation is water hemlock, sedges, and grasses. Willow, alder, and dogwood are the primary woody plants in the riparian zone. White fir, Douglas-fir, ponderosa pines, gamble oak, and New Mexico locust were prevalent upland vegetation species. In the stream, especially north of Dark Canyon, high densities of aquatic vegetation exist, including elodea, algae and mosses.

Twenty-six (26) side channels are in Reach 1. The main channel flows through a section of boulder braiding between Dark Canyon and the La Cueva Picnic Area. Boulder braiding and secondary channels increase habitat complexity and are beneficial to fish habitat.

Due to high turbidity, fish were difficult to see. One dead brown trout was found between Rincon and Dark Canyon. At the La Cueva Picnic Area a number of 6-9" trout were in a large pool, but were unidentifiable due to poor water clarity.

Water temperatures were measured at random intervals during the survey using an alcohol thermometer. Main channel temperature readings were taken in the water column in main channel habitats during the survey (grab samples). The 23 water temperatures samples ranged between 59 and 70 °F. Average grab sample temperature was 62.5 °F.

A water temperature station was located at the mouth of the river and recorded temperatures between June 11th and December 16th, 2002. The highest temperatures were between June and August (see Figure 6). San Antonio Creek was compared to Santa Fe National Forest (SFNF) and New Mexico Environment Department (NMED) standards for classification as either properly functioning (PF), at risk or not properly functioning (NPF) (see Temperature section). Temperatures at the Battleship Station were **not properly functioning** by SFNF classification 21 of the 114 days between June 11th and September 30th 2002. Temperatures were **properly functioning** for NMED standards.

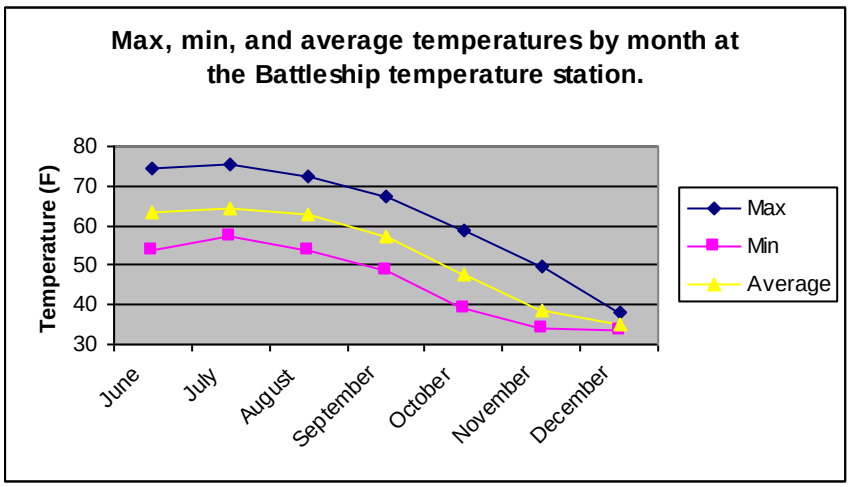


Figure 6. Maximum, minimum and average temperatures for each month

Habitat Characteristics

Reach 1 was divided into 124 NSOs, measuring 3.3 miles or 17,410 feet. Thirty-five (35) pool habitats, comprise only 8.5% of the stream habitat. The 53 riffle NSOs make up 81.7% of the stream habitat in Reach 1 (see Table 14).

Table 14. Summary of Reach 1 habitat types.

Habitat Type	Number of Habitats	Total Stream Habitat (ft)	Stream Length* (%)	Stream Habitat** (%)	Properly Functioning Indicators
Pool	35	1627	9.3	8.5	>30%
Riffle	53	15,697	90.2	81.7	-
Culvert	1	52	0.3	0.3	-
Tributary	7	NA	NA	NA	-
Falls	0	34	0.2	0.2	-
Side Channel	26	1779	NA	9.3	-
Total	124	19,189	100.0	100.0	-

*Percent Stream Length calculated with only riffle, pool, culvert, and falls habitat types.
**Percent Stream Habitat calculated using all stream habitat types except tributary.

When compared to the matrix of factors and indicators of stream health condition for historic and occupied Rio Grande cutthroat trout streams, Reach 1 has both not properly functioning and properly functioning characteristics. The parameters that are **not properly functioning** include pool habitat volume by length, width-to-depth ratio and the number of large woody debris per mile. **Properly functioning** characteristics include the relative sediment content in riffle habitat and bank condition.

Riffle habitat in Reach 1 is **properly functioning** for average relative sediment content. The relative sediment content is just below the standard (19.5%; see Table 15). Relative sediment content is an uncorrected surveyor estimation and subject to error. The difference that separates the percentage fine sediment from its associated standard is marginal and should be considered for a more detailed analysis. Until a more definitive sediment survey is conducted this factor will be considered high but **properly functioning**.

Table 15. Summary of Habitat and Substrate Percentages for Riffles in Reach 1.

Riffle Habitat Summary						
Reach	Number of Riffles	Avg. Length	Avg. Width	Avg. Depth	Avg. Max. Depth	
1	53	296.2	16.7	1.1	2.4	
Substrate Summary						
Reach	% Sand	% Gravel	% Cobble	% Boulder	% Bedrock	Total
1	19.5	19.1	26.3	31.9	3.2	100.0
Properly Functioning Indicators	<20.0	-	-	-	-	-

The high fine sediment content has several possible sources both localized in Reach 1 and upstream. Upstream sediment is washed downstream by flood events spreading the effects of unstable banks or other erosion to downstream habitat. Although the estimated length of bank instability is **properly functioning** (see Table 17) in Reach 1**,** the focused high use areas contribute to the riffle sediment content (many of which are outside the measured scope of the survey). Many dispersed trails are located near high use areas like Battleship Campground, Dark Canyon and Spence Hot Springs. The many dispersed trails located in these areas create erosion and sediment inputs to San Antonio Creek. Installing designated trails in these areas might decrease the riffle sediment content. In addition, slumping caused by the Highway 4 road cut continues to be a source of sediment during rain events (see Roads section).

Pool development is **not properly functioning** as determined by pool habitat by area. (7.5%; see Table 14). Pool development should be a priority in the management of Reach 1. The number of quality pools (max depth greater than 3') is significantly low (6 out of 35 pools surveyed), a possible indication that pools are filling in.

Photo 17. Reach 1, NSO 81, R35. Some of the best pool habitat was located within riffles in the form of step pools, which were too small to consider as an individual habitat (by definition a pool has been to be longer than it is wide and be channel-spanning). This step pool had a maximum depth greater than 7' but was not long enough to be called a pool (2 July 2002).

Table 16. Summary of Pool Habitat and Substrate Percentages in Reach 1.

Pool Habitat Summary											
Reach	# Of Pools	Avg. Length	Avg. Width	Avg. Max Depth	Avg. PTC	Avg. Residual Depth	Pools/Mile	# of Pools w/ Residual Depth >1'	Pools w/ Residual Depth >1'/Mile	# of Pools w/ Max. Depth >3'	# of Pools w/ Max. Depth >3'/Mile
1	35	46.5	18.2	3.0	0.7	2.3	10.6	35	10.6	6	1.8
Properly Functioning Indicators	-	-	-	-	-	≥1ft[1]	-	-	-	-	-

Substrate Summary							
Reach	% Sand	% Gravel	% Cobble	% Boulder	% Bedrock	Total	
1	44.0	15.7	14.3	21.1	4.9	100.0	

[1]The pool quality parameter is excluded from analysis in San Antonio Creek due to surveyor error.

Large woody debris density in Reach 1 is **not properly functioning** with only 8.2 pieces per mile (see Table 17). Large woody debris is a key factor in pool development and is related to the substandard pool development in the reach. Large woody debris density should be a focus of the management of this reach.

The lack of LWD in Reach 1 can be attributed to projects that focused on its removal from fish bearing streams. It was a common practice in the 1960's to 1970's to remove LWD from streams in an attempt to improve stream habitat. Logjams were believed to be barriers to fish passage, creating negative impacts on fish population dynamics. It is now understood that LWD does not hinder fish movement in stream systems. In fact, LWD is an essential part of pool formation and critical in providing complex fish habitat (Fausch and Northcote 1992). The accessibility of this reach may be another reason for the low LWD density. Campers and other recreational users may have physically removed LWD for use in campfires.

Table 17. Habitat Characteristics for San Antonio Creek.

Area	Pool:Riffle Ratio	Avg. Bankfull Width:Depth	Pieces of LWD per Mile	Total Unstable Banks (ft)	% Unstable Banks
Reach 1	1:1.5	12:1	8.2	2375	6.8
Properly Functioning Indicators	-	<12	>30	-	<10

Historic fire suppression practices may be another reason for the lack of LWD in this reach. Fire ecology is an important part of the landscape in New Mexico. Large fires would remove the under story, and open up the canopy for ponderosa pine, the dominant tree species. Fires assist in LWD recruitment for streams in this region. The dying trees would eventually fall into the stream channel. The stream would then move the LWD during floods, settling in stream margins or in the channel, creating pool and side channel habitat. The lack of major fires over the last century has greatly diminished the amount of LWD in New Mexico streams.

The bankfull width-to-depth ratio is **at risk** for a Rosgen A-type channel (see Table 17). This bankfull measurement should be verified with additional measurements throughout the reach.

Streambank condition by length is **properly functioning** in Reach 1. Several high use areas create severe impacts in focused areas, which aren't represented by the length analysis (see Photo 18). Dispersed access trails were the primary factor degrading streambank condition. The high use areas could contribute to the high relative fine sediment in riffle habitats.

decreasing sediment loading in riffle habitat. Restoring LWD density to historic levels would improve both stream habitat and increase fish populations.

The dispersed trails in Reach 1 should be blocked off and redirected to properly constructed trails that minimize erosion. Areas which are now eroded should be replanted with vegetation to further reduce the erosion potential. Currently, these areas are causing sedimentation problems and adding to the high fine sediment content in Reach 1.

Personal contact with users and educational signs would be necessary to ensure that the restoration would be truly effective. This area receives heavy recreational use from early spring to late fall.

Reach 2: NM Highway 4 crossing to Hidden Valley Road crossing

Reach 2 begins just above the culvert that runs under Highway 4 in La Cueva (T19N, R3E, Sec. 20, elev. 7610') and ends at the top of the culvert under Hidden Valley Road, north of La Cueva (T19N, R3E, Sec. 17, elev. 7630'). The stream length is 0.47 miles, most of which is on private land with a number of different landowners. A small section of US Forest Service land lies in between the privately owned sections. The entire section of the stream is low gradient (0.8%) and completely unconfined, in a wide meadow floodplain. Classified as a Rosgen C3 reach, dominant habitat features include long riffles with a cobble dominant substrate. Surveyed between June 26th and July 8th, 2002, the end of Reach 2 is related to a significant decrease in gradient and widening of the valley floor.

Sulphur Creek is the only tributary drainage in this reach; however, at the time of our survey this creek was dry. Three beaver dams are dispersed throughout this reach (see Photo 19). The largest beaver dam is at the beginning of this reach, creating a 420-foot long pool.

Photo 19. Reach 2, NSO 125, P36. A beaver created pool in proximity to the housing and roads of La Cueva (17 July 2002).

Many signs of anthropogenic impacts are evident in Reach 2, which could be related to land ownership and the reach's proximity to the town of La Cueva. Barbed wire fencing marked each property boundary. Multiple manmade cobble dams are scattered through the reach in attempts to create pool habitat. Five trash collectors or fencing stakes anchored in the substrate connected by a wire fence are located near the middle of the reach. The trash collectors have been in the channel for some time. Some have begun to

disappear under the substrate. Private land in Reach 2 consists of a scattered housing development with no signs of streamside grazing.

There is no large woody debris in Reach 2 and only one side channel.

Most of the herbaceous streamside vegetation is water hemlock, sedges, rushes and grasses. Willow and alder are the primary woody plants that grow close to the stream. Through much of this reach the willow and alder hung far out into the stream, providing shade and covering the stream. The upland area was scattered with ponderosa pines. High density of aquatic vegetation is located in the main channel including elodea, coontail, and potamogeten, as well as algae.

Due to poor water clarity many fish were not visible. One dead rainbow trout was found.

Photo 20. Reach 2, NSO 126, R54. Typical riffle habitat with atypical woody riparian vegetation (17 July 2002).

Water temperatures were measured at random intervals during the survey using a handheld thermometer. Main channel temperatures were taken in the water column in main channel habitats. Two temperatures were taken during the survey of Reach 2. The higher temperature was 64°F (11:15) and the lower temperature was 58°F (10:05).

A water temperature station was established in Reach 2 on June 11th and removed on November 23rd, 2002. The station was located at the downstream end of the reach. The highest temperatures were between June and August (see Figure 7). San Antonio Creek is compared to Forest and NMED standards for classification as either properly functioning, at risk or not properly functioning (see Temperature section). Temperatures at the La

Cueva temperature station are **not properly functioning** by Forest standards 35 days and by NMED standards 12 of the 114 days between June 11th and September 30th 2002.

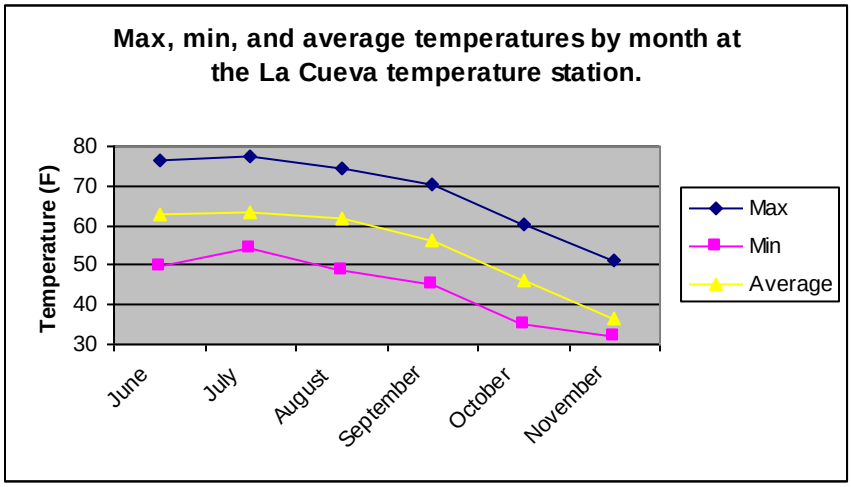


Figure 7. Maximum, minimum and average temperatures for each month from thermograph station in Reach 2.

Habitat Characteristics

Reach 2 is divided into 12 NSOs, measuring 0.47 miles or 2,502 feet. Four NSO's are pool habitats, and comprised over 34% of the stream habitat. Five riffle habitats make up 60.5 % of the stream habitat in Reach 2 (see Table 18).

Table 18. Summary of Reach 2 habitat types

Habitat Type	Number of Habitats	Total Stream Habitat (ft)	Stream Length* (%)	Stream Habitat** (%)	Properly Functioning Indicators
Pool	4	896	35.7	34.1	>30%
Riffle	5	1590	63.5	60.5	-
Culvert	1	16	0.6	0.6	-
Tributary	1	NA	NA	NA	-
Falls	0	0	0	0	-
Side Channel	1	126	NA	4.8	-
Total	12	2,628	100.0	100.0	-

*Percent Stream Length calculated with only riffle, pool, culvert, and falls habitat types.
**Percent Stream Habitat calculated using all stream habitat types except tributary.

When compared to the matrix of factors and indicators of stream health condition condition for historic and occupied Rio Grande cutthroat trout streams, Reach 2 contains characteristics that are both **not properly functioning** and **properly functioning.** The parameters that are **not properly functioning** include the relative sediment content in riffles and LWD density. **Properly functioning** factors include pool development, width-to-depth ratio, and bank stability.

The average relative sediment content in Reach 2 is **not properly functioning**. The estimation of fine sediment in riffles is 24% (see Table 19).

The high fine sediment content has several possible sources both localized in Reach 2 and upstream. Upstream sources affect the sediment content in Reach 2. Upstream sediment is washed downstream by flood events spreading the effects of unstable banks or other erosion to downstream habitat. Localized sediment sources are related to management of private land.

Table 19. Summary of Habitat and Substrate Percentages for Riffles in Reach 2.

Riffle Habitat Summary						
Reach	# of Riffles	Avg. Length	Avg. Width	Avg. Depth	Avg. Max. Depth	
2	5	318	20.3	1.0	2.0	
Substrate Summary						
Reach	% Sand	% Gravel	% Cobble	% Boulder	% Bedrock	Total
2	24.0	28.0	36.0	12.	0.0	100.0
Properly Functioning Indicators	<20.0	-	-	-	-	-

Pool development is **properly functioning** (see Table 20) in Reach 2, with a higher pool than riffle volume. This is the only reach with properly functioning pool habitat and is entirely related to beaver habitation through most of the reach length.

Table 21. Summary of Pool Habitat and Substrate Percentages in Reach 2.

Pool Habitat Summary											
Reach	# Of Pools	Avg. Length	Avg. Width	Avg. Max Depth	Avg. PTC	Avg. Residual Depth	Pools/Mile	# of Pools w/ Residual Depth >1'	Pools w/ Residual Depth >1'/Mile	# of Pools w/ Max. Depth >3'	# of Pools w/ Max. Depth >3'/Mile
2	4	224	25.0[1]	2.9	0.9	2.0	8.4	4	8.4	0	0
Properly Functioning Indicators	-	-	-	-	-	≥1ft[2]	-	-	-	-	-

Substrate Summary							
	Reach	% Sand	% Gravel	% Cobble	% Boulder	% Bedrock	Total
	2	55.0	27.5	15.0	2.5	0.0	100.0

[1]Average width calculation is an uncorrected surveyor estimate due to the lack of measured pool habitat in Reach 2.
[2]The pool quality parameter is excluded from analysis in San Antonio Creek due to surveyor error.

The number of large woody debris per mile in Reach 2 is **not properly functioning**. No LWD was located in Reach 2, far below the standard of 30 pieces per mile (see Table 22). Large woody debris is a key factor in pool development and is related to the substandard pool development in the reach. It is likely that through private land management, LWD has been removed when it has accumulated in this reach. Further human manipulation is observed long sections of stream have been straightened.

Width-to-depth ratio is within the expected range for a Rosgen C3 stream and bank stability was well below the standard (see Table 22).

Table 22. Habitat Characteristics for Reach 2 of San Antonio Creek.

Reach	Pool:Riffle Ratio	Avg. Bankfull Width:Depth	Pieces of LWD per Mile	Total Unstable Banks (ft)	% Unstable Banks
2	1:1.3	21:1	0	141	2.8
Properly Functioning Indicators	-	12-30	>30	-	<10

Recommendations

Management suggestions for Reach 2 include the evaluation of the Hidden Valley Road box culvert crossing, increasing LWD density and reducing stream sediment. The bridge should be evaluated for its suitability to handle high flow and flood events of San Antonio Creek (see Photo 21).

For interested private landowners, the Forest could work in partnership to assist in improving stream habitat through LWD placement to increase habitat complexity. In addition, riparian zones could be placed in conservation easements and excluded from livestock grazing. These mitigation efforts will assist in decreasing stream temperatures and reducing sediment content in riffles

Photo 21. Reach 2, NSO 136, C2. Serina Adams at the Hidden Valley box culvert crossing (17 July 2002).

Reach 3: Hidden Valley Road crossing to the downstream end of the Sheen Estates Pond

Reach 3 runs through private land, access to survey this area was not granted and therefore no natural sequence orders were assigned to Reach 3. Beginning directly upstream of the Hidden Valley Road box culvert (T19N, R3E, Sec. 17, elev. 7630'), the reach ends approximately 0.1 miles upstream at a barbed wire fence line (T19, R3E, Sec. 17, elev. 7640'). Most of this reach is visible from the road allowing general observations. A low gradient open valley (1.8%) characterizes Reach 3. Evidence of stream modifications was apparent, including log structures anchored across the stream, probably an attempt to create pool habitat. A few small manmade pools are located between short riffles. Extensive horse grazing is apparent on the stream bank. The stream is bordered by green grass stubble (due to grazing) but no other herbaceous or woody vegetation.

Photo 22. Reach 3, unsurveyed private land (17 July 2002).

Reach 4: Downstream end of Sheen Estates Pond to NM Highway 126 crossing

Reach 4 begins just north of the fence line at the end of the unsurveyed private land (T19, R3E, Sec. 17, elev. 7640') and ends 1.5 miles upstream after the culvert under Highway 126 (T19N, R3E, Sec. 8, elev. 7720'). The first section of this reach is on private land, with a number of landowners, while the second is on Forest land. Stream gradient increases slightly from the previous reaches, but remains relatively flat with a 1.0% gradient. For most of the reach, the channel was unconfined in a wide valley. Just south of San Antonio Creek Campground the valley width decreases slightly, marginally confining the stream channel. Reach 4 can be characterized by beaver dam complexes and riffles with cobble dominant substrate. Reach 4 is classified as a Rosgen B3 stream class. The reach ends due to a narrowing of the valley floor and a slight increase in gradient.

Photo 23. Reach 4, NSO 155, P47. S. Adams at the base of a substantial beaver dam. Beaver-created pools constituted nearly 65% of the pool habitat in the reach.

Beaver activity is substantial in this reach with three large complexes and a few smaller dams (see Photo 23). The largest beaver dam complex is 385 feet long. The dams are wide, creating pools with an average width of up to 80 feet and contain more than one hydraulic release. Multiple side channels exist below most of the dams, which increase habitat complexity. Eight side channels are located in the reach. One human constructed side channel diverts approximately half of its flow into an irrigation ditch, while the other half returns to the main channel.

Many signs of anthropogenic impacts are evident in Reach 4, as the first section of this land passed through private land, and the last part moved through San Antonio Campground. Barbed wire fencing marks private land boundaries. Near the beginning of the reach, a small percentage of the flow is diverted to fill a man-made pond. The pond was 69°F, three degrees warmer than the stream water during the survey. Horses graze streamside through most of the private land with obvious impacts. Reach 4 streamside grazing impacts include decreased bank stability and riparian vegetation reduced to stubble. Several riparian sections are protected by fencing, exhibiting increased bank stability and dense woody riparian vegetation (see Photos 24 and 25).

Photo 24 and 25. Reach 4, NSO 144, R62. Differences in private land management: Grazing exclosure fence protects riparian (above) compared to lack of fencing (below). Pictures were taken in same riffle habitat unit (17 July 2002).

Three single-lane bridges cross San Antonio Creek on private land including the Sheen Estates, Twisted Juniper Road, and Horseshoe Springs Road. The bridges appear to be properly constructed as to not degrade stream habitat even during high flow events.

San Antonio Campground lies close to the creek and illustrates the impacts of anthropogenic degradation (see Photo 26). Dispersed trails originating at the campground parallel the creek. Dispersed trail density is the highest near the campground as well as the associated decreased bank stability. The Campground is scheduled for renovation in 2005 and has design plans to minimize these impacts.

Several anthropogenic stream modifications in Reach 4 include cobble dams and "trash collectors". Manmade cobble dams are spread through the reach, unsuccessfully attempting to increase pool habitat (see Photo 26). Ten "trash collectors" are located near the campground, which consist of fencing stakes pounded into the river substrate, with fencing strung between each post. The collectors have been there since the 1960's, and several are disappearing below the substrate. The "trash collectors" present a hazard for the many recreational users of this area and should be removed.

Photo 26. Reach 4, NSO 162, P50. Surveyors near San Antonio Campground with a manmade cobble dam and bank instability caused by dispersed trails (22 July 2002).

The majority of herbaceous streamside vegetation consists of water hemlock, horsetail, sedges, rushes and grasses. Willow, alder, and current are the primary woody plants that grow close to the stream. In several areas, willow and alder hung far out into the stream, providing shade and cover for fish. Upland vegetation is dominated by ponderosa pines with several white firs near the end of the reach. Aquatic vegetation in Reach 4 is dense; species present include elodea, potamogeten, and coontail, as well as algae.

One 500 meter snorkel survey was conducted from just south of San Antonio Campground to 50 meters upstream of the Highway 126 culvert. The survey was conducted on July 9th and 11th and divided into 5 transects. Snorkelers observed fish even in the poor water clarity, although it is probable that some were missed. The majority of the fish counted below the Highway 126 culvert were longnose dace between two and six inches. Brown trout had the second largest population followed by the Rio Grande sucker. Other fish observed included rainbow trout, white sucker and Rio Grande Chub (see Appendix A, Table 5 for total observations). The largest size class of brown trout is < 3 inches, demonstrating their continuing reproduction. The lack of <3 inch rainbow trout indicates limited natural recruitment, which might be explained by the assumed sterile condition of hatchery-stocked fish (see Figure 8).

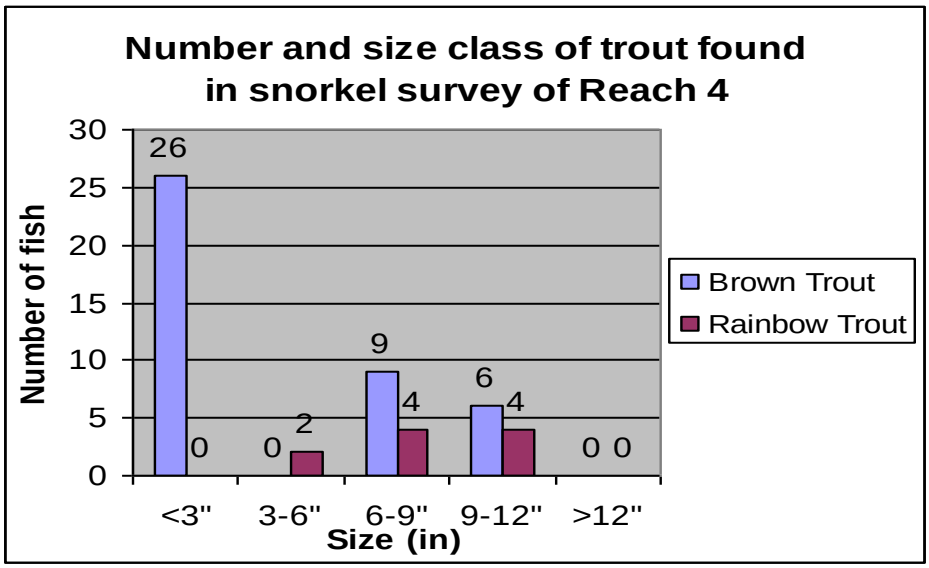


Figure 8. Trout species and size class in a 500-meter snorkel survey of San Antonio Creek.

Water temperatures were measured at random intervals during the survey using a handheld thermometer. Main channel temperature readings were taken in the water column. Eight temperatures were taken during the survey of Reach 4. The highest temperature was 68°F and the lowest, 60°F.

A water temperature station was established in Reach 4 on June 11th and removed on November 10th, 2002. The highest temperatures were between June and August (Figure 8). San Antonio Creek is compared to Forest and NMED standards for classification as either properly functioning, at risk or not properly functioning (see Temperature section). Temperatures at the Campground temperature station are **not properly functioning** by Forest standards 21 of the 114 days between June 11th and September 30th 2002. Fifty-one days are classified as **at risk** by NMED standards.

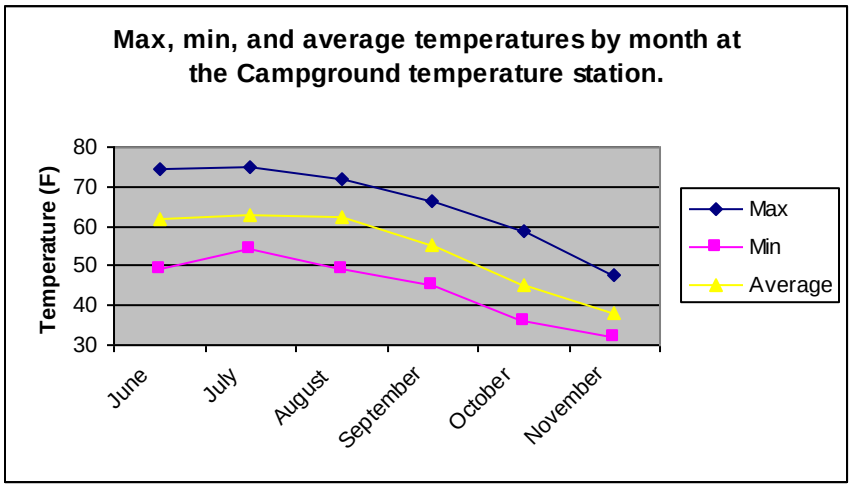


Figure 9. Maximum, minimum and average temperatures for each month from thermograph station in Reach 4.

Habitat Characteristics

The 1.5 miles (7,819 ft) of Reach 4 is divided into 37 NSOs. Fourteen NSOs are pool habitat and comprised 27.9% of the stream habitat. The 14 riffle habitats make up 58.5% of stream habitat in Reach 4 (see Table 23).

Table 23. Summary of Reach 4 habitat types

Habitat Type	Number of Habitats	Total Stream Habitat (ft)	Stream Length* (%)	Stream Habitat** (%)	Properly Functioning Indicators
Pool	14	2481	31.7	27.9	>30%
Riffle	14	5194	66.5	58.5	-
Culvert	1	144	1.8	1.7	-
Tributary	0	NA	NA	NA	-
Falls	0	0	0	0	-
Side Channel	8	1058	NA	11.9	-
Total	37	8,877	100.0	100.0	-

*Percent Stream Length calculated with only riffle, pool, culvert, and falls habitat types.
**Percent Stream Habitat calculated using all stream habitat types except tributary.

When compared to the matrix of factors and indicators for stream health condition of historic and occupied Rio Grande cutthroat trout streams, Reach 4 contains both **not properly functioning** and **properly functioning** characteristics. Parameters that are **not properly functioning** include the relative fine substrate in riffle habitat, percent of pool habitat by length, and number of large woody debris (LWD) per mile. The **properly functioning** characteristics include width to depth ratio, and stream bank condition.

Riffle habitat in Reach 4 is **not properly functioning** for average relative sediment content (32.9%; see Table 24). The possible sources of sediment in this reach include bank instability, road crossings, dispersed trails and natural erosion. Well above the matrix standard, decreasing inputs of fine sediment should be a focus in the management of this and upstream reaches.

Table 24. Summary of Habitat and Substrate Percentages for Riffles in Reach 4.

Riffle Habitat Summary						
Reach	Number of Riffles	Avg. Length	Avg. Width	Avg. Depth	Avg. Max. Depth	
4	14	371	18.3	0.9	1.8	
Substrate Summary						
Reach	% Sand	% Gravel	% Cobble	% Boulder	% Bedrock	Total
4	32.9	21.4	39.3	6.4	0.0	100.0
Properly Functioning Indicators	<20.0	-	-	-	-	-

Pool development is **not properly functioning** as determined by pool habitat by area. The relative pool habitat was 2.1% below the matrix standard (see Table 23). Much of the pool development is created by beaver activity. While this standard is nearly properly functioning, there is opportunity to increase pool development by allowing beaver activities to continue as well as adding large wood structure on private and Forest land.

Table 25. Summary of Pool Habitat and Substrate Percentages in Reach 4.

Pool Habitat Summary											
Reach	# Of Pools	Avg. Length	Avg. Width	Avg. Max Depth	Avg. PTC	Avg. Residual Depth	Pools/Mile	# of Pools w/ Residual Depth >1'	Pools w/ Residual Depth >1'/Mile	# of Pools w/ Max. Depth >3'	# of Pools w/ Max. Depth >3'/Mile
4	14	177.2	32.0	3.0	0.7	2.3	9.5	14	9.5	3	2
Properly Functioning Indicators	-	-	-	-	-	≥1ft[1]	-	-	-	-	-

Substrate Summary							
	Reach	% Sand	% Gravel	% Cobble	% Boulder	% Bedrock	Total
	4	55.0	10.7	22.1	10.7	1.5	100.0

[1]The pool quality properly functioning indicator as determined by average residual depth is omitted from analysis in San Antonio Creek due to surveyor error.

The number of LWD per mile in Reach 4 is **not properly functioning**. No LWD was located in Reach 4, far below the standard of 30 pieces per mile (see Table 26). Large woody debris is a key factor in pool development and is related to the substandard pool development in the reach.

Table 26. Habitat Characteristics for Reach 4 of San Antonio Creek.

Reach	Pool:Riffle Ratio	Avg. Bankfull Width:Depth	Pieces of LWD per Mile	Total Unstable Banks (ft)	% Unstable Banks
4	1:1	21.6:1	0	480	3.1
Properly Functioning Indicators	-	-	>30	-	<10

The lack of LWD in Reach 4 can be attributed to private land management which likely included large wood removal and stream channel straightening. In addition, historical management of the campground as well as firewood gathering has limited large wood accumulation. The recent addition of the Highway 126 culvert also minimizes the delivery of upstream sources of wood.

The bankfull width-to-depth ratio is **properly functioning** for a Rosgen B3 stream (see Table 26). The bankfull measurement should be verified with additional cross-sections throughout the reach.

Stream bank condition is **properly functioning** and the percentage unstable banks were almost 7% below the matrix standard. Sore spots were observed in localized areas on private land as well as within San Antonio Campground. On private land, it was mostly related to stock grazing; the campground has several user created stream crossings and angler trails that are causing unstable banks and stream widening.

Recommendations

Recommendations for Reach 4 focus on improving the factors that are **not properly functioning**. Decreasing the relative sediment content and increasing the number of LWD per mile should be management priorities. The relative quantity of pool habitat is another management focus for management to improve fish habitat. The Highway 126 culvert should also be evaluated for suitability to handle high flow events.

To decrease the relative sediment content, areas of bank instability should be addressed. Although the length of bank instability is **properly functioning**, the areas that are unstable are in poor condition due to the high use of areas like San Antonio Creek Campground (see Photo 26). The high use areas should be managed to improve bank stability and reduce fine sediment inputs. Management could include creation of designated trails, and the closure of dispersed trails. Areas of exposed soils should also be planted with native riparian or upland vegetation to further control erosion. The trail closures should be combined with educational signs describing the importance of bank stability for fish populations. The planned 2005 renovation of the Campground will likely address these concerns. In addition, the Forest can work in partnership with interested landowners in improving stream bank conditions. One such step would be to develop a conservation easement along the stream corridor, which would include a riparian exclosure fence.

Reach 4 is lacking LWD and the increase should be a priority in the management of this reach. Large woody debris should be strategically placed throughout the reach. If properly installed, LWD will increase habitat complexity and available fish habitat. This management should be accompanied by educational signs outlining the importance of LWD to stream habitat, in an attempt to reduce recreational wood use. Large woody debris will also increase pool habitat, another **not properly functioning** characteristic of Reach 4. Interested landowners could work in partnership with the Forest to design and implement large wood structures in the stream.

Photo 27. Reach 4, NSO 173, C3. Surveyors at the Highway 126 culvert.
Notice the bank instability and stream widening below the culvert (22 July 2002).

State Highway 126 culvert is too small to handle the high flow events of San Antonio Creek and should be evaluated. Erosion and stream widening on the downstream side of the culvert demonstrates a source of fine sediment and increased temperatures in San Antonio Creek, degrading fish habitat (see Photo 27). Evaluation of the culvert should include possible erosion mitigation or replacement with a larger culvert or bridge.

Reach 5: Highway 126 to San Antonio Hot Springs

Reach 5 begins at State Highway 126 road crossing just above San Antonio Campground (T19N, R3E, Sec. 8, elev. 7720') and ends 4.3 miles (22,464 ft) upstream at San Antonio Hot Springs confluence (T20N, R3E, Sec. 29, elev. 8200'). The average gradient is 2.1%. Reach 5 is on the Santa Fe National Forest except a quarter mile of private land. The private land consists of two consecutive pieces and begins approximately a quarter mile into the reach. The reach ends due to a decreased gradient, increased valley floor width, decrease in substrate size, and a change in flow regime at the San Antonio Hot Springs. The tributary contributed approximately 10-15% flow of the main channel flow and causes an increase in the main channel's temperature. This reach is classified as a Rosgen C3 stream class, which is exemplified by long riffles with cobble dominant substrate, moderately confined valley with a moderately low gradient.

Photo 28. Reach 5, NSO 205, P63. Typical pool in the lower portion of the reach (23 July 2002).

FS Road 132 follows the east bank of the stream to Ice Cave Canyon. The road is passable until the end of private land, where boulders block the road. This road, between the end of private land and Ice Cave Canyon, is hard packed with little vegetation. Several areas on FS Road 132 are washed out, increasing the fine sediment within San Antonio Creek. The road should be considered for re-contouring to mitigate its effects on the river. FS Road 376 runs along the west side of the stream the entire length of Reach 5 and is approximately one quarter mile from the floodplain. The road's distance from the stream minimizes its impacts to the river. Although the abandoned section is causing

impacts to the stream (see Reach 6 summary). FS Road 376 is the main access for San Antonio Hot Springs.

The stream is somewhat confined with a valley floor ranging from 100-300 feet wide. The valley floor is widest at the beginning and end of the reach. Large woody debris is more abundant than previous reaches. The upland vegetation consists primarily of ponderosa pine and white fir. The riparian vegetation includes willow, alder, water hemlock, current, horsetail, locust, grasses, sedges, and a scattering of dogwoods. Streamside vegetation is characterized by groups of willow and alder alternating with open grassy areas. The stream has a high concentration of aquatic vegetation throughout this reach, with some present in nearly every NSO. The aquatic vegetation observed were elodea, coontail, potamogeten, and a grassy looking species. Algal blooms on substrate and aquatic vegetation was prevalent in the area around Ice Cave Canyon.

All substrate types are present, but cobble and boulder are dominant. The overall substrate size increases with upstream progression.

Two waterfalls occur at River Mile 8.67 and 8.7 (nearly one mile downstream from San Antonio Hot Springs confluence) and are formed by bedrock outcrops and very large

San Antonio Hot Springs was 88°F at the mouth at the time of the survey and increased main channel temperatures 2°F (70 to 72°F as determined by grab samples). Fish are located both above and below the hot springs; although population densities appeared to increase once above the springs.

Photo 30. Reach 5, NSO 293, T19. San Antonio Hot Springs (88°F at mouth) is the end of Reach 5.

Evidence of disturbance from both recreation and grazing is spread through Reach 5. Dispersed recreation and other anthropogenic impacts are minimal until San Antonio Hot Springs. Dispersed campsites, fire rings and trails are concentrated along the river and near the hot springs. Stock impacts are focused in the Ice Cave Canyon Area.

Fish observed during the habitat survey include long nose dace and brown trout, including two dead brown trout (7 and 10”).

A snorkeling survey was conducted on July 24, 2002, beginning at Ice Cave Canyon (below the two waterfalls). Ten-100 meter transects were established but due to time restraints only 7 were surveyed, totaling 700 meters. Water clarity was poor during the survey and it is possible that fish were missed. Fish species identified in the survey include brown and rainbow trout, Rio Grande sucker, and longnose dace. Brown trout is the dominant trout species with prevalence in the 6 to 9” size class (see Figure 10). There were very few rainbows observed. Rio Grande sucker is the most abundant of the 421 fish identified in the snorkel survey (see Appendix A, Table 6). Over half of the Rio Grande suckers were young-of-the-year found in a beaver pond.

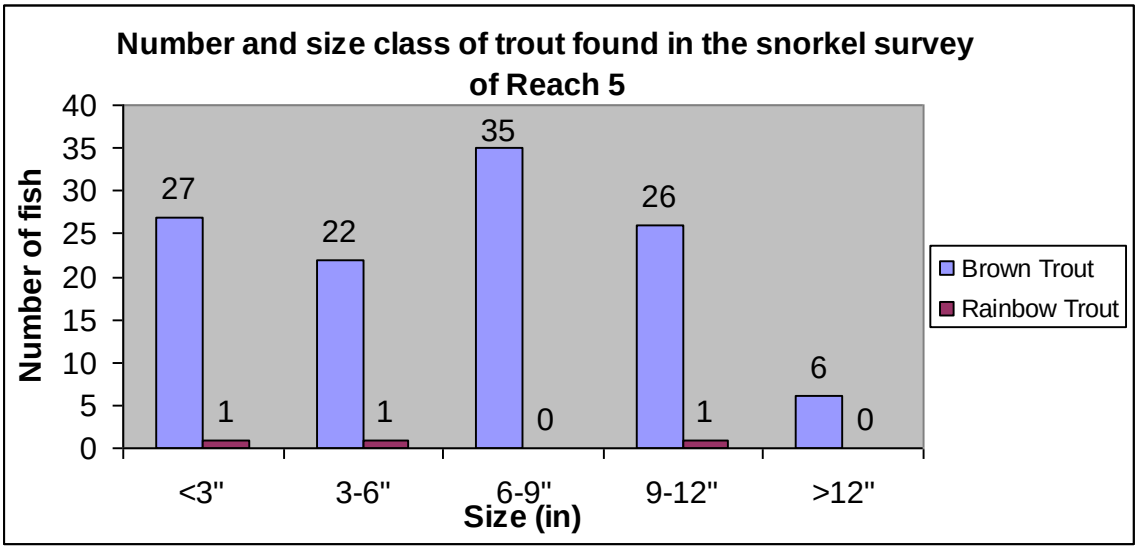


Figure 10. Trout species and size classes observed during a 700 meter snorkel survey of San Antonio Creek in Reach 5 (T19N R3E S31&32) starting at Ice Cave Canyon Creek, on July 25, 2002.

Water temperatures were measured at random intervals during the survey using a handheld thermometer. Main channel temperature readings were taken in the water column. Eighteen temperatures were taken during the survey of Reach 5. The highest temperature was 72°F and the lowest, 60°F.

Habitat Characteristics

The 4.3 stream miles (22,555 ft) of Reach 5 is divided into 120 NSO's. Thirty-three (33) NSO's are pool habitat, a mere 9.3% of stream habitat. Forty-two (42) riffles comprised 81.7 of the habitat (see Table 27).

Table 27. Summary of Reach 5 habitat types

Habitat Type	Number of Habitats	Total Stream Habitat (ft)	Stream Length* (%)	Stream Habitat** (%)	Properly Functioning Indicators
Pool	33	2311	10.2	9.3	>30%
Riffle	42	20,224	89.7	81.5	-
Culvert	0	0	0	0	-
Tributary	11	NA	NA	NA	-
Falls	2	20	0.1	0.1	-
Side Channel	32	2257	NA	9.1	-
Total	120	24,812	100.0	100.0	-

*Percent Stream Length calculated with only riffle, pool, culvert, and falls habitat types.
**Percent Stream Habitat calculated using all stream habitat types except tributary.

When compared to the matrix of factors and indicators of stream health condition for historic and occupied Rio Grand Cutthroat trout streams, Reach 5 contains both **not properly functioning** and **properly functioning** characteristics. The parameters that are **not properly functioning** include the amount of large woody debris and the relative

quantity of pool habitat. **Properly functioning** characteristics include the sediment content in riffle habitat, width-to-depth ratio and bank stability.

Riffle habitat in Reach 5 is **properly functioning** for relative sediment content. Sediment content is 19%. Since this parameter is uncorrected surveyor estimation and very close to the matrix standard, the **properly functioning** classification is suspect and should be more objectively examined to determine its condition. Until further analysis, this parameter will be considered high but **properly functioning.** Local sources of the sediment could be associated to the dispersed trails and stock use. Upstream sediment sources could also contribute to this parameter.

Table 28. Summary of Habitat and Substrate Percentages for Riffles in Reach 5.

Riffle Habitat Summary						
Reach	Number of Riffles	Avg. Length	Avg. Width	Avg. Depth	Avg. Max. Depth	
5	42	481.5	19.4	1.0	1.9	
Substrate Summary						
Reach	% Sand	% Gravel	% Cobble	% Boulder	% Bedrock	Total
5	19.0	21.6	27.8	23.5	8.0	100.0
Properly Functioning Indicators	<20.0	-	-	-	-	-

Pool development is very low for Reach 5 and **not properly functioning** as determined by pool habitat by area. The relative pool habitat is 9.3%, well below the minimum standard (see Table 27). This is further signified by the lack of quality pools greater than 3 feet in depth. This complemented by the high sediment content in pools may quantify that pools are filling in due to an excess in sediment loading. Pool development should be a priority in the management of this reach.

Table 29. Summary of Pool Habitat and Substrate Percentages in Reach 5.

Pool Habitat Summary											
Reach	# Of Pools	Avg. Length	Avg. Width	Avg. Max Depth	Avg. PTC	Avg. Residual Depth	Pools/Mile	# of Pools w/ Residual Depth >1'	Pools w/ Residual Depth >1'/Mile	# of Pools w/ Max. Depth >3'	# of Pools w/ Max. Depth >3'/Mile
5	33	70	18.8	3.0	0.9	2.1	7.7	33	7.7	3	0.7
Properly Functioning Indicators	-	-	-	-	-	≥1ft[1]	-	-	-	-	-

Substrate Summary							
	Reach	% Sand	% Gravel	% Cobble	% Boulder	% Bedrock	Total
	5	48.4	13.4	9.4	21.6	7.2	100.0

[1]The pool quality properly functioning indicator as determined by average residual pool depth is excluded from analysis in San Antonio Creek due to surveyor error.

The number of pieces of LWD per mile is **not properly functioning** with 17 pieces (see Table 30). Large woody debris is a key factor in the development of pool habitat and could be related to the **not properly functioning** condition of pool development in the reach. Increasing the LWD density should be a focus in the management of this reach.

Photo 31. Reach 5, NSO 280, R110. S. Adams at a log jam created by a fallen ponderosa pine (30 July 2002).

The lack of LWD in Reach 5 may be attributed to projects that focused on its removal from fish bearing streams. It was a common practice in the 1960's and 1970's to remove LWD from streams in an attempt to improve stream habitat. A more extensive road system was located in Reach 5 in the 1970's and 1980's. Logjams were believed to be barriers to fish passage, creating negative impacts on fish population dynamics. It is now understood that LWD does not hinder fish movement in stream systems. In fact, LWD is an essential part of pool formation and critical in providing complex fish habitat (F " SE

would eventually fall into the stream channel. The stream then moves LWD during flood events, settling in stream channel or margins, creating pool and secondary channel habitat. The lack of major fires over the last century has greatly diminished the amount of LWD in New Mexican streams.

The bankfull width-to-depth ratio is within the expected range of for a Rosgen C3 stream at 14.3:1. The bankfull measurement should be verified with additional measurements throughout the reach.

Photo 32. Reach 5, NSO 206, R84. Unstable banks and stream widening related to grazing, downstream from Ice Cave Canyon (23 July 2002).

Stream bank condition is **properly functioning** in Reach 5 at 8.1%. Most of the unstable conditions are localized around dispersed recreation areas (San Antonio Hot Springs) and livestock gathering areas (Ice Cave Canyon; see Photo 32).

Recommendations

The management focus for this reach is to mitigate the **not properly functioning** parameters. Large woody debris density and pool development are both substandard and should be improved. Other recommendations include the evaluation of land use in the reach including both stock use and dispersed camping.

Large woody debris has been shown to increase habitat complexity, which includes pool formation (Fausch and Northcote 1992). With strategic placement of LWD, pool formation and increased habitat complexity would occur. With the introduction of LWD, both parameters that are not properly functioning could be mitigated.

Photo 33. Reach 5, NSO 214, R86. Dispersed campsite with garbage near the bank of San Antonio Creek (24 July 2002).

Land use in Reach 5 should also be evaluated. Bank instability due to stock use and dispersed camping is evident. Stock grazing of the riparian area and water access to San Antonio Creek and its tributaries is adding to the sediment problem. Several dispersed camping areas and associated trails degrade the stream banks and act as a sediment source (see Photo 33).

Reach 6: San Antonio Hot Springs to Valles Caldera National Preserve Boundary

Reach 6 begins at the confluence with San Antonio Hot Springs (T20N, R3E, Sec. 29, elev. 8200') and ends 2.5 miles upstream at the boundary fence of the Valles Caldera National Preserve (T20N, R3E, Sec. 16/VCNP, elev. 8320'). The majority of this reach is in a wide, unconfined valley. A short section near the beginning of the reach is marginally confined by a bedrock wall. The entire reach is on Forest land and has a low gradient, 0.9 percent. The stream sinuosity increases in the upper sections of the reach. Riffle and pool habitat have substrate dominated by sand substrate. These attributes equate to an E5 Rosgen stream class. The reach ends with a considerable valley floor widening and shift in land ownership from Forest Service to VCNP. The change in land ownership is also reflected in historic management practices and differences in habitat condition.

Photo 34. Reach 6, NSO 314, R126. Cattle from the San Antonio/Cebolla Allotment have access to this reach when they transition between Mushroom Basin and Barley Pasture. Currently fencing does not prevent cattle from straying back to this area. Jemez Ranger District is planning to implement a new pasture fence as early as 2004 that would minimize riparian grazing (5 August 2002).

Many signs of anthropogenic impacts exist in Reach 6, especially in the vicinity of San Antonio Hot Springs. The hot springs area is accessed by FS Road 376 and has a parking area on the left side of the stream (see Photo 35). An old administrative bridge, now used only by foot traffic, crosses the stream near the beginning of the reach. The bridge is impassable and a vehicle ford has been created upstream in a relatively flat section of the valley. An increased density of user trails and dispersed campsites are representative of the area's intense recreational use (see Photo 36). The current level of recreational use and the closed and abandoned section FS Road 376 create large areas of stream bank instability.

Cattle exacerbate the bank instability in relation to streamside grazing. Signs of cattle utilization, including bank slumping and waste, are spread through the reach. Signs of recreation decreased with the increasing distance from the hot springs, but dispersed trails and FS Road 376 (abandoned roadbed) continued for the rest of the reach.

Photo 35 and 36. Reach 6, NSO 294, R115. Hot Springs Area: Parking lot (*above*) and user-created trail along shore of creek (*above and below*). Note: wheel tracks into stream (*above*) established before parking area was fenced off (30 July 2002).

Photo 36. Reach 6, NSO 294, R115. Steam surveyor with failed stream modification increasing the wetted width of San Antonio Creek and degrading fish habitat. A dispersed recreation trail on the left side of the photo exacerbates the erosion problem (30 July 2002).

Numerous "stream improvement" structures are located in the channel, many of which have failed. The 13 pieces of large woody debris in the reach are all bank stabilization projects. Six V-log and rebar structures, intended to create pools, actually forced the stream to widen and erode large sections of the bank (see Photo 36). Four (4) old gabion structures installed to increase bank stability are still stabilizing the bank. Several of the gabions are now incorporated into the bank with vegetation growing on them. Five (5) triangle or square log and rebar structures come out from the bank into the middle of the stream. These structures have no effect on the stream channel and their intended function is not clear. Public-made cobble dams are also dispersed through the reach, but do not create significant changes in habitat. Numerous stakes have been pounded into the stream and surrounding banks. In one instance these stakes appeared to be an old trash collector, while most of the others may have just been markers.

Two (2) small tributaries, one of which is a spring that contributes about 5% of the flow, were inventoried in Reach 6. Both tributaries were too shallow (0.1 foot maximum depth) to provide fish habitat.

Reach 6 is considered a meadow reach. The majority of herbaceous streamside vegetation are sedges, rushes, grasses, sorrel, buttercups, flea bane, dandelion, yarrow, thistle, sunflowers (Mexican hats), hair bell, heal all, clover, spearmint, and scarlet Gila. Near the beginning of the reach alder and currant (*Ribes spp*.) are the primary woody plants that grow close to the stream. In addition, there is an occasional blue spruce or ponderosa pine next to the stream. As the surveyors neared the VCNP boundary, only cinquefoil was observed. Upland is scattered with ponderosa pines, blue spruce and white firs with aspen even farther upland. A high density of aquatic vegetation is along the stream margins, including elodea, potamogeten, and coontail, as well as algae.

Fish seen during the habitat survey include brown trout and longnose dace. Tadpoles and crayfish were also seen in the stream.

Water temperatures were measured at random intervals during the survey using a handheld thermometer. Main channel temperature readings were taken in the water column. Eight (8) temperatures were taken during the survey of Reach 6. The highest temperature was 77°F and the lowest was 66°F.

Habitat Characteristics

The 2.5 stream miles of Reach 6 are divided into 28 NSO's. Ten NSO's are pool habitat, a mere 7.5 % of the stream habitat. 16 riffle habitats comprise 92.5% of the stream habitat (see Table 31).

When compared to the matrix of factors and indicators of stream health condition fro historic and occupied Rio Grand cutthroat trout streams, Reach 6 contains only **not properly functioning** characteristics. The parameters that are **not properly functioning** include the sediment content in riffles, large woody debris density, relative quantity of pool habitat, width to depth ratio, and bank stability. No characteristics are **properly functioning** in San Antonio Creek.

Table 31. Summary of Reach 6 habitat types

Habitat Type	Number of Habitats	Total Stream Habitat (ft)	Stream Length* (%)	Stream Habitat** (%)	Properly Functioning Indicators
Pool	10	977	7.5	7.5	>30%
Riffle	16	12,017	92.5	92.5	-
Culvert	0	0	0	0	-
Tributary	2	NA	NA	NA	-
Falls	0	0	0	0	-
Side Channel	0	0	NA	0	-
Total	28	12,994	100.0	100.0	-

*Percent Stream Length calculated with only riffle, pool, culvert, and falls habitat types.
**Percent Stream Habitat calculated using all stream habitat types except tributary.

Photo 37. Reach 6, NSO 301, R119. M. Andre with typical riffle habitat (5 August 2002).

Riffle habitat in Reach 6 is **not properly functioning** for relative sediment content. The fine sediment content is 33.1%, well above the matrix standard (see Table 32). Sedimentation originates in a variety of sources including bank instability. Major sources of sediment in this reach is a road crossing, high use areas like San Antonio Hot Springs, and grazing practices as well as upstream sources in VCNP. The high quantities of sediment should be a focus of the management of Reach 6.

Table 32. Summary of Habitat and Substrate Percentages for Riffles in Reach 6.

Riffle Habitat Summary						
Reach	Number of Riffles	Avg. Length	Avg. Width	Avg. Depth	Avg. Max. Depth	
6	16	751.1	14.7	1.0	1.8	
Substrate Summary						
Reach	% Sand	% Gravel	% Cobble	% Boulder	% Bedrock	Total
6	33.1	31.3	23.8	5.0	6.8	100.0
Properly Functioning Indicators	<20.0	-	-	-	-	-

Pool development is extremely low for Reach 6 and **not properly functioning** as determined by pool habitat by area. The relative pool habitat was 7.5% (see Table 31). Similar issues related to fine sediments in riffles are likely culprits for the lack of pool habitat. Pool development should be a priority in the management of this reach.

LWD is not analyzed since it is a meadow reach. Given that, large woody debris is a key factor in the development of pool habitat and distribution of fine sediments. An increase of LWD would assist in improving the not properly functioning condition of pool development and riffle fines in the reach.

Table 33. Summary of Pool Habitat and Substrate Percentages in Reach 6.

Pool Habitat Summary											
Reach	# Of Pools	Avg. Length	Avg. Width	Avg. Max Depth	Avg. PTC	Avg. Residual Depth	Pools/Mile	# of Pools w/ Residual Depth >1'	Pools w/ Residual Depth >1'/Mile	# of Pools w/ Max. Depth >3'	# of Pools w/ Max. Depth >3'/Mile
6	10	97.7	17.9	2.6	0.6	2.0	4.1	10	4.1	1	0.4
Properly Functioning Indicators	-	-	-	-	-	≥1ft[1]	-	-	-	-	-

Substrate Summary							
	Reach	% Sand	% Gravel	% Cobble	% Boulder	% Bedrock	Total
	6	60.0	25.0	13.0	2.0	0.0	100.0

[1]The pool quality properly functioning indicator as determined by average residual pool depth is excluded from analysis in San Antonio Creek due to surveyor error.

The bankfull width-to-depth ratio was 16.3 to 1, which is above the expected range for an E5 stream. Bankfull width-to-depth is **not properly functioning**, which indicates that

the channel is evolving from an “E to a “C”. This is often due to unnatural disturbances (Rosgen and Silvey 1998).

Table 34. Habitat Characteristics for Reach 6 of San Antonio Creek.

Reach	Pool:Riffle Ratio	Avg. Bankfull Width:Depth	Pieces of LWD per Mile	Total Unstable Banks (ft)	% Unstable Banks
6	1:1.6	16:1	1.6	2,874	11.1
Properly Functioning Indicators	-	<12	>30	-	<10

The length of unstable banks was above the matrix standard and **at risk** (see Table 34). The lack of bank stability increases the stream fine sediment content and increases the water temperature as well as part of the unnatural process of channel evolution. Intensive cattle grazing, dispersed recreation use and the abandoned road corridor are the primary causes of the instability in Reach 6 (see Photos 34, 38 and 40).

Photo 38. Reach 6, NSO 300, R118. Typical bank instability related to grazing. Note: stream widening (5 August 2002).

Recommendations

Recommendations for the management of this reach include the mitigation of the **not properly functioning** and **at risk** characteristics, re-contouring FR 376 and the removal of dysfunctional stream improvements. The fine sediment content in riffles, quantity of pool habitat, and width-to-depth ratio are all **not properly functioning** characteristics and are in need of attention. In addition, bank stability is **at risk.** This reach contains the most **not properly functioning** characteristics of any reach in San Antonio Creek. Reach 6 is in poor condition and should be a priority in management of San Antonio Creek.

Several general management goals should improve many of the **not properly functioning** and **at risk** parameters and other degraded characteristics in Reach 6. General management suggestions include the strategic placement of LWD and removal of previous stream improvements, evaluation of land use, erosion mitigation, road removal, beaver introduction, and public education. The combination of these practices should help mitigate the current condition of Reach 6. In addition, there is an expectation that upper watershed conditions will improve with new management on the VCNP.

The strategic placement of LWD will have many beneficial affects on the fisheries habitat in Reach 6. Large woody debris will increase habitat complexity, provide fish cover from predators and increase pool volume. Large woody debris will improve and increase fisheries habitat in Reach 6. Previously stream improvements should be removed from the river. Many of the anchored stream improvements are actually degrading the habitat of Reach 6. The previous stream projects rarely create pool habitat and usually increase the wetted width of the stream.

Further evaluation should be done of the land use in Reach 6. Impacts from cattle grazing and dispersed recreational campsites and trails are spread throughout the reach. Evaluating and managing the land use will improve the degraded condition of this reach.

Photo 39. Reach 6, NSO 297, R117. Severe bank instability, a source of fine sediment for San Antonio Creek (5 August 2002). Note: exposed banks on right are related to grazing.

Erosion is a significant problem in Reach 6 that also contributes to downstream degradation (see Photo 39). Erosion mitigation can be accomplished through removing the cause of the erosion and replanting exposed soils with native riparian vegetation.

Stopping the cause of erosion may include closing dispersed trails and replacing them with properly constructed trails, and decommissioning FS Road 376.

Currently FS Road 376 is a major source of fine sediment in San Antonio Creek (see Photo 40). The closure and re-contouring of this road should be a primary management focus for San Antonio Creek. This road is a major source of the sediment problem in San Antonio Creek.

Photo 40. Reach 6, NSO 294, R115. One example of the sediment contribution from FS Road 376 (30 July 2002). Note: road cut is white exposed soil and road surface sits on top of slumping red soil.

If a location could be found with sufficient riparian vegetation, a beaver introduction to this area of San Antonio Creek could help mitigate the sediment problem. A beaver dam has been shown to reduce suspended sediments and reduce sediment transport in stream systems (Olson 1994). In addition, a riparian exclosure fence with a complimentary willow and aspen planting program would improve streambank conditions, water temperature, bankfull width-to-depth ratio as well as entice beaver occupation.

Public education would complement all of the management practices. Explaining to visitors why the changes are taking place and how the public can help may reduce the impact that many people have on this area. Education could take the form of signs, informative brochures, or direct communication to the users of this area.

Reach 7: VCNP Boundary to an unnamed tributary on west side of Valle San Antonio

Reach 7 begins at the VCNP boundary fence (T20N, R3E, Sec. 16/VCNP, elev. 8320') and ends at Valle San Antonio at a seven-foot wide seep on the left bank (T20N, R3E, VCNP, elev. 8360'). The stream length is 1.2 miles and is entirely on the VCNP. This reach begins in wide, unconfined Valle San Antonio and moves into a marginally confined area within the Valle. Stream sinuosity is high at the beginning of the reach and decreases as the channel becomes confined. The stream width varies considerably within each riffle, which may not be apparent in habitat averages. The channel gradient is very low, 0.1 percent. The habitat is characterized by long riffles dominated by gravel substrate and deep pocket pools with primarily sand substrate. These attributes equate to an E4 stream class. The reach ends at a significant expansion of the valley floor, at the beginning of Valle San Antonio.

Photo 41. Reach 7, NSO 341, R141. Atypical habitat. This section of Reach 7 is a strong reference of how banks and riparian grasses should look. Note: Stream width has shrunk, creating undercut banks and deep-scoured riffles, which should be typical for these valley formations (6 August 2002).

VCNP and the former Baca Ranch has been closed to public use (at the time of the survey), so recreational impact is low. A faint trespass trail is on the right bank, and one illegal camper was observed near the stream during the survey. One bridge is washed out near the beginning of the reach with a vehicle ford just downstream (see Photos 42 and 43). The washed-out bridge debris creates a pool habitat but also significant bank instability.

Photo 42 and 43. Reach 7, NSO 338/339, R138/P104. Washed out bridge (*above*) with associated vehicle ford downstream (*below*). Road crossing is degrading fish habitat. The crossing increases wetted width, introduces fine sediment, and increases stream temperature (6 August 2002).

Historic livestock grazing management and elk grazing have had a significant impact on the stream habitat. Dung, hoof prints, and collapsed undercut banks were evidence of grazing pressure. The constant presence of the grazing animals over the last 140 years may have destroyed woody streamside vegetation (such as alder and willow) that grew along the stream banks and provided a buffer. In other reaches streamside woody vegetation was observed in meadow valleys (i.e. in sections of Reach 4 a buffer of riparian vegetation was maintained due to streamside cattle enclosures; in addition, willow and alder was prevalent in the bottom section of Reach 6). However, it is not known whether the grasslands of

Valles San Antonio ever supported this type of vegetation. To further complicate this issue, the stream has lost many of its undercut banks. The lack of shade provided by riparian vegetation and undercut banks are related to the highly variable stream temperatures in the creek. The grab sample temperatures ranged from 64° to 80°F. Bank erosion and stream widening are extreme in the highly sinuous areas.

Two (2) small tributaries contribute less than 5% of the main channel flow. Three (3) short side channels increase habitat complexity and provide a little fish habitat.

The majority of herbaceous streamside vegetation are sedges, rushes, grasses, sorrel, buttercups, flea bane, dandelion, yarrow, thistle, horsetail (in wetter areas), hair bell, heal all, and clover. Cinquefoil was the only near stream woody vegetation and is a red flag for grazing pressure. Cinquefoil is a native species that is associated with dry sites. Finding cinquefoil in a riparian area is a red flag. The riparian area is being converted from a wet to dry site, usually associated with major disturbances such as overgrazing and soil compaction. At a distance from the stream are ponderosa pine, blue spruce and white fir. Throughout the reach, aquatic vegetation is common along the stream margins. Aquatic vegetation species include elodea, duckweed, potamogeten, and coontail, as well as algae.

While conducting the survey, brown trout, longnose dace, and crayfish were easily identifiable. A snorkel survey was conducted within the reach. Six, approximately 100 meters transects, were surveyed. Fish species identified in the snorkel survey include longnose dace and German brown trout. 1,137 longnose dace were identified, with larger populations in the last three sections. One hundred and sixty-eight (168) German brown trout were spotted and classified by size class (see Figure 11).

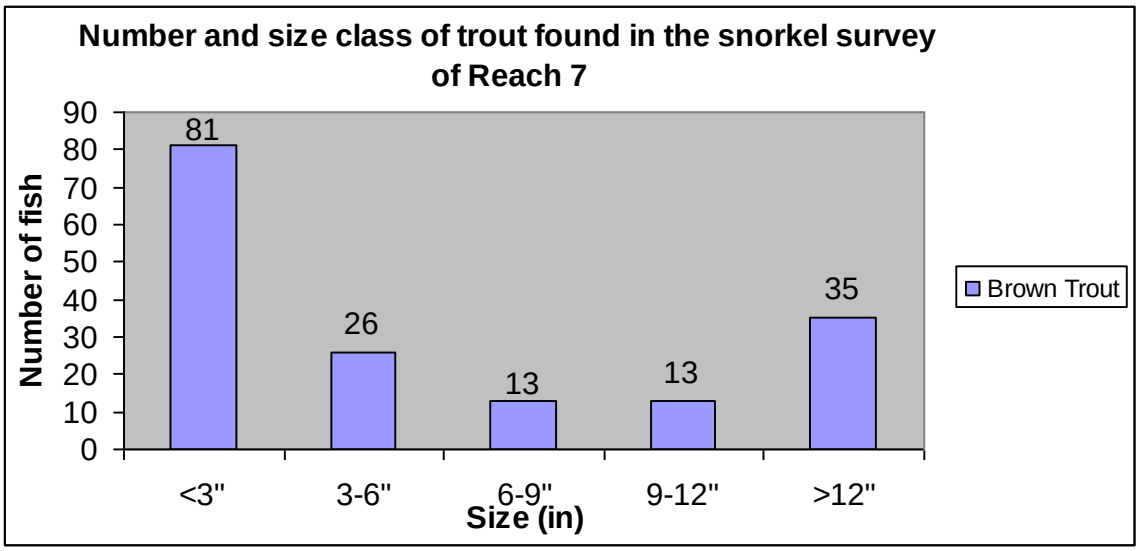


Figure 11. Fish species size classes observed during a 600 meter snorkel survey of San Antonio Creek, (T19N R3E VCNP) on the eastern part of Valle San Antonio, on August 8, 2002. Brown trout were the only trout species observed.

Water temperatures are measured at random intervals during the survey using a handheld thermometer. Main channel temperature readings are taken in the water column. Eight

(8) temperatures were taken during the survey of Reach 7. The highest temperature was 68°F and the lowest, 64°F.

A water temperature station was established in Reach 7 on June 11th and removed on November 10th, 2002. The highest temperatures were between June and August (see Figure 12). San Antonio Creek temperatures are compared to Forest and NMED standards for classification as either properly functioning, at risk or not properly functioning (see Temperature section). Temperatures at the Boundary Station are **not properly functioning** by SFNF classification 48 days and by the NMED classification 21 of the 114 days between June 11th and September 30th 2002.

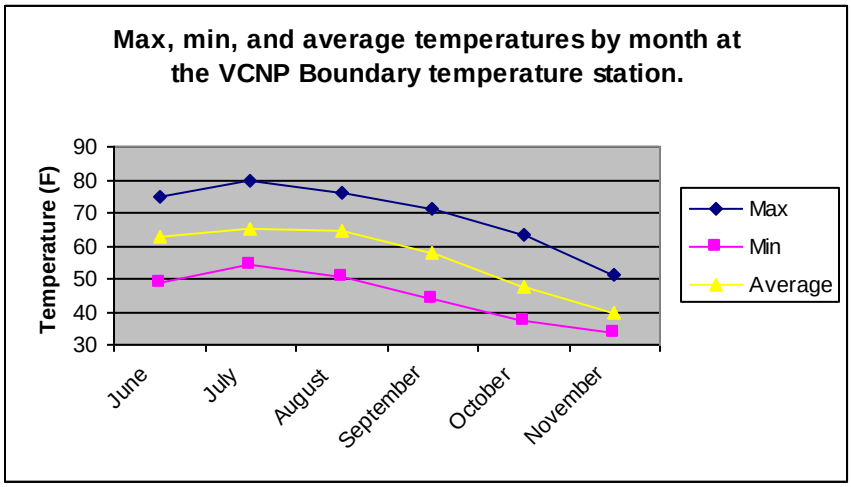


Figure 12. Maximum, minimum and average temperatures for each month from thermograph station in Reach 7.

Habitat Characteristics

The 1.5 stream miles (7,868 ft) of Reach 7 is divided into 28 NSO's. Ten (10) NSO's are pool habitat, 13.6% of the reach's stream habitat. Thirteen (13) NSO's are riffles comprising 84.8 % of the stream habitat (see Table 35). The lack of side channel habitat (1.6%) in a wide meadow valley is a concern.

Table 35. Summary of Reach 7 habitat types

Habitat Type	Number of Habitats	Total Stream Habitat (ft)	Stream Length* (%)	Stream Habitat** (%)	Properly Functioning Indicators
Pool	10	1,061	13.8	13.6	>30%
Riffle	13	6,607	86.2	84.8	-
Culvert	0	0	0	0	-
Tributary	2	NA	NA	NA	-
Falls	0	0	0	0	-
Side Channel	3	123	NA	1.6	-
Total	28	7,991	100.0	100.0	-

*Percent Stream Length calculated with only riffle, pool, culvert, and falls habitat types.
**Percent Stream Habitat calculated using all stream habitat types except tributary.

When compared to the matrix of factors and indicators of stream health condition for historic and occupied Rio Grande cutthroat trout streams, Reach 7 contains both **not properly functioning** and **properly functioning** characteristics. Parameters that are not properly functioning include the riffle sediment content, and pool development. **Properly functioning** characteristics include width-to-depth ratio and stream bank condition. Large woody debris is excluded from the analysis of this reach because it is a meadow reach.

Riffle habitat in Reach 7 is **not properly functioning** for the relative sediment content. Sediment content is 25.4% (see Table 36). This may indicate that the high number of spawning gravels (54.6%) have become embedded, which limits spawning success.

Table 36. Summary of Habitat and Substrate Percentages for Riffles in Reach 7.

Riffle Habitat Summary						
Reach	Number of Riffles	Avg. Length	Avg. Width	Avg. Depth	Avg. Max. Depth	
7	13	508.2	11.8	1.2	2.3	
Substrate Summary						
Reach	% Sand	% Gravel	% Cobble	% Boulder	% Bedrock	Total
7	25.4	54.6	17.7	2.3	0.0	100.0
Properly Functioning Indicators	<20.0	-	-	-	-	-

Pool development is far below the standard for pool habitat, therefore **not properly functioning** (see Table 35). This is further accentuated by the lack of deep pools, with only 2 greater than three feet deep. Pool development should be a priority of the management of this reach.

Table 37. Summary of Pool Habitat and Substrate Percentages in Reach 7.

Pool Habitat Summary											
Reach	# Of Pools	Avg. Length	Avg. Width	Avg. Max Depth	Avg. PTC	Avg. Residual Depth	Pools/Mile	# of Pools w/ Residual Depth >1'	Pools w/ Residual Depth >1'/Mile	# of Pools w/ Max. Depth >3'	# of Pools w/ Max. Depth >3'/Mile
7	10	106.1	16.8	3.4	0.6	2.8	6.9	10	6.9	2	1.4
Properly Functioning Indicators	-	-	-	-	-	≥1ft[1]	-	-	-	-	-

Substrate Summary							
	Reach	% Sand	% Gravel	% Cobble	% Boulder	% Bedrock	Total
	7	60.0	31.0	7.0	2.0	0.0	100.0

[1]The pool quality properly functioning indicator as determined by average residual pool depth is excluded from analysis in San Antonio Creek due to surveyor error.

Bankfull width-to-depth ratio is within the expected range for an E4 classification and **properly functioning**. Bankfull width-to-depth ratio was 4.3 to 1 (see Table 38).

Streambank condition is **properly functioning** in Reach 7 with nearly 6% of the streambanks unstable (see Table 38)

Table 38. Habitat Characteristics for Reach 7 of San Antonio Creek.

Reach	Pool:Riffle Ratio	Avg. Bankfull Width:Depth	Pieces of LWD per Mile	Total Unstable Banks (ft)	% Unstable Banks
7	1:1.3	4:1	0.0	885	5.8
Properly Functioning Indicators	-	<12	NA[1]	-	<10

[1]Large woody debris indicator is excluded from analysis in Reach 7 because it is a meadow.

Recommendations

Recommendations for this reach include mitigating **not properly functioning** characteristics, evaluation of road crossings, removal of the failed bridge, and learning from historic land use. The **not properly functioning** characteristics that should be improved include the sediment content in riffles and pool development.

Much of the stream bank in of Reach 7 is currently in a state of rehabilitation. Grazing pressure by both cattle and elk has collapsed undercut banks throughout the reach. The undercut banks provide critical fish habitat in low gradient, wide meadow valley systems. Undercut banks provide fish refuge from predators and create a cooling effect on water temperatures. The collapse of the undercut banks creates a sediment source, which fills in both fish spawning gravels in riffles and reduces pool habitat.

Photo 44. Reach 7, NSO 329, P100. Limited bank recovery. The upper vertical portion will continue to slough if grazing pressure is felt in these locations (6 August 2002).

Cattle grazing had not occurred on San Antonio Creek since the establishment of the VCNP in 1999. Approximately 300 head of cattle grazed in this reach after the survey

was completed (last three weeks in September 2002) (K. Lee, personal communication, 2003). The reduction in grazing pressure has given the streambanks a chance to begin the recovery process. Many of the streambanks were collapsed, but recovering with new vegetation (see Photo 44). By pulling off pressure, the stream will find its equilibrium, forming new undercut banks and allowing unstable banks to heal (see Photo 41 for optimum condition). Limited pressure in these areas could be accomplished through a variety of activities, which would include but is not limited to: An intensive range riding program, riparian fence exclosure, rotational grazing programs, or rest. The timing of recovery is dictated by which practice or combination of practices that is selected.

The vehicle crossing and failed bridge is a concern in the management in Reach 7. The failed bridge is now scrap in the river and surrounded by severe erosion and bank instability (see Photos 42 and 45). Rehabilitation should include the removal of the bridge scraps and replanting of native grasses in the areas of instability. There may also be a need to re-shape the bank so that it is less steep, which would allow for a faster recovery. An exclosure fence might also improve this area, allowing it to rehabilitate without grazing pressure.

Photo 45. Reach 7, NSO 339, P104. Failed bridge crossing of San Antonio Creek with associated bank instability (6 August 2002).

Since the bridge failed, vehicles have been fording San Antonio Creek degrading fish habitat in Reach 7. The current road crossing (see Photo 43) has several degrading impacts on San Antonio Creek including increased wetted width, decreased bank stability, acts as a source of fine sediment, and increases water temperature. The road crossing should be closed and its impacts mitigated. If the road will continue to be used, a proper bridge or culvert should be installed.

Reach 8: Unnamed tributary in Valle San Antonio to Rito de los Indios

Reach 8 begins with Valle San Antonio and an unnamed 7-foot wide seep on the left bank (T20N, R3E, VCNP, elev. 8360'). The reach ends 12.0 miles upstream at a change in flow regime at the confluence with Rito de los Indios (T20N, R4E, VCNP, elev. 8550'). The reach was surveyed between August 7th and 22nd, 2002.

The stream in this reach was very sinuous, with long meanders winding through a flat valley (see Photo 46). Riffles were dominated by gravel substrate. The average stream gradient is 0.3%. The valley was wide ranging from 0.5 to 1.5 miles except for one short section around San Luis Creek. The short section is less than 0.5 miles long and only 75 to 150 feet wide. Most of the reach is very similar with tributaries and side channels increasing habitat complexity. These attributes equate to an E4 Rosgen stream classification.

Photo 46. Reach 8. Stream sinuosity in Valle San Antonio (22 August 2002).

The reach contains one piece of large woody debris and no woody riparian vegetation. The riparian vegetation consists primarily of grasses, sedges, rushes and wildflowers. Riparian vegetation species include harebell, iris, clover, yarrow, dandelion, thistle, sorrel, fleabane, and a scattering of milkweed. The stream contains high concentrations of aquatic vegetation including but not limited to elodea, coontail, duckweed, and potamogeten. The upland vegetation, which is a considerable distance from the stream, consisted of grasses, wildflowers, pine, spruce and fir trees. The substrate is dominated by sand and gravel with small quantities of cobble and the occasional boulder. This reach has many long riffles and relatively few pools. Several riffles are over 2000 feet long with the longest at 4195 feet. Riffle habitats contain many deep pockets, specifically in the meander bends.

Photo 47. Reach 8, NSO 403, R164. Bank instability is a source of fine sediment to San Antonio Creek (14 August 2002).

Moderate to long areas of bank instability are associated with historic grazing practices and current elk use (see Photo 47). Much of the instability has begun to recover and stabilize with vegetation. The stream bank recovery process could be related to the decrease in grazing pressure since the government acquisition of the VCNP.

Of the 11 tributaries in this reach, the largest five are Rito de los Indios (an estimated 15% of main channel flow), Rito Santa Rosa (5 to 10%), San Luis Creek (5%), an unnamed spring (5%) and a hot spring (1%). The hot spring (T26) enters the stream 4.9 miles up from the beginning of the reach. Hot water flows 15 feet from a pipe down the bank into the stream. The hot spring was 100 °F at 12:30 on August 13th and increased the main channel temperature 1°F (63 to 64 °F).

Four road crossings exist in Reach 8. All of the crossings are in poor condition and have degrading impacts on the stream habitat. The first crossing occurs 3.4 miles upstream from the beginning of the reach and is the main road crossing Valle San Antonio. The remains of a roadbed and bridge still exist, but the bridge is gone (see Photo 49). The unstable banks of this old roadbed have exposed soil. Upstream from the failed bridge the stream is wide and shallow. In the absence of the bridge, a major ford has been created just downstream. Several other crossings have been created at this spot, but are not used as frequently. The Pipeline Road creates the second crossing on the west side of Valle San Antonio just upstream from an unnamed stream coming out of Valle Santa Rosa (T33). This crossing occurs at an oblique angle to the river and is 110 feet long. The stream is shallow and wide in the areas where the road enters and leaves the stream. The third crossing is just upstream from the first Pipeline Road crossing and decreases the stream depth and increases the width. The fourth crossing is at the east end of Valle San Antonio just downstream from the mouth of Rito de los Indios where again the Pipeline Road crosses the stream. This crossing is very bad, with water pooled up on Pipeline Road on the west side of the stream. Some of this water runs back into the stream a few yards down the road (see Photo 48).

Photo 48. Reach 8, NSO 433, R179. Serina Adams and the Pipeline Road crossing. One of the four road crossings that changes the stream channel shape, introduces fine sediment and degrades fish habitat (22 August 2002).

Photo 49. Reach 8, NSO 369, R152. Old bridge crossing with road fill squeezing stream, not allowing stream to meander naturally (12 August 2002).

During the survey many brown trout and longnose dace were observed. On September 13th, 2001 a snorkel survey was conducted near the confluence of San Antonio Creek and Rito de los Indios (see Figure 13). Six 100-meter transects were snorkeled, two of which were in Rito de los Indios. The fish population observed near Rito de los Indios was exclusively brown trout. Due to the deeply undercut banks, it is possible that some fish were missed in the survey. Abnormal growth was observed during the snorkel (see Photo 50) as well as by surveyors in this and upstream reaches (see further discussion in Reach 10).

Photo 50. Abnormal growth of German brown trout in upper reaches of San Antonio Creek. Snorkeling observers noted that approximately 40% of brown trout were abnormal.

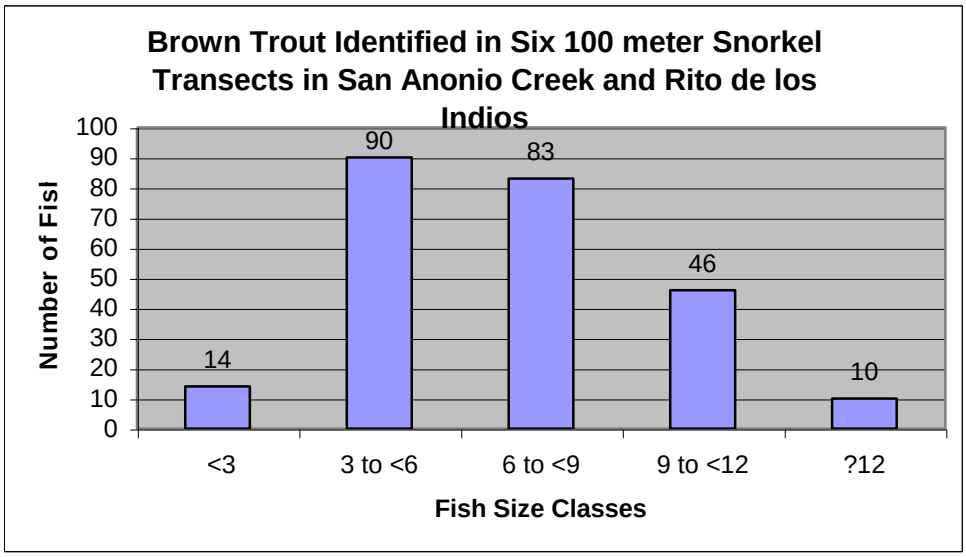


Figure 13. Snorkel survey conducted near the confluence of Rito de los Indios and San Antonio Creek, shows an exclusively brown trout fish population.

Water temperatures are measured at random intervals during the survey using a handheld thermometer. Main channel temperature readings are taken in the water column. Seventeen (17) temperatures were taken during the survey of Reach 8. The highest temperature was 73°F and the lowest, 55°F.

A water temperature station was established in Reach 8 on June 11th and removed on November 24th, 2002. The highest temperatures were between June and August (see Figure 14). San Antonio Creek temperatures are compared to Forest and NMED standards for classification as either properly functioning, at risk or not properly functioning (see Temperature section). Temperatures at the Rito de los Indios temperature station are **at risk**. 77 days or half of the temperatures are **at risk** by Forest standards and 6 days by NMED between June 11th and September 30th 2002.

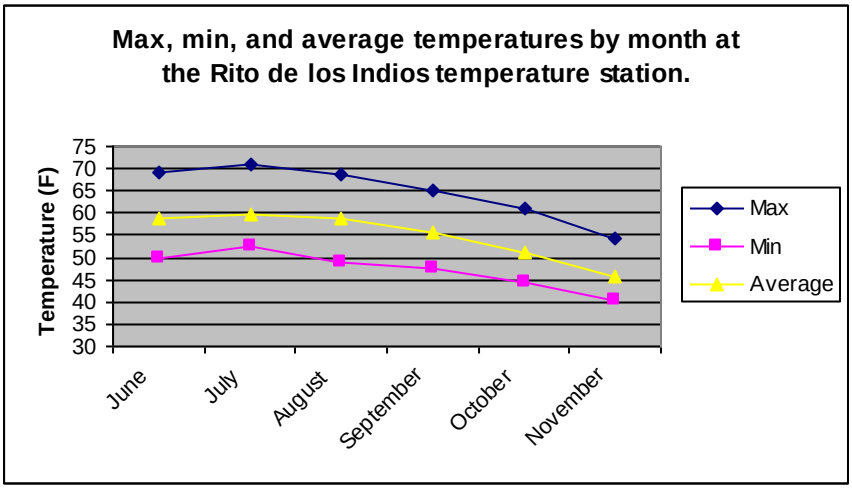


Figure 14. Maximum, minimum and average temperatures for each month from thermograph station in Reach 8.

Habitat Characteristics

The 12.0 stream miles (63,402 ft) of Reach 8 are divided into 85 NSOs. Twenty (20) NSOs are pool habitat and comprise a mere 2.6 % if the stream habitat. Thirty-six (36) riffle habitats consist of 96.0 % of the stream habitat (see Table 39). The lack of side channel habitat (1.3%) in a wide meadow valley is a concern.

Table 39. Summary of Reach 8 habitat types

Habitat Type	Number of Habitats	Total Stream Habitat (ft)	Stream Length* (%)	Stream Habitat** (%)	Properly Functioning Indicators
Pool	20	1,697	2.7	2.6	>30%
Riffle	36	61,705	97.3	96.0	-
Culvert	0	0	0	0	-
Tributary	14	NA	NA	NA	-
Falls	0	0	0	0	-
Side Channel	15	851	NA	1.3	-
Total	85	64,253	100.0	100.0	-

*Percent Stream Length calculated with only riffle, pool, culvert, and falls habitat types.
**Percent Stream Habitat calculated using all stream habitat types except tributary.

When compared to the matrix of factors and indicators of stream health condition condition for historic and occupied Rio Grande cutthroat trout streams, Reach 8 contains both **not properly functioning**

Large woody debris is excluded from analysis of this reach due to its meadow status and lack of local wood recruitment. One medium sized piece of LWD (diameter between 12 and 20 inches at a length of 35 feet) is located in Reach 8.

Table 42. Habitat Characteristics for Reach 8 of San Antonio Creek.

Reach	Pool:Riffle Ratio	Avg. Bankfull Width:Depth	Pieces of LWD per Mile	Total Unstable Banks (ft)	% Unstable Banks
8	1:1.8	7.0:1	0.1	2,375	1.9
Properly Functioning Indicators	-	<12	NA[1]	-	<10

[1]Large woody debris density is excluded from analysis due to the meadow classification of Reach 8

Bankfull width-to-depth ratio is within the expected range for a Rosgen E4 stream. The bankfull ratio is 7.0 to 1. There was only one bankfull measurement taken. There are localized conditions where stream widening and shallowing is taking place related to unstable banks and road crossings.

Bank stability is **properly functioning** for length of unstable banks. The banks in Reach 8 are currently in a state of recovery from historic intensive grazing pressure and land use practices. Many undercut banks are collapsed, but new vegetation growth is showing signs of mending (see Photo 51). The current state of the banks should be taken into consideration for future land use management.

Photo 51. Reach 8, NSO 350, R144. Surveyor next to unstable banks. Grazing pressure along these banks would continue to cause bank sloughing (7 August 2002).

Recommendations

The management focus for this reach is to mitigate the not properly functioning parameters and insure the properly functioning characteristics are maintained. Both the riffle sediment content and pool development are **not properly functioning**. Other management recommendations include the evaluation of all road crossings and their impacts on San Antonio Creek's stream habitat.

Photo 52. Reach 8, NSO 419, R172. Elk and cattle wallowing area approximately 350 square feet in size and 100 feet from the stream. This location would be ideal for an elk exclosure to allow the area to recover (21 Aug 2002).

Historic intensive grazing and poor road planning may explain the current degraded condition in the stream habitat of Reach 8. Cattle grazing had not occurred on San Antonio Creek since the establishment of the VCNP in 1999. Approximately 300 head of cattle grazed in this reach after the survey was completed (last three weeks in September 2002) (K. Lee, personal communication, 2003). The collapsed undercut banks and road crossings are sources of fine sediment to stream habitat. In low gradient sections like Reach 8, fine sediment settles into the substrate. The fine sediment fills in spawning habitat in riffles, as well as decreases pool habitat. Protection of the currently recovering banks should be a management focus of this reach. By pulling off pressure, the stream will find its equilibrium, forming new undercut banks and allowing unstable banks to heal. Limited pressure in these areas could be accomplished through a variety of activities, which would include but is not limited to: An intensive range riding program, riparian fence exclosure, rotational grazing programs, or rest. The timing of recovery is dictated by which practice or combination of practices that is selected.

The four road crossings of San Antonio Creek should be evaluated. Many of the roads have failed bridges, which led to fords through the creek. The fords are a source of fine sediment, increased wetted width and water temperature, reduced bank stability, and a change in channel shape (see Photo 53). The roads that ford San Antonio Creek should be evaluated. The roads that are deemed necessary should be improved with proper bridge or culvert crossings. Further measures should be taken to mitigate the current impacts caused by the crossings.

Photo 53. Reach 8, NSO 369, R152. S. Adams with a road crossing in San Antonio Creek causing fish habitat degradation (12 August 2002).

Reach 9: Rito de los Indios to Pipeline Road crossing in Valle Toledo

Reach 9 begins at confluence with Rito de los Indios (T20N, R4E, VCNP, elev. 8550'), and ends at the Pipeline Road crossing (5-culvert complex) (T20N, R4E, VCNP, elev. 8,580') and the beginning of Valle Toledo. This reach begins in a confined valley section, opens up slightly, and then becomes confined again (varying between 10 and 1000 feet wide). Stream sinuosity is high in the less confined sections and decreases with channel confinement. Stream width varies considerably within each riffle, which may not be apparent from the habitat averages. The channel gradient is low, 0.5% percent. The reach's habitat is characterized by riffles with short glides equally dominated by sand and gravel. Given the overall predominance of fines, the reach has been classified as E5. The reach ends at a dramatic increase in valley width.

Photo 54. Reach 9, NSO 454, R188. A confined section just before Valle Toledo (23 August 2002).

VCNP and the former Baca Ranch has been closed to public use (at the time of the survey), so recreational impact is low. One fence line crosses the stream near the middle of the reach. Elk utilization of San Antonio Creek has a significant impact on the habitat. Dung, hoof prints, trails, matted grass beds and sloughing banks can be attributed to elk presence. The total length of bank instability is minimal, but concentrated in areas of high sinuosity. Some of the bank instability and current degradations may be a result of past cattle utilization. Natural erosion is minimal along the cut bank sides of the stream, and is also concentrated in the highly sinuous areas.

The majority of herbaceous streamside vegetation is sedges, rushes, grasses, buttercups, fleabane, dandelion, yarrow, thistle, wild iris, hair bell, small water hemlock, spearmint, and clover. Cinquefoil was the only near stream woody vegetation and is a red flag for grazing pressure. Cinquefoil is a native species that is associated with dry sites. Finding

cinquefoil in a riparian area is a red flag. The riparian area is being converted from a wet to dry site, usually associated with major disturbances such as overgrazing and soil compaction. Upland vegetation is ponderosa pines and white firs. Aquatic vegetation is common along the stream margins. Aquatic vegetation species include elodea, watercress, and potamogeten, as well as algae.

Photo 55. Reach 9, NSO 454, R188. Entering the west end of Valle Toledo. M. Andre is wading through stream and grasses (23 August 2002).

Five (5) spring-fed tributaries are in Reach 9, increasing stream flow by approximately 25% (combined). Two multiple source springs (NSO 446, T41 & NSO 447, T42), each over 100 feet long, are in the same area on opposite banks. Fish are present in one unnamed tributary (NSO 443 T39). One short secondary channel contributes a small amount of habitat. No barriers, falls, or large woody debris are within this reach.

Photo 56. Reach 9, NSO 444, T40. Multiple small tributaries entered this reach. This small tributary winds through the grass behind M. Andre (22 August 2002).

While conducting the survey, brown trout and longnose dace were easily observed through the entire reach

Water temperatures were measured at random intervals during the survey using a handheld thermometer. Main channel temperature readings were taken in the water column. Seven (7) main channel temperatures were taken in Reach 9. The highest temperature was 66°F and the lowest was 57°F.

Habitat Characteristics

The 1.2 stream miles (6,297 feet) of Reach 9 is divided into 25 NSO's. Seven (7) of the NSOs are pool habitat, comprising 5.0 % of the stream habitat. Eleven (11) of the habitats are riffles, 94.3% of the stream habitat (see Table 42). The lack of side channel habitat (0.3%) in a wide meadow valley is a concern.

Table 42. Summary of Reach 9 habitat types

Habitat Type	Number of Habitats	Total Stream Habitat (ft)	Stream Length* (%)	Stream Habitat** (%)	Properly Functioning Indicators
Pool	7	319	5.1	5.0	>30%
Riffle	11	5,955	94.5	94.3	-
Culvert	1	23	0.4	0.4	-
Tributary	5	NA	NA	NA	-
Falls	0	0	0	0	-
Side Channel	1	20	NA	0.3	-
Total	25	6,317	100.0	100.0	-

*Percent Stream Length calculated with only riffle, pool, culvert, and falls habitat types.
**Percent Stream Habitat calculated using all stream habitat types except tributary.

When compared to the matrix of factors and indicators of stream health condition for historic and occupied Rio Grande cutthroat trout streams, Reach 9 contains both **not properly functioning** and **properly functioning** characteristics. The parameters that are **not properly functioning** include the riffle sediment content and pool development. The **properly functioning** parameters include stream bank condition and width-to-depth ratio. Large woody debris is excluded from analysis in this reach because it is a meadow.

Table 43. Summary of Habitat and Substrate Percentages for Riffles in Reach 9.

Riffle Habitat Summary						
Reach	Number of Riffles	Avg. Length	Avg. Width	Avg. Depth	Avg. Max. Depth	
9	11	541.4	6.6	0.9	1.9	
Substrate Summary						
Reach	% Sand	% Gravel	% Cobble	% Boulder	% Bedrock	Total
9	36.4	36.4	22.7	4.5	0.0	100.0
Properly Functioning Indicators	<20.0	-	-	-	-	-

Riffle habitat in Reach 9 is **not properly functioning** for the relative amount of sediment (36.4 %; see Table 43). Mitigating sediment content should be a management focus in Reach 9.

Pool development is very low for Reach 9 and **not properly functioning** as determined by pool habitat by area (calculated by habitat length). The relative pool habitat was only 5.0% (see Table 42). A further indication of concern is that there were no deep pools. Increasing pool habitat should be a focus in the management of this reach.

Table 44. Summary of Pool Habitat and Substrate Percentages in Reach 9.

Pool Habitat Summary											
Reach	# Of Pools	Avg. Length	Avg. Width	Avg. Max Depth	Avg. PTC	Avg. Residual Depth	Pools/Mile	# of Pools w/ Residual Depth >1'	Pools w/ Residual Depth >1'/Mile	# of Pools w/ Max. Depth >3'	# of Pools w/ Max. Depth >3'/Mile
9	7	45.6	10.4	2.8	0.5	2.3	5.6	7	5.9	0	0.0
Properly Functioning Indicators	-	-	-	-	-	≥1ft[1]	-	-	-	-	-

Substrate Summary							
Reach	% Sand	% Gravel	% Cobble	% Boulder	% Bedrock	Total	
9	85.7	10.0	4.3	0.0	0.0	100.0	

[1]The pool quality properly functioning indicator as determined by average residual pool depth is excluded from analysis in San Antonio Creek due to surveyor error.

Large woody debris density analysis is excluded from analysis due to its meadow classification.

Table 45.. Habitat Characteristics for Reach 9 of San Antonio Creek.

Reach	Pool:Riffle Ratio	Avg. Bankfull Width:Depth	Pieces of LWD per Mile	Total Unstable Banks (ft)	% Unstable Banks
9	1:1.6	7.5:1	0.0	670	5.3
Properly Functioning Indicators	-	<12	NA[1]	-	<10

[1]Reach 9 is a meadow and large woody debris are excluded from matrix analysis.

Bankfull width-to-depth ratio is **properly functioning**, since it is within the expected range for a Rosgen E5 stream

Bank stability is **properly functioning** for length of unstable banks. The banks in Reach 8 are currently in a state of recovery from historic intensive grazing pressure and land use practices. Many undercut banks have collapsed, but new vegetation growth is showing signs of mending. The current state of the banks should be taken into consideration for future land use management.

Recommendations

The management focus for this reach is to mitigate the not properly functioning parameters and insure the properly functioning characteristics are maintained. Both the riffle sediment content and pool development are **not properly functioning**. Anther management recommendation is the replacement of the Pipeline Road culvert complex.

Historic land use and intensive grazing practices may explain the current impacts to stream habitat. The collapsed undercut banks and road crossings are sources of fine sediment to stream habitat. In low gradient sections like Reach 9, fine sediment settles into the substrate. The fine sediment fills in spawning habitat in riffles, as well as decreases pool habitat. Protection of the currently recovering banks should be a management focus of this reach. By pulling off pressure, the stream will find its equilibrium, forming new undercut banks and allowing unstable banks to heal. Limited pressure in these areas could be accomplished through a variety of activities, which would include but is not limited to: An intensive range riding program, riparian fence exclosure, rotational grazing programs, or rest. The timing of recovery is dictated by which practice or combination of practices that is selected.

Photo 57. Reach 9, NSO 455, C4. The Pipeline Road culvert complex increases wetted width, stream temperature and degrades stream habitat (23 August 2002).

The Pipeline Road culvert complex at the end of Reach 9 is currently the cause of stream habitat degradation. The culvert complex is made up of five separate culverts, which appear to be insufficient to handle the flow regime of San Antonio Creek (see Photo 57). Below the culvert complex, the river's width increases significantly, changing the channel shape and increasing stream temperature. The culvert complex should be removed and replaced with an appropriate bridge or single culvert crossing.

Reach 10: Pipeline Road Culvert to a tributary formed by an artesian well in Valle Toledo

Reach 10 begins at the pipeline road crossing at the west end of Valle Toledo just after coming out of a canyon area above Valle San Antonio (T20N, R4E, VCNP, elev. 8,580'). The reach ends 2.2 miles upstream at an artesian well tributary and dramatic flow change (T20N, R4E, VCNP, elev. 8635'). The artesian well contributes an estimated 60-70% of the stream flow.

The stream is very sinuous with an average gradient of 0.5% in a wide valley, ranging from ½ to 1 mile wide. The stream meanders through a meadow with many short bends. The reach contains only one pool and many long riffles with deep pockets and glides. Riffle widths constantly changed ranging from 1 to 18 feet. Sand and gravel are the dominant substrate types with many areas containing thick layers of fine sediment up to 1½' deep. These attributes equate to an E5 Rosgen class type.

This reach contained no large woody debris or woody riparian vegetation. The riparian vegetation consisted of grasses, sedges and wildflowers. Some of the species present were dandelion, buttercup, yarrow, fleabane, clover, harebell, wild onion, and small cinquefoil. Upland vegetation is a quarter mile or more away from the stream and consists of white fir and aspen. High quantities of aquatic vegetation are in the reach, including reed grass, elodea, watercress, duckweed, and filamentous algae. The banks in this section have sporadic undercuts of 4-10 inches. In several areas, undercut banks have collapsed and are now beginning to stabilize and grow vegetation (see Photo 58). The improving bank stability is likely associated with the ease in grazing pressure since the formation of the VCNP in 2000.

Photo 58. Reach 10, NSO 464, R194. Recovering bank instability (23 August 2002).

Of the six (6) tributaries that enter San Antonio Creek in Reach 10, only two contribute more than an estimated 5% flow. An unnamed tributary (T44) enters the stream 0.7 miles into the reach and contributes 10-15% of the stream flow. The other major tributary is created by the easternmost of three artesian wells in the middle of Valle Toledo. All three wells are flowing, but only the one farthest east has enough flow to make it to the creek. The well tributary contributes 60-70% San Antonio Creek's main channel flow. The flow regime change from the artesian well marks the end of Reach 10. The other two wells create large marsh areas with some pooled water. The other four (4) tributaries are either springs or draining wet meadows.

Photo 59. Reach 10, NSO 477, T48. Mouth of an artesian well tributary and the end of Reach 10. Note: discoloration of substrate (24 August 2002).

No recreational impacts are evident in Reach 10. Historic extensive grazing occurred in Valle Toledo. Many sections of collapsed banks, which are now beginning to stabilize and grow vegetation, are evidence of this historic grazing. Currently, elk are utilizing San Antonio Creek. Streamside evidence of elk use includes grass stubble, elk scat, and elk beds.

Brown trout and longnose dace are present throughout Reach 10. Some of the brown trout observed showed signs of stress and were abnormal. The shape of the abnormal brown trout is short and stout, lacking the torpedo body type of typical brown trout. The abnormal trout shape is also found in the Valle Grande of the East Fork Jemez River, located on the southeast corner of VCNP.

Water temperatures are measured at random intervals during the survey using a handheld thermometer. Main channel temperature readings are taken in the water column. Five (5) temperatures were taken during the survey of Reach 10. The highest temperature was 67°F and the lowest 48°F.

Habitat Characteristics

The 2.2 stream miles (11,407 feet) of Reach 10 is divided into 18 NSOs. Reach 10 contains only one pool, comprising 0.4 % of stream habitat. The nine (9) riffles consist of 99.1 % of the stream habitat (see Table 46).

Table 46. Summary of Reach 10 habitat types

Habitat Type	Number of Habitats	Total Stream Habitat (ft)	Stream Length* (%)	Stream Habitat** (%)	Properly Functioning Indicators
Pool	1	44	0.4	0.4	>30%
Riffle	9	11,363	99.6	99.1	-
Culvert	0	0	0	0	-
Tributary	6	NA	NA	NA	-
Falls	0	0	0	0	-
Side Channel	2	62	NA	0.5	-
Total	18	11,469	100.0	100.0	-

*Percent Stream Length calculated with only riffle, pool, culvert, and falls habitat types.
**Percent Stream Habitat calculated using all stream habitat types except tributary.

When compared to the matrix of factors and indicators of stream health condition for historic and occupied Rio Grande cutthroat trout streams, Reach 10 contains **not properly functioning, at risk** and **properly functioning** characteristics. The parameters that are **not properly functioning** include the riffle sediment content and pool development, and bank condition is **at risk**. The only **properly functioning** parameter is the width-to-depth ratio. Large woody debris is excluded from analysis in this reach because it is a meadow.

Riffle habitat in Reach 10 is **not properly functioning** for the relative amount of sediment (52.2%). Mitigating the high sediment content should be a management focus in Reach 10.

Table 47. Summary of Habitat and Substrate Percentages for Riffles in Reach 10.

Riffle Habitat Summary						
Reach	Number of Riffles	Avg. Length	Avg. Width	Avg. Depth	Avg. Max. Depth	
10	9	1,262.6	9.5	0.9	1.8	
Substrate Summary						
Reach	% Sand	% Gravel	% Cobble	% Boulder	% Bedrock	Total
10	52.2	42.2	5.6	0.0	0.0	100.0
Properly Functioning Indicators	<20.0	-	-	-	-	-

Pool development is paltry in Reach 10 and **not properly functioning** . The relative pool habitat was only 0.4 (see Table 46). This lack of pool formation is related to excessive sediment loading caused mostly by unstable banks and upland sources. Increasing pool habitat should be a focus in the management of this reach.

Table 48. Summary of Pool Habitat and Substrate Percentages in Reach 10.

Pool Habitat Summary											
Reach	# Of Pools	Length	Width	Max Depth	PTC	Residual Depth	Pools/Mile	# of Pools w/ Residual Depth >1'	Pools w/ Residual Depth >1'/Mile	# of Pools w/ Max. Depth >3'	# of Pools w/ Max. Depth >3'/Mile
10	1	44.4	18.0	2.4	0.4	2.0	0.5	1	0.5	0	0
Properly Functioning Indicators	-	-	-	-	-	≥1ft[1]	-	-	-	-	-

Substrate Summary							
Reach	% Sand	% Gravel	% Cobble	% Boulder	% Bedrock	Total	
10	80.0	20.0	0.0	0.0	0.0	100.0	

[1]The pool quality properly functioning indicator as determined by average residual pool depth is excluded from analysis in San Antonio Creek due to surveyor error.

Large woody debris density analysis is excluded from Reach 10 due to its meadow classification.

Table 49. Habitat Characteristics for Reach 10 of San Antonio Creek.

Reach	Pool:Riffle Ratio	Avg. Bankfull Width:Depth	Pieces of LWD per Mile	Total Unstable Banks (ft)	% Unstable Banks
10	1:9	6:1	0.0	2,325	10.2
Properly Functioning Indicators	-	<12	NA[1]	-	<10

[1]Large woody debris was excluded from analysis in this meadow reach.

The bankfull width-to-depth ratio is within the expected range and **properly functioning** (see Table 49).

Streambank condition is **at risk** for the length of unstable banks in Reach 10. The percentage of unstable banks is 10.2 % (see Table 49), with nearly a half mile of eroding banks.

Recommendations

The management focus for this reach is to mitigate the **not properly functioning** and **at risk** parameters and insure **properly functioning** characteristics are maintained. Both the riffle sediment content, pool development and bank stability are out of compliance with matrix standards. Other management recommendations include the evaluation of the artesian wells.

Photo 60. Reach 10, NSO 477, T48. Artesian well with a tap attempting to control the flow of one of San Antonio Creek's tributaries (24 August 2002).

Historic land use and intensive grazing practices may explain the current impacts to stream habitat in Reach 10. The collapsed undercut banks and road crossings are sources of fine sediment to stream habitat. In low gradient sections like Reach 10, fine sediment settles into the substrate. The fine sediment fills in spawning habitat in riffles, as well as decreases pool habitat. Protection of the currently recovering banks should be a management focus of this reach. By pulling off pressure, the stream will find its equilibrium, forming new undercut banks and allowing unstable banks to heal. Limited pressure in these areas could be accomplished through a variety of activities, which would include but is not limited to: An intensive range riding program, riparian fence exclosure, rotational grazing programs, or rest. The timing of recovery is dictated by which practice or combination of practices that is selected.

The taps placed on the artesian wells in Reach 10 should be evaluated for their impacts to stream habitat. If these taps are not necessary and are causing impact to stream conditions, they should be removed or modified to allow for a natural stream course.

Reach 11: Artesian Well to the Headwater Source

Reach 11 begins at the unnamed artesian well (T48) in the middle of Valle Toledo (T20N, R4E, VCNP, elev. 8635') and ends 1.7 miles upstream at the end of the stream flow (T20N R5E, VCNP, 8760' elev.). The valley is approximately ¾-mile wide at the beginning of the reach and gradually narrows to 200 feet. The average gradient of the reach is 1.4%. The stream width ranges from 1 (see Photo 62) to 12 feet. The channel is sinuous with many short meanders. This reach's habitat is characterized by sluggish flow with lots of fine sediment. The dominant substrate is sand with areas of gravel and small amounts of cobble. Much of the gravel and cobble is covered with fine sediment. This section contains a channel that is often indistinct, the stream often leaving the channel and flowing through the grass along its margins. Much of these attributes equate to a Rosgen E5 stream class.

Photo 61. Reach 11. Valle Toledo near the headwaters of San Antonio Creek with smoke from the Lakes Fire (26 August 2002).

Upland vegetation in this reach consists of aspen and fir and is several hundred feet to ½ mile from the stream. The riparian vegetation consists of grasses, sedges, rushes, and wildflowers (see Photos 61 and 62). Riparian vegetation species include yarrow, buttercup, dandelion, harebell, iris, and clover. Aquatic vegetation was abundant throughout and includes elodea, potamogeten spp., watercress, and filamentous algae.

All three (3) of the tributaries that enter the stream in this reach contribute between 10 and 40% of the stream flow. The most downstream tributary (T49) is an artesian well located about 300 feet away from the stream on the left bank. This well forms a 50x75 foot marshy area before becoming a channel and flowing into the stream. This well contributes 10-20% of stream flow. The second tributary (T50) in this section originates at an artesian well ¼-mile away on the right bank and enters the stream in a two-foot wide channel contributing approximately 15% of stream flow. The third tributary (T51) is a spring 200 feet downstream from the end of the survey and contributes 40% of stream flow.

Photo 62. Reach 11, NSO 482, R202. Riparian vegetation and narrow stream width near the headwaters of San Antonio Creek in Valle Toledo (24 August 2002).

One large adult brown trout, longer than 12 inches, was observed in the stream. Other aquatic species in Reach 11 include tadpoles and water shrews.

Water temperatures are measured at random intervals during the survey using a handheld thermometer. Main channel temperature readings are taken in the water column. Seven (7) temperatures were taken during the survey of Reach 11. The highest temperature was 70°F and the lowest was 54°F.

Habitat Characteristics

The 1.7 stream miles (8,922 feet) of Reach 11 is divided into 14 NSOs. Reach 11 contains one pool, comprising only 0.7% of the stream habitat. The nine (9) riffles consist of 99.0% of the stream habitat (see Table 50).

Table 50. Summary of Reach 11 habitat types

Habitat Type	Number of Habitats	Total Stream Habitat (ft)	Stream Length* (%)	Stream Habitat** (%)	Properly Functioning Indicators
Pool	1	51	0.7	0.7	NA[1]
Riffle	9	8,871	99.3	99.0	-
Culvert	0	0	0	0	-
Tributary	3	NA	NA	NA	-
Falls	0	0	0	0	-
Side Channel	1	16	NA	0.3	-
Total	14	8,938	100.0	100.0	-

*Percent Stream Length calculated with only riffle, pool, culvert, and falls habitat types.
**Percent Stream Habitat calculated using all stream habitat types except tributary.
[1] Stream segments smaller than 3rd order are not analyzed

When compared to the matrix of factors and indicators of stream health condition for historic and occupied Rio Grande cutthroat trout streams, Reach 11 contains **not properly functioning** and **properly functioning** characteristics. The only parameters that are **not properly functioning** include the riffle sediment content and pool development. The **properly functioning** parameters include stream bank condition and the width-to-depth ratio. Large woody debris is excluded from analysis in this reach because it is a meadow and lacks local wood recruitment.

Riffle habitat in Reach 11 is **not properly functioning** for the relative quantity of fine sediment, 68.9% (see Table 51). Mitigating the high sediment content should be a management focus in Reach 11 although could be limited by natural stream conditions due to relatively low flow.

Table 51. Summary of Habitat and Substrate Percentages for Riffles in Reach 11.

Riffle Habitat Summary						
Reach	Number of Riffles	Avg. Length	Avg. Width	Avg. Depth	Avg. Max. Depth	
11	9	1,262.6	3.6	0.5	1.3	
Substrate Summary						
Reach	% Sand	% Gravel	% Cobble	% Boulder	% Bedrock	Total
11	68.9	24.4	5.6	1.1	0.0	100.0
Properly Functioning Indicators	<20.0	-	-	-	-	-

Pool development is not analyzed since the stream segment is smaller than a 3rd order stream.

Table 52. Summary of Pool Habitat and Substrate Percentages in Reach 11.

Pool Habitat Summary											
Reach	# Of Pools	Length	Width	Max Depth	PTC	Residual Depth	Pools/Mile	# of Pools w/ Residual Depth >1'	Pools w/ Residual Depth >1'/Mile	# of Pools w/ Max. Depth >3'	# of Pools w/ Max. Depth >3'/Mile
11	1	51	10	2.3	0.5	1.8	0.6	1	0.6	0	0
Properly Functioning Indicators	-	-	-	-	-	≥1ft[1]	-	-	-	-	-

Substrate Summary							
Reach	% Sand	% Gravel	% Cobble	% Boulder	% Br	Total	
11	50.0	50.0	0.0	0.0	0.0	100.0	

[1]The pool quality properly functioning indicator as determined by average residual pool depth is excluded from analysis in San Antonio Creek due to surveyor error.

Large woody debris density analysis is excluded from Reach 11 due to its meadow classification. No LWD is located in Reach 11.

Table 53. Habitat Characteristics for Reach 11 of San Antonio Creek.

Reach	Pool to Riffle Ratio by number of habitats	Avg. Riffle Width to Depth	Pieces of LWD per Mile	Total Unstable Banks (ft)	Percentage of Unstable Banks
11	1:9	1.3:1	0.0	1,320	7.4
Properly Functioning Indicators	-	<12	NA[1]	-	<10

[1]Large woody debris was excluded from analysis in this meadow reach.

The bankfull width-to-depth ratio is within the expected range of <12 and **properly functioning** (see Table 53).

Streambank condition is **properly functioning** for the length of unstable banks in Reach 11. Bank stability is 2.6% below the <10% standard (see Table 53).

Recommendations

There are no project level recommendations for this reach other than to monitor conditions over time and make certain that future management does not impair downstream segments of San Antonio Creek as well as headwater sources (see Photo 63).

Photo 63. Reach 11, NSO 492, R208. Terminus of San Antonio Creek and survey. Note: standing water and raw banks (26 August 2002).

APPENDIX A

Protocol Components

Table 1. Summary of measurements and estimations used in the Region 3 Hankins/Reeves stream suvey protocol (Stream Inventory Handbook April 2002).

Measurements	Estimations
Maximum depth of pools, riffles, and side channels	Average depth of riffles
Depth of pool tail crest	Substrate percentages in bankfull width
One bankfull width depth transect per reach	Average wetted width of riffles and pools*
Number of large woody debris within bankfull	Length of bank instability
Surveyor collected main channel and tributary water temperature and time	Total length, wetted width, and maximum depth of side channels
Thermograph collected water temperature (Recorded every four hours)	Length of first habitat unit of tributaries and percent stream flow contribution

*Width estimations were corrected by the comparison of a minimum of 10% measured habitats in each reach to the related estimates. This technique was used to produce correction factor for each reach, which was then applied to analysis of the widths of that reach and the entire stream analysis.

Table 2. Feature types collected by Trimble Geo Explorer 3 GPS units.

Reach Breaks	Tributary Mouth
Woody Debris Jams (of 3 or More Pieces)	Barriers to Fish Passage
Areas of Concern (Major Erosion, Road Crossings, Etc…)	Side Channels (only longer than 10 times the wetted width of the main channel)
Beaver Dams (If Active and over 1’ in Height)	Thermograph Stations
Snorkel Survey Transect Locations	Culverts
Flow Stations	Water Temperature Monitoring Stations

Tributaries

Table 3. Information summary of the tributaries to San Antonio Creek.

Reach	Habitat Number	Bank	Type	Name	Percent Flow*	Time	Tributary Temp (°F)	Stream Temp (°F)	Comments
1	T1	Right			15	1252	73		
1	T2	Right			<5	1648	68	70	One to two feet wide and covered with brush
1	T3	Right	Spring		<5	1722	78	65	Steep gradient
1	T4	Right	Spring	Spence Hot Springs	5	1746	82	65	High gradient with anthropogenic degredation
1	T5	Right	Seep		<5	1154	60	62	Enters stream at Dark Canyon fishing access area
1	T6	Right	Seep		<5	1218	61	62	Five feet upstream from T5
1	T7	Left	Spring		<5	1253	60	65	Source is 2-3 small metal pipes that cross Highway 4
2	T8	Right	Stream	Sulphur Creek	0	1005	58	58	Dry at time of survey. Temperature taken in beaver-dam pool.
5	T9	Left	Spring		<5	1350	55	64	Source is 4, 2 inch pvc pipes.
5	T10	Right	?		<5	0930	60	60	Originates in a wet meadow
5	T11	Left	Seep		<5	0945	65	61	Total wetted width is six feet from a couple unconnected points
5	T12	Right	Spring		<5	1600	62		Drain's Ice Cave Canyon
5	T13	Left	Seep		<5	1200	62	60	
5	T14	Right	Seep		<5	1350	70	62	
5	T15	Right	?		<5	1415	61		High gradient-steady trickle
5	T16	Right	?		5	1430	65	65	
5	T17	Right	Seep		<5	1615	65		
5	T18	Left	Spring		<5	1140	60		High gradient (approx. 45 degree slope)
5	T19	Right	Spring	San Antonio Hot Springs	10-15	1325	88	72	Temperature immediately upstream of tributary was 70
6	T20	Right			<5	1410	67	71	

6	T21	Left	Seep		<5	1000	73	66	Marshy area across F.R. 376 drains through culvert to stream
7	T22	Right				1515	62	68	Approximately ¼ mile upstream from VCNP boundary
7	T23	Left	Spring		<5	1250	80	65	At the end of the reach as valley opens wide up
8	T24	Left	Spring		<5	1300	62		
8	T25	Right	Spring		<5	1350	66		Originates in Marshy area before forming a channel
8	T26	Left	Spring		<5	1230	100	63	Hot spring in Valle San Antonio- Temperature immediately upstream was 63
8	T27	Right			<5	1245	67	63	Low gradient, slow flow and lots of aquatic vegetation.
8	T28	Right			5	1405	67		
8	T29	Right	Stream	San Luis Creek	<5	1530	66		
8	T30	Right	Spring		<5	1600	73		
8	T31	Right	Spring		<5	1045	56	55	
8	T32	Left			<5	1025	60	55	
8	T33	Right	Stream		5-10				Stream flows out of Valle Santa Rosa
8	T34	Right	Seep		<5				Large wet meadow seeps into stream
8	T35	Left			<5	1550	78	72	
8	T36	Left			<5	1415	64		Originates in a wet meadow
8	T37	Left	Stream	Rito de los Indios	15	1335	56		Enters stream between Valle San Antonio and Valle Toledo
9	T38	Right			<5	1624	63	62	
9	T39	Left	Spring		<5	1600	68	62	Fish observed in this tributary
9	T40	Right	Spring		<5	1610	72	62	
9	T41	Left	Spring		10	1245	57	57	Springs flowing out of rock enter stream in an approx. 100 foot area
9	T42	Right			<5	1241	60	57	Multiple springs over an approx. 200 foot area
10	T43	Right	Spring		<5	1005	55	59	Three small

									channels feed into the stream from large marshy area
10	T44	Right	Spring		10-15				
10	T45	Right	Spring		<5	1105	60		
10	T46	Right	Spring		<5	1141	63		
10	T47	Right			<5	1240	79		
10	T48	Left			65	1420	60		Source is artesian Well in Valle Toledo
11	T49	Left			15	1440	74	70	Source is artesian well in Valle Toledo
11	T50	Right			15	1535	64	66	Source is artesian well
11	T51	Right	Spring		40	1425	46	54	Enters stream 600 feet downstream from end of stream

Stream Temperature

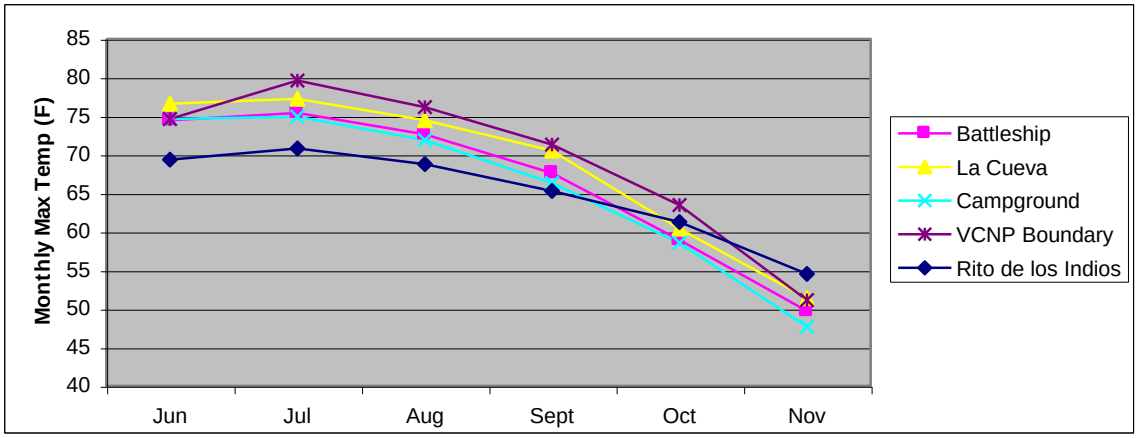


Figure 1. Monthly average maximum temperatures in San Antonio Creek at five thermograph stations.

Table 4. Monthly max, min and average temperatures recorded at Battleship temperature station between June 11th and September 30th 2002.

Battleship temperature station			
Month	Maximum (°F)	Minimum (°F)	*Average (°F)*
June	74.47	53.64	*63.47521*
July	75.4	57.26	*64.54172*
August	72.64	53.64	*62.81333*
September	67.6	48.9	*57.48839*

Snorkeling Results

Table 5. Fish species observed during a 500 meter snorkel survey of San Antonio Creek of San Antonio Creek (T19N R3E S8) near San Antonio Campground, Reach 4. Survey conducted on July 9th and 11th 2002.

Common Name	Scientific Name	Number
Brown Trout	*Salmo trutta*	41
Rainbow Trout	*Oncorhynchus mykiss*	10
Longnose Dace	*Rhinichthys cataractae*	153
Rio Grande Sucker	*Catastomus plebius*	20
White Sucker	*Catostomus commersoni*	3
Rio Grande Chub	*Gila pandora*	1

Table 6. Fish species observed during a 700 meter snorkel survey near Ice Cave Canyon (T19N R3E S31 and 32) of San Antonio Creek, Reach 5. Survey was conducted on July 25th, 2002.

Common Name	Scientific Name	Number
Brown Trout	*Salmo trutta*	116
Rainbow Trout	*Oncorhynchus mykiss*	3
Longnose Dace	*Rhinichthys cataractae*	72
Rio Grande Sucker	*Catastomus plebius*	219
Unknown Sucker	-	10
Unknown Fish	-	1

APPENDIX B:
Pool Volume Proof

$$f(x,y) := \left(\frac{x}{a}\right)^2 + \left(\frac{y}{b}\right)^2$$

Area of an Ellipe

$$\int_{-a}^{a} \int_{-b\cdot\frac{\left(a^2-x^2\right)^{.5}}{a}}^{b\cdot\frac{\left(a^2-x^2\right)^{.5}}{a}} 1\,dy\,dx \rightarrow$$

3.141592653589793238462 b·a

or π*b*a

Volume of a parabolic ellipsoid with h=height a=from ctr to b is
from center to edge 1

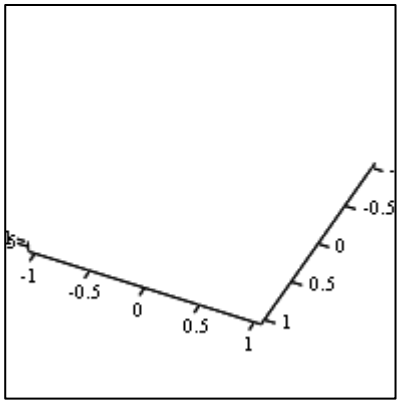
$$\int_{-a}^{a} \int_{-b\cdot\frac{\left(a^2-x^2\right)^{.5}}{a}}^{b\cdot\frac{\left(a^2-x^2\right)^{.5}}{a}} \int_{0}^{h\cdot\left[\left(\frac{x^2}{a^2}\right)+\left(\frac{y^2}{b^2}\right)\right]} 1\,dz\,dy\,dx \rightarrow$$

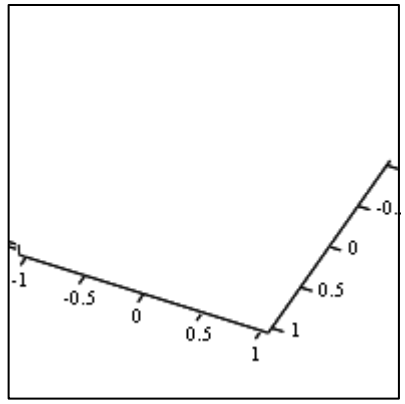
$$\frac{\pi}{2}\cdot h\cdot b\cdot a$$ I believe this is your volume

$a := 4 \qquad b := 5$

$$f(x,y) := \left(\frac{x}{a}\right)^2 + \left(\frac{y}{b}\right)^2$$

Surface Plot **Contour Plot**

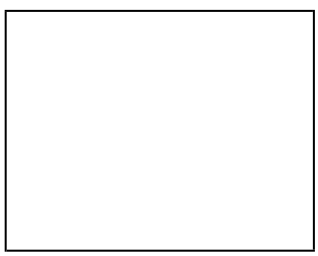




f x = 0 f y = 0

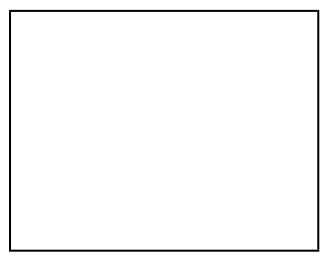
Cross Sections (2-D)

$f(0,y)$



y

$f(x,0)$



x

For pool volume calculations the corrected average width, average max depth and average length is applied to the formula and multiplied by the number of habitats.

Riffle volume is estimated by the volume of a prism. Measurements used are average length (L), corrected average width (W) and average depth (D) multiplied by the number of riffle habitats (N).

$$L_{ave} * w_{ave} * d_{ave} * N = \text{Riffle Volume}$$

GLOSSARY

Artesian Well: A well drilled through impermeable strata into a strata that receives water from a higher altitude so there is pressure to force the water to flow upward.

Eutrophication: Having waters rich in mineral and organic nutrients that promote a proliferation of plant life, especially algae, which reduces dissolved oxygen content and often causes the extinction of other organisms.

Gabion Structures: Wire boxes filled with cobble or larger sized substrate to create "walls" and used for bank stability. Much like riprap, these structures to have equally adverse affects as streams adjust to this hardening.

Hybridization: The result of a genetic cross between different species. In the fish populations of New Mexico, Rio Grande cutthroat trout when in contact with rainbow trout will cross breed to produce cut-bows. Hybridization destroys the genetic purity of Rio Grande cutthroat trout populations.

HUC Code: Hydrologic Unit Code used to identify watersheds.

Large Woody Debris (LWD): Wood that is within the bankfull channel for a habitat unit and is above the minimum size requirement. Woody debris is classified into categories with relation to length and diameter. The smallest wood classified in this survey must be greater than 6 inches in diameter at a length of 20 feet from the largest end. For analysis only wood with a diameter of greater than 12 inches at a length of 35 feet from the large end are used (designated as medium and large pieces).

Large Woody Debris Jams: A minimum of 3 pieces of LWD interacting within the bankfull channel.

Meadow Reach: Predominance of valley formation has meadow characteristics which includes lacking trees in the active floodplain. No LWD recruitment within the reach.

Natural Sequence Order (NSO): A division system used to classify stream habitats. Each habitat is assigned a unique NSO number in consecutive order from the mouth upstream.

Response Reach: Low-gradient and/or constricted reaches typically located downstream from high gradient transportation reaches. Response reaches are noted for their channel and habitat formation caused by upstream factors.

Riparian Vegetation: Streambank or streamside vegetation; influenced by wet conditions associated to a high water table or live water.

Riprap: A loose assemblage of broken stones erected in water or on soft ground as a foundation. Riprap is used to improve bank stability in streams, but has other and occasionally adverse effects.

Seep: A tributary with very slow flow, often associated with draining wet meadows

Spring: A flowing tributary with a source within 100 feet from the stream channel.

Stream: All tributaries that are not classified as a seep or spring. Usually streams are associated with a distinct drainage and have a more significant flow than the other tributary types.

Stream Habitat (%): A calculation of relative habitat types, which includes culverts, falls, pools, riffles and secondary channels. Tributary habitats are not included in the calculation.

Stream Length (%): A calculation of relative main channel habitat types which includes culverts, falls, pools, and riffles. Tributary and secondary channel habitats are not included in the calculation.

Transport Reach: High gradient and non-constricted reaches that act as a conveyor belt of source materials, such as large wood, substrate and fine materials.

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The Crew (L to R): Serina, Matt (Team Leader) and Amos

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