6.0 TEMPERATURE

Monitoring for temperature was conducted by SWQB in 2006. Based on available data, several exceedences of the New Mexico WQS for temperature were noted throughout the watershed (Figure 6.1). Thermographs were set to record once every hour for several months during the warmest time of the year (generally May through October). Thermograph data are assessed using Appendix C of the *State of New Mexico Procedures for Assessing Standards Attainment for the Integrated CWA §303(d)/§305(b) Water Quality Monitoring and Assessment Report [Assessment Protocol]* (NMED/SWQB 2009). Based on 2006 data, temperature listings were added to the *2010-2012 State of NM §303(d) List for Impaired Waters* (NMED/SWQB 2010a) for Cieneguilla Creek (Eagle Nest Lake to headwaters), Cimarron River (Cimarron Village to Turkey Creek), Moreno Creek (Eagle Nest Lake to headwaters), Rayado Creek (Miami Lake diversion to headwaters), Sixmile Creek (Eagle Nest Lake to headwaters), South Ponil Creek (Ponil Creek to headwaters), and Ute Creek (Cimarron River to headwaters). The following assessment units have a previous temperature TMDL and were still found to be impaired for temperature based on the assessment of 2006 data: Middle Ponil Creek (South Ponil Creek to Greenwood Creek), North Ponil Creek (South Ponil Creek to Seally Canyon), and Ponil Creek (US 64 to confluence of North and South Ponil Creeks). Temperature data from 2006 were used to develop these TMDLs.

6.1 Target Loading Capacity

For this TMDL document, target values for temperature are based on the reduction in solar radiation necessary to achieve numeric criteria as predicted by a temperature model. Because all seven AUs with temperature impairments are classified in 20.6.4.309 NMAC and have the designated use of high quality coldwater aquatic life, the applicable temperature criterion is 20°C (68°F). Table 6.1 and Figure 6.1 highlight the 2006 thermograph deployments. This TMDL addresses seven reaches where temperatures exceeded the criterion (**Appendix C** of this document provides a graphical representation of thermograph data):

Cieneguilla Creek (Eagle Nest Lake to headwaters): One thermograph was deployed on this reach in 2006 at Cieneguilla Creek above Eagle Nest Lake at USGS gage (site A). Recorded temperatures from May 16 through August 29 exceeded the HQCW aquatic life use criterion 581 of 2,518 times (23%) with a maximum temperature of 27.063°C on July 20. An air thermograph was deployed at this station during the same time period.

Cimarron River (Cimarron Village to Turkey Creek): One thermograph was deployed on this reach in 2006 at Cimarron River above Cimarron Village at gage (site B). Recorded temperatures from May 16 through September 13 exceeded the HQCW aquatic life use criterion 401 of 2,879 times (13.9%) with a maximum temperature of 26.2°C on July 16. An air thermograph was deployed at this station during the same time period.

Moreno Creek (Eagle Nest Lake to headwaters): One thermograph was deployed on this reach in 2006 at Moreno Creek on NM 64 at gage (site D. Recorded temperatures from May 16 through September 13 exceeded the HQCW aquatic life use criterion 567 of 3,900 times (20%) with a maximum temperature of 27.4°C on Aug 10.

Rayado Creek (Miami Lake Diversion to headwaters): One thermograph was deployed on this reach in 2006 at Rayado Creek at NM 21 (site H). Recorded temperatures from May 16 through September 14 exceeded the HQCW aquatic life use criterion 873 of 2,899 times (30%) with a maximum temperature of 27.3°C on July 16.

Sixmile Creek (Eagle Nest Lake to headwaters): One thermograph was deployed on this reach in 2006 at Sixmile Creek above US 64 at gage (site J). Recorded temperatures from May 16 through September 13 exceeded the HQCW aquatic life use criterion 483 of 2,876 times (19.8%) with a maximum temperature of 28.1°C on July 16.

South Ponil Creek (Ponil Creek at Middle Ponil Creek): One thermograph was deployed on this reach in 2006 at South Ponil Creek above North Ponil (site L). Recorded temperatures from May 16 through June 14 exceeded the HQCW aquatic life use criterion 72 of 689 times (10%) with a maximum temperature of 24.6°C on June 2.

Ute Creek (Cimarron River to headwaters): One thermograph was deployed on this reach in 2006 at Ute Creek above US 64 at Ute Park (site M). Recorded temperatures from May 16 through September 13 exceeded the HQCW aquatic life use criterion 198 of 2,879 times (6.9%) with a maximum temperature of 24.75°C on July 16.

Table 6.1 Cimarron River watershed thermograph sites (2006)

Site Number	STORET ID	Site Name	Deployment Dates (2006)
A	05Cieng006.3	Cieneguilla Creek above Eagle Nest Lake at gage [a]	16 May – 29 Aug
B	05Cimarr050.8	Cimarron River above Cimarron Village at gage [a]	16 May - 13 Sep
C	05MPonil000.1	Middle Ponil Creek above South Ponil Creek	16 May - 14 Sep
D	05Moreno003.7	Moreno Creek on NM 64 at gage	16 May - 13 Sep
E	05NPonil000.1	North Ponil Creek above South Ponil	16 May - 14 Sep
F	05PonilC014.9	Ponil Creek above NM 64	16 May - 13 Sep
G	05PonilC000.1	Ponil Creek above Cimarron River	16 May - 13 Sep
H	05Rayado033.8	Rayado Creek on NM 21	16 May - 14 Sep
I	05Rayado001.8	Rayado Creek above Cimarron River	16 May - 14 Sep
J	05Sixmil001.4	Sixmile Creek above US 64 near gage	16 May - 13 Sep
K	05SPonil008.5	South Ponil above Middle Ponil [a]	16 May – 14 June
L	05SPonil000.1	South Ponil above North Ponil	16 May – 14 June
M	05UteCre000.6	Ute Creek above US 64 at Ute Park	16 May - 13 Sep

[a] air thermographs also deployed

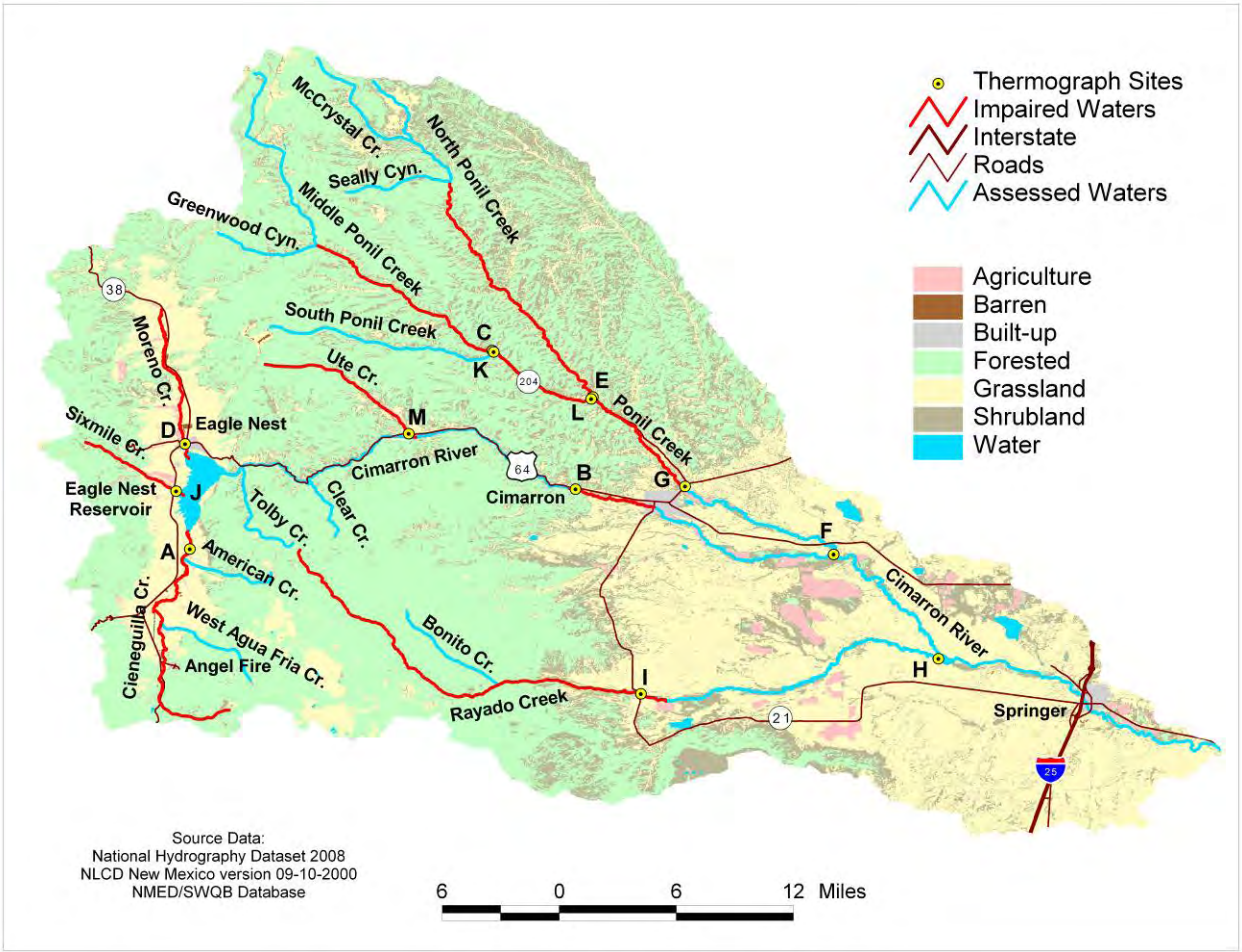


Figure 6.1 Cimarron River watershed thermograph sites (2006)

6.2 Flow

The critical flow condition for these TMDLs was obtained using a 4-day, 3-year low-flow frequency (4Q3) regression model. The 4Q3 is the minimum average four consecutive day flow that occurs with a frequency of at least once every 3 years. Low flow was chosen as the critical flow because of the negative effect low flows have on temperatures.

Table 6.2. USGS gages in the Cimarron Watershed (HUC 11080002)

Agency	Site Number	Site Name	Period of Record
USGS	7204000	Moreno Creek at Eagle Nest, NM	1928 - 2008
USGS	7204500	Cieneguilla Creek near eagle Nest. NM	1928 - 2008
USGS	7205000	Sixmile Creek near Eagle Nest, NM	1958 - 2008

USGS	7205500	Eagle Nest Lake near Eagle Nest, NM	1987 - present
USGS	7206000	Cimarron River below Eagle Nest Dam, NM	1950 - present
USGS	7207000	Cimarron River near Cimarron, NM	1950 - present
USGS	7207500	Ponil Creek near Cimarron, NM	1916 - present
USGS	7208500	Rayado Creek near Cimarron, NM	1911 - present
USGS	7211000	Cimarron River at Springer, NM	1907 - 2004

When available, USGS gages are used to estimate flow. There are nine gages that were active in the Cimarron Watershed around the time of the water quality survey and data collection efforts (Table 6.2). The 4Q3 flows for Cieneguilla Creek, Cimarron River, Moreno Creek, Rayado Creek, and Sixmile Creek were estimated using the appropriate gage data and DFLOW software, Version 3.1b (USEPA 2006). DFLOW 3.1b is a Windows-based tool developed to estimate user selected design stream flows for low flow analysis by utilizing algorithms based on Log Pearson Type III distribution.

A climatic year starting April 1 of the prior year and ending March 31 is often used when examining critical low flow conditions in the United States. This choice reduces the likelihood of splitting low flow periods - typically found in the summer or fall - across different years and thereby affecting the results of Log Pearson Type III analysis of series of annual low flows. A different climatic year or shorter season may be used if low flow periods occur at other times of the year or overlap the boundaries of the climatic year.

DFLOW 3.1 allows the user to specify a season that lasts less than a year by indicating the start date and end date of the season. A seasonal component was added to the higher elevation reaches (i.e. Cieneguilla Creek, Moreno Creek, and Sixmile Creek) because cold temperatures and freezing conditions combine to create zero dischage during the winter months. The 4Q3 flows for Cieneguilla Creek, Moreno Creek, and Sixmile Creek were calculated using gage data from the typical growing season for the ecoregion and elevation (July 1 – October 31). The growing seasons were established for three general regions by using the median annual dates of the last and first frost from the National Weather Service (Table 6.3). If a full year's worth of data were included in the critical flow calculations for these high elevation streams then the 4Q3 values would be zero.

Table 6.3. Growing season definitions for ecoregion and elevation classes

Regions	Ecoregion Names	Ecoregion	Begin	End	Length
Mountain >7500 ft	S. Rockies & AZ/NM Mountains	22 & 23	1-July	1-Oct	3 months
Mountains <7500 ft & Plateau	S. Rockies, AZ/NM Mountains & AZ/NM Plateau	20, 21, 22 & 23	15-Jun	1-Nov	4 ½ months
S. Deserts and Plains	SW Tablelands & Chihuahuan Desert	24, 25, 26, & 79	15-May	15-Nov	6 months

A seasonal component was also added to the Cimarron River (Cimarron Village to Turkey Creek) because streamflow in this reach is dependent on releases from Eagle Nest Dam. Eagle Nest Water is released from Eagle Nest Dam because of irrigation demands downstream. The 4Q3 flow for this portion of the Cimarron River was calculated using gage data from the Cimarron River near Cimarron, NM (USGS 07207000) during the typical growing season for the ecoregion and elevation (June 15 – October 31). Consistent water releases of 45 to 50 cubic feet per second occur throughout the growing season and can be expected until October. However, in the winter months when water is stored up in Eagle Nest Lake, flows in the Cimarron River can slow to a trickle.

The specific inflow and outflow values used in the SSTEMP model are discussed in detail in Appendix D.

6.3 Calculations

The Stream Segment Temperature (SSTEMP) Model, Version 2.0, developed by the USGS Biological Resource Division (Bartholow 2002) was used to predict stream temperatures based on watershed geometry, hydrology, and meteorology. The model predicts mean, minimum, and maximum daily water temperatures throughout a stream reach by estimating the heat gained or lost from a parcel of water as it passes through a stream segment (Bartholow 2002). The predicted temperature values are compared to actual thermograph readings measured in the field in order to calibrate the model. The SSTEMP model identifies current stream and/or watershed characteristics that control stream temperatures. The model also quantifies the maximum loading capacity of the stream to meet water quality criteria for temperature. This model is important for estimating the effect of changing controls, or constraints, (such as riparian grazing, stream channel alteration, and reduced streamflow) on stream temperature. The model can also be used to help identify possible implementation activities to improve stream temperature by targeting those factors causing impairment to the stream.

6.4 Waste Load Allocations and Load Allocations

6.4.1 Waste Load Allocation

With the exception of the Cienguilla Creek (Eagle Nest Lake to headwaters), there are no point source contributions associated with these TMDLs.

The Angel Fire Wastewater Treatment Plant (WWTP) discharges directly into Cienguilla Creek. There is some debate regarding whether or not effluent from WWTPs has an impact on temperature. The Angel Fire WWTP NPDES permit (NM0030503) does not have limitations or monitoring requirements for temperature. WWTP effluent has never been noted to be a significant source contributor of temperature impairment. Data indicate that the Angel Fire WWTP is not contributing to elevated temperature in Cienguilla Creek. Figure 6.2 displays the temperature data collected in 2006. Site 05Cieneg19.3 is 1.6 miles upstream of the WWTP and

05Cieng006.3 is 6.7 miles downstream of the WWTP. During the eight discrete sampling events during 2006, the differences between the upstream and downstream sites ranged from 4.24°C (June 13) to 0.39°C (March 14) with the average difference between the sites being 2°C.

According to discharge records, the Angel Fire WWTP was not discharging to Cienguilla Creek from February-November 2006. There is a diminutive change in temperature between the two monitoring sites and no significant temperature contribution is assumed from the WWTP. Although no WLA is assigned to the Angel Fire WWTP, a monitoring requirement should be added to the NM0030503 NPDES permit to ensure that that the discharge meets the WQS of 20oC at the discharge point to Cienguilla Creek.

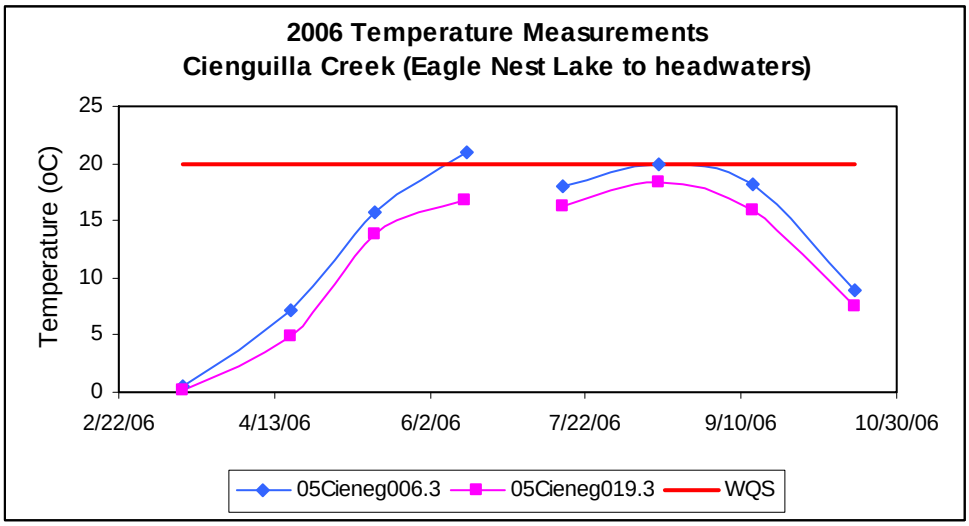


Figure 6.2 Temperature Measurements at Cienguilla Creek (2006)

6.4.2 Load Allocation

Water temperature can be expressed as heat energy per unit volume. SSTEMP provides an estimate of heat energy expressed in joules per square meter per second (j/m^2/s) and Langley's per day. The following information relevant to the model runs used to determine temperature TMDLs is taken from the SSTEMP documentation (Bartholow 2002). Please refer to the SSTEMP User's Manual for complete text. Various notes have been added below in brackets to clarify local sources of input data.

The program will predict the minimum, mean, and maximum daily water temperature for the set of variables you provide. The theoretical basis for the model is strongest for the mean daily temperature. The maximum is largely an estimate and likely to vary widely with the maximum daily air temperature. The minimum is computed by subtracting the difference between maximum and mean from the mean; but the minimum is always positive. (Bartholow 2002).

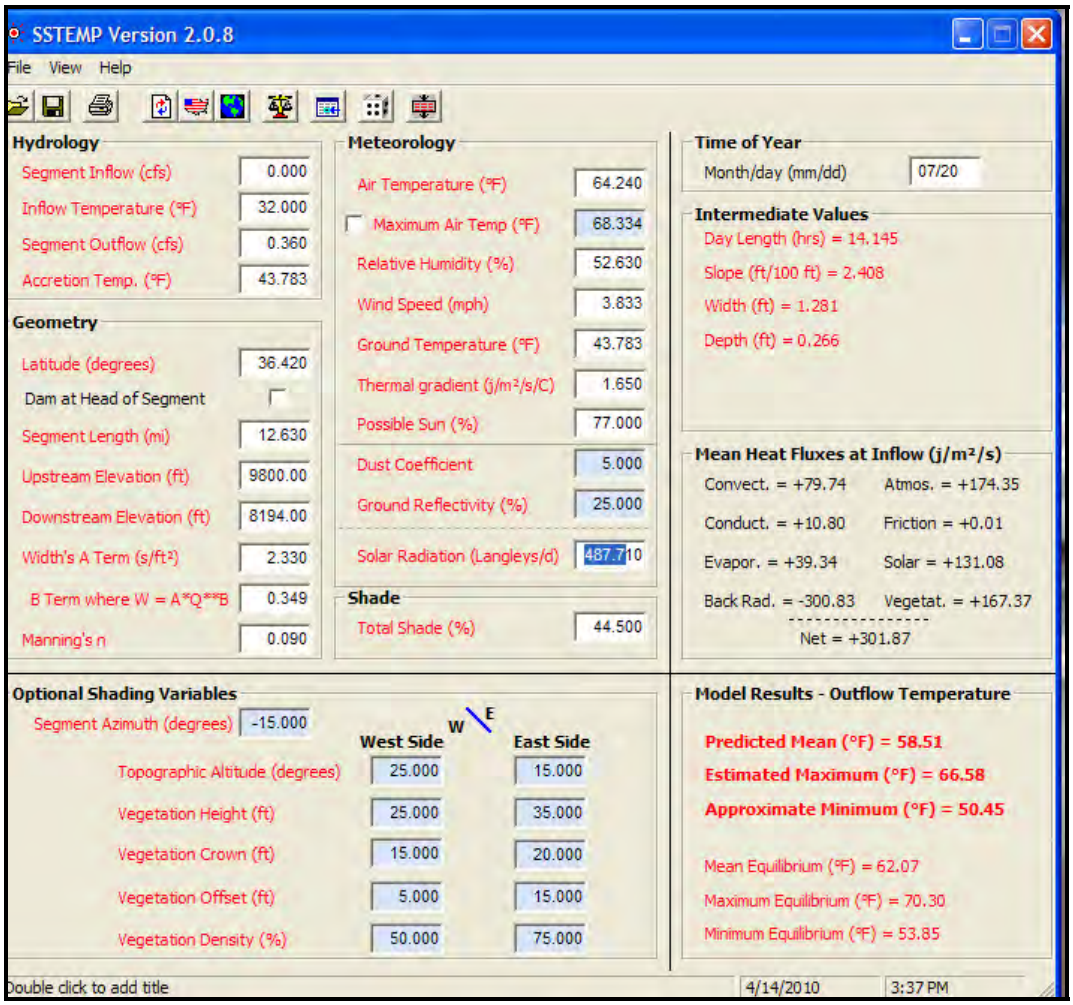


Figure 6.3 Example of SSTEMP input and output for Cienguilla Creek

SSTEMP may be used to compute, one-at-a-time, the sensitivity input values. This simply increases and decreases most active input (i.e., non-grayed out values) by 10% and displays a screen for changes to mean and maximum temperatures. The schematic graph that accompanies the display gives an indication of which variables most strongly influence the results (Bartholow 2002). See Figure 6.4 for an example of a sensitivity analysis.

6.4.2.1 Temperature Allocations as Determined by % Total Shade and Width-to-Depth Ratios

Tables 6.4-6.10 detail model run outputs for segments on Cienguilla Creek, Cimarron River, Moreno Creek, Rayado Creek, Sixmile creek, South Ponil, and Ute Creek. SSTEMP was first calibrated against thermograph data to determine the standard error of the model. Initial conditions were determined. As the percent total shade was increased and the Width's A term was decreased, the maximum 24-hour temperature decreased until the segment-specific standard of 20ºC was achieved. The calculated 24-hour solar radiation component is the maximum solar load that can occur in order to meet the WQS (i.e., the target capacity). In order to calculate the

actual load allocation (LA), the waste load allocation (WLA) and margin of safety (MOS) were subtracted from the target capacity (TMDL) following **Equation 6-1**.

$$WLA + LA + MOS = TMDL \qquad \text{(Eq. 6-1)}$$

The allocations for each assessment unit requiring a temperature TMDL are provided in the following tables:

Temperature Load Allocation for Cienguilla Creek (Eagle Nest Lake to headwaters)

For Cienguilla Creek (Eagle Nest Lake to headwaters) the WQS for temperature is achieved when the percent total shade is increased to 38%. According to the SSTEMP model, the actual LA of 131.79 j/m^2/s is achieved when the shade is further increased to 44% (Table 6.4).

Table 6.4 SSTEMP Model Results for Cienguilla Creek (Eagle Nest Lake to headwaters)

Rosgen (1996) Channel Type	WQS (HQCW Aquatic Life)	Model Run Date	Segment Length (miles)	Solar Radiation Component per 24-Hours (+/-)	% Total Shade	Width's A Term	Modeled Temperature °C (24 hour)
---	20°C (68°F)	7/20/06	12.63	**Current Field Condition** +207.83 j/m^2/s	12	2.33	Minimum: 10.53 Mean: 16.80 Maximum: 23.07
TEMPERATURE ALLOCATIONS FOR Cienguilla Creek (Eagle Nest Lake to headwaters) [a] **24-HOUR ACHIEVEMENT OF SURFACE WQS FOR TEMPERATURE** [b] 24-HOUR LOAD ALLOCATION (LA) NEEDED TO ACHIEVE SURFACE WQS WITH A 10% MARGIN OF SAFETY Actual reduction in solar radiation necessary to meet surface WQS for temperature: Current Condition – Load Allocation = 207.83 j/m^2/s – 131.79 j/m^2/s **= 76.04 j/m^2/s**				**Run 1** +188.94 j/m^2/s	20	2.33	Minimum: 10.45 Mean: 16.30 Maximum: 22.15
				Run 2 +146.43 [a] j/m^2/s	38	2.33	Minimum: 10.29 Mean: 15.15 Maximum: 20.01
				Actual LA 131.79 [b] j/m^2/s	44	2.33	Minimum: 10.25 Mean: 14.73 Maximum: 19.21

Temperature Load Allocation for Cimarron River (Cimarron Village to Turkey Creek)

For Cimarron River (Cimarron Village to Turkey Creek), the WQS for temperature is achieved when the percent total shade is increased to 60%. According to the SSTEMP model, the actual LA of 104.70 j/m^2/s is achieved when the shade is further increased to 64% (Table 6.5).

Table 6.5 SSTEMP Model Results for Cimarron River (Cimarron Village to Turkey Creek)

Rosgen (1996) Channel Type	WQS (Coldwater Aquatic Life)	Model Run Date	Segment Length (miles)	Solar Radiation Component per 24-Hours (+/-)	% Total Shade	Width's A Term	Modeled Temperature °C (24 hour)
---	20°C (68°F)	7/16/06	4.25	**Current Field Condition** +157.05 j/m^2/s	46	5.78	Minimum: 12.05 Mean: 16.98 Maximum: 21.92
				Run 1 +130.88 j/m^2/s	55	5.78	Minimum: 11.96 Mean: 16.32 Maximum: 20.69
				Run 2 +116.33 [(a)] j/m^2/s	60	5.78	Minimum: 11.92 Mean: 15.96 Maximum: 19.98
				Actual LA 104.70 [(b)] j/m^2/s	64	5.78	Minimum: 11.90 Mean: 15.66 Maximum: 19.42

TEMPERATURE ALLOCATIONS FOR Cimarron River (Cimarron Village to Turkey Creek)

[(a)] **24-HOUR ACHIEVEMENT OF SURFACE WQS FOR TEMPERATURE**

[(b)] 24-HOUR LOAD ALLOCATION (LA) NEEDED TO ACHIEVE SURFACE WQS WITH A 10% MARGIN OF SAFETY

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

Current Condition – Load Allocation =

157.05 j/m^2/s – 104.70 j/m^2/s

= 52.35 j/m^2/s

Temperature Load Allocation for Moreno Creek (Eagle Nest Lake to headwaters)

For Moreno Creek (Eagle Nest Lake to headwaters), the WQS for temperature is achieved when the percent total shade is increased to 41%. According to the SSTEMP model, the actual LA of 97.35 j/m^2/s is achieved when the shade is further increased to 47% (Table 6.6).

Table 6.6 SSTEMP Model Results for Moreno Creek (Eagle Nest Lake to headwaters)

Rosgen (1996) Channel Type	WQS (HQCW Aquatic Life)	Model Run Date	Segment Length (miles)	Solar Radiation Component per 24-Hours (+/-)	% Total Shade	Width's A Term	Modeled Temperature °C (24 hour)
---	20°C (68°F)	8/10/06	9.0	**Current Field Condition** +170.48 j/m^2/s	7	2.18	Minimum: 12.79 Mean: 18.04 Maximum: 23.28
				Run 1 +146.65 j/m^2/s	20	2.18	Minimum: 12.59 Mean: 17.32 Maximum: 22.04
				Run 2 +108.16 [(a)] j/m^2/s	41	2.18	Minimum: 12.31 Mean: 16.13 Maximum: 19.95
				Actual LA +97.35 [(b)] j/m^2/s	47	2.18	Minimum: 12.24 Mean: 15.78 Maximum: 19.32

TEMPERATURE ALLOCATIONS FOR Moreno Creek (Eagle Nest Lake to headwaters)

[(a)] **24-HOUR ACHIEVEMENT OF SURFACE WQS FOR TEMPERATURE**

[(b)] 24-HOUR LOAD ALLOCATION (LA) NEEDED TO ACHIEVE SURFACE WQS WITH A 10% MARGIN OF SAFETY

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

Current Condition – Load Allocation =

170.48 j/m^2/s – 97.35 j/m^2/s

= 73.13 j/m^2/s

Temperature Load Allocation for Rayado Creek (Miami Lake Diversion to headwaters)

For Rayado Creek (Miami Lake Diversion to headwaters), the WQS for temperature is achieved when the percent total shade is increased to 45%. According to the SSTEMP model, the actual LA of 143.96 j/m^2/s is achieved when the shade is further increased to 51% (Table 6.7).

Table 6.7 SSTEMP Model Results for Rayado Creek (Miami Lake Diversion to headwaters)

Rosgen (1996) Channel Type	WQS (HQCW Aquatic Life)	Model Run Date	Segment Length (miles)	Solar Radiation Component per 24-Hours (+/-)	% Total Shade	Width's A Term	Modeled Temperature °C (24 hour)
---	20°C (68°F)	7/16/06	24.26	**Current Field Condition** +226.85 j/m^2/s	22	3.95	Minimum: 11.31 Mean: 17.14 Maximum: 22.97
				Run 1 +203.58 j/m^2/s	30	3.95	Minimum: 11.15 Mean: 16.53 Maximum: 21.92
				Run 2 +159.96 [(a)] j/m^2/s	45	3.95	Minimum: 10.86 Mean: 15.37 Maximum: 19.87
				Actual LA 143.96 [(b)] j/m^2/s	51	3.95	Minimum: 10.75 Mean: 14.89 Maximum: 19.03

TEMPERATURE ALLOCATIONS FOR
Rayado Creek
(Miami Lake Diversion to headwaters)

[(a)] **24-HOUR ACHIEVEMENT OF SURFACE WQS FOR TEMPERATURE**

[(b)] 24-HOUR LOAD ALLOCATION (LA) NEEDED TO ACHIEVE SURFACE WQS WITH A 10% MARGIN OF SAFETY

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

Current Condition – Load Allocation =

226.85 j/m^2/s – 143.96 j/m^2/s

=82.89 j/m^2/s

Temperature Load Allocation for Sixmile Creek (Eagle Nest Lake to headwaters)

For Sixmile Creek (Eagle Nest Lake to headwaters), the WQS for temperature is achieved when the percent total shade is increased to 44%. According to the SSTEMP model, the actual LA of 171.46 j/m^2/s is achieved when the shade is further increased to 50% (Table 6.8).

Table 6.8 SSTEMP Model Results for Sixmile Creek (Eagle Nest Lake to headwaters)

Rosgen (1996) Channel Type	WQS (HQCW Aquatic Life)	Model Run Date	Segment Length (miles)	Solar Radiation Component per 24-Hours (+/-)	% Total Shade	Width's A Term	Modeled Temperature °C (24 hour)
---	20°C (68°F)	7/15/06	4.6	**Current Field Condition** +265.36 j/m^2/s	22	0.735[c]	Minimum: 4.28 Mean: 13.92 Maximum: 23.55
TEMPERATURE ALLOCATIONS FOR Sixmile Creek (Eagle Nest Lake to headwaters) [(a)] **24-HOUR ACHIEVEMENT OF SURFACE WQS FOR TEMPERATURE** [(b)] 24-HOUR LOAD ALLOCATION (LA) NEEDED TO ACHIEVE SURFACE WQS WITH A 10% MARGIN OF SAFETY Actual reduction in solar radiation necessary to meet surface WQS for temperature: Current Condition – Load Allocation = 265.36 j/m^2/s – 171.46 j/m^2/s **=93.90 j/m^2/s**				**Run 1** +255.15 j/m^2/s	25	0.735[c]	Minimum: 4.40 Mean: 13.73 Maximum: 23.07
				Run 2 +190.51 [(a)] j/m^2/s	44	0.735[c]	Minimum: 5.26 Mean: 12.59 Maximum: 19.92
				Actual LA 171.46 [(b)] j/m^2/s	50	0.735[c]	Minimum: 5.56 Mean: 12.23 Maximum: 18.89

[c] rounded to 1.00 by SSTEMP

Temperature Load Allocation for South Ponil Creek (Ponil Creek to Middle Ponil)

For South Ponil Creek (Ponil Creek to Middle Ponil), the WQS for temperature is achieved when the percent total shade is increased to 9%. According to the SSTEMP model, the actual LA of 143.09 j/m^2/s is achieved when the shade is further increased to 18% (Table 6.9).

Table 6.9 SSTEMP Model Results for South Ponil Creek (Ponil Creek to Middle Ponil) [1]

Rosgen (1996) Channel Type	WQS (HQCW Aquatic Life)	Model Run Date	Segment Length (miles)	Solar Radiation Component per 24-Hours (+/-)	% Total Shade	Width's A Term	Modeled Temperature °C (24 hour)
---	20°C (68°F)	6/2/06	5.3	**Current Field Condition** +165.98 j/m^2/s	5 [c]	6.98	Minimum: 8.81 Mean: 14.57 Maximum: 20.34
				Run 1 +160.74 j/m^2/s	8	6.98	Minimum: 8.76 Mean: 14.41 Maximum: 20.07
				Run 2 +158.99 [(a)] j/m^2/s	9	6.98	Minimum: 8.74 Mean: 14.36 Maximum: 19.98
				Actual LA 143.09 [(b)] j/m^2/s	18	6.98	Minimum: 8.61 Mean: 13.88 Maximum: 19.15

TEMPERATURE ALLOCATIONS FOR South Ponil Creek (Ponil Creek to Middle Ponil)

[(a)] **24-HOUR ACHIEVEMENT OF SURFACE WQS FOR TEMPERATURE**

[(b)] 24-HOUR LOAD ALLOCATION (LA) NEEDED TO ACHIEVE SURFACE WQS WITH A 10% MARGIN OF SAFETY

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

Current Condition – Load Allocation =

165.98 j/m^2/s – 143.09 j/m^2/s

=22.89 j/m^2/s

[c] Actual measured densiometer reading used (11%). The % shade parameter was then adjusted so the conditions closer to actual temperatures (as recorded by the thermograph) were reflected in SSTEMP.

Temperature Load Allocation for Ute Creek (Cimarron River to headwaters)

For Ute Creek (Cimarron River to headwaters), the WQS for temperature is achieved when the percent total shade is increased to 32%. According to the SSTEMP model, the actual LA of 177.99 j/m^2/s is achieved when the shade is further increased to 39% (Table 6.10).

Table 6.10 SSTEMP Model Results for Ute Creek (Cimarron River to headwaters)

Rosgen (1996) Channel Type	WQS (HQCW Aquatic Life)	Model Run Date	Segment Length (miles)	Solar Radiation Component per 24-Hours (+/-)	% Total Shade	Width's A Term	Modeled Temperature °C (24 hour)
---	20°C (68°F)	7/16/06	8.04	**Current Field Condition** +232.67 j/m^2/s	20 [c]	0.748 [d]	Minimum: 4.96 Mean: 13.28 Maximum: 21.61
				Run 1 +218.13 j/m^2/s	25	0.748 [d]	Minimum: 5.12 Mean: 13.02 Maximum: 20.93
				Run 2 +197.77 [(a)] j/m^2/s	32	0.748 [d]	Minimum: 9.73 Mean: 14.86 Maximum: 19.98
				Actual LA 177.99 [(b)] j/m^2/s	39	0.748 [d]	Minimum: 5.59 Mean: 12.30 Maximum: 19.01

TEMPERATURE ALLOCATIONS FOR
Ute Creek (Cimarron River to headwaters)

[(a)] **24-HOUR ACHIEVEMENT OF SURFACE WQS FOR TEMPERATURE**

[(b)] 24-HOUR LOAD ALLOCATION (LA) NEEDED TO ACHIEVE SURFACE WQS WITH A 10% MARGIN OF SAFETY

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

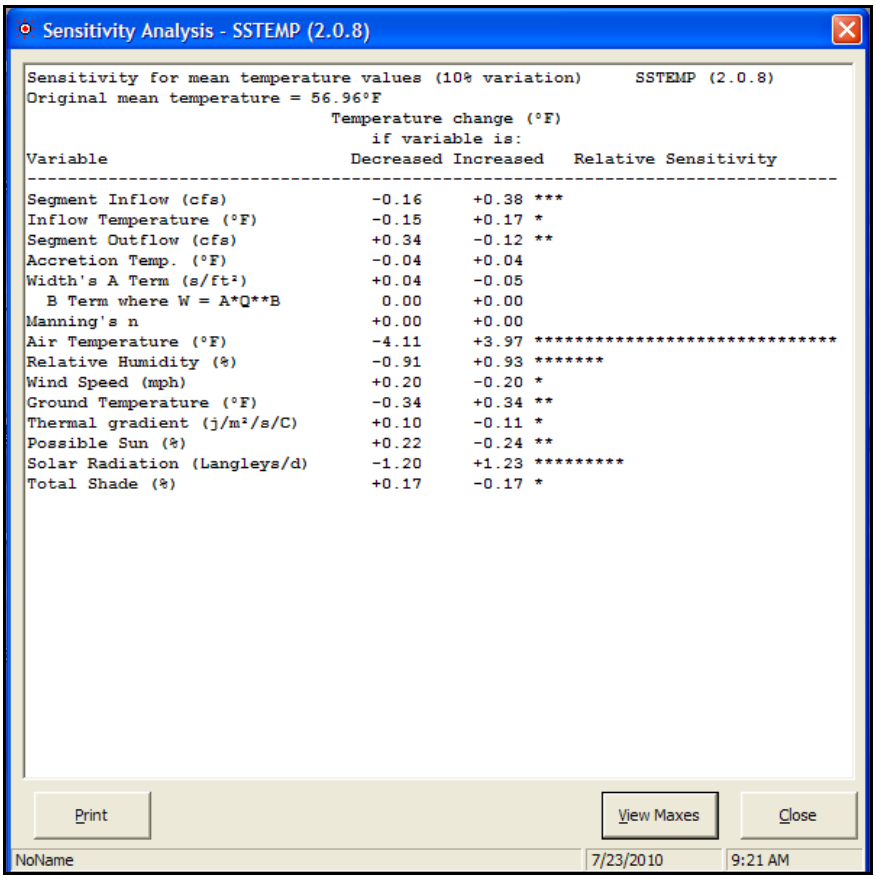
Current Condition – Load Allocation =

232.67 j/m^2/s – 177.99 j/m^2/s

=54.68 j/m^2/s

[c] lowest densiometer reading used (76%). The % shade parameter was then adjusted so the actual recorded conditions (as recorded by the thermograph) were reflected in SSTEMP.
[d] rounded to 1.00 by SSTEMP

According to the Sensitivity Analysis feature of the model runs (Figure 6.4), mean daily air temperature and inflow temperatures had the greatest influences on the predicted outflow temperatures and total shade values have the greatest influence on temperature reduction.



Sensitivity Analysis - SSTEMP (2.0.8)

Sensitivity for mean temperature values (10% variation) SSTEMP (2.0.8)
Original mean temperature = 56.96°F

Variable	Temperature change (°F) if variable is: Decreased	Increased	Relative Sensitivity
Segment Inflow (cfs)	-0.16	+0.38	***
Inflow Temperature (°F)	-0.15	+0.17	*
Segment Outflow (cfs)	+0.34	-0.12	**
Accretion Temp. (°F)	-0.04	+0.04	
Width's A Term (s/ft²)	+0.04	-0.05	
B Term where W = A*Q**B	0.00	+0.00	
Manning's n	+0.00	+0.00	
Air Temperature (°F)	-4.11	+3.97	**********
Relative Humidity (%)	-0.91	+0.93	*******
Wind Speed (mph)	+0.20	-0.20	*
Ground Temperature (°F)	-0.34	+0.34	**
Thermal gradient (j/m²/s/C)	+0.10	-0.11	*
Possible Sun (%)	+0.22	-0.24	**
Solar Radiation (Langleys/d)	-1.20	+1.23	*********
Total Shade (%)	+0.17	-0.17	*

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Figure 6.4 Example of SSTEMP sensitivity analysis for South Ponil

The estimate of total shade used in the model calibration was based on densiometer readings (field notes) and examination of aerial photographs (see **Appendix D**). Target loads as determined by the modeling runs are summarized in Tables 6.4 – 6.10. The MOS is estimated to be 10% of the target load calculated by the modeling runs. Results are summarized in Table 6.11. Additional details on the MOS are presented in Section 6.7 below.

Table 6.11 Calculation of TMDLs for Temperature

Assessment Unit	WLA ($j/m^2/s$)	LA ($j/m^2/s$)	MOS (10%)[a] ($j/m^2/s$)	TMDL ($j/m^2/s$)
Cieneguilla Creek (Eagle Nest to headwaters)	0[b]	131.79	14.64	146.43
Cimarron River (Cimarron Village to Turkey Creek)	0	104.70	11.63	116.33
Moreno Creek (Eagle Nest Lake to headwaters)	0	97.35	10.82	108.16
Rayado Creek (Miami Lake Diversion to headwaters)	0	143.96	16.00	159.96
Sixmile Creek (Eagle Nest Lake to headwaters)	0	171.46	19.05	190.51
South Ponil Creek (Ponil Creek to Middle Ponil)	0	143.09	15.90	158.99
Ute Creek (Cimarron River to headwaters)	0	177.99	19.78	197.77

Notes: [a] Actual MOS values may be slightly greater than 10% because the final MOS is back calculated after the Total Shade value is increased enough to reduce the modeled solar radiation component to a value less than the target load minus 10%.
[b] See discussion in Section 6.4.1.
* Values rounded to three significant figures.

The load reductions that would be necessary to meet the target loads were calculated to be the difference between the calculated target load and the measured load (i.e., current field condition in Tables 6.4 – 6.10), and are shown in Table 6.12.

Table 6.12 Calculation of Load Reduction for Temperature

Location	Target Load[a] ($j/m^2/s$)	Measured Load ($j/m^2/s$)	Load Reduction ($j/m^2/s$)	Percent Reduction[b]
Cieneguilla Creek (Eagle Nest to headwaters)	131.79	207.83	76.04	37
Cimarron River (Cimarron Village to Turkey Creek)	104.70	157.05	52.35	33
Moreno Creek (Eagle Nest Lake to headwaters)	97.35	170.48	73.13	43
Rayado Creek (Miami Lake Diversion to headwaters)	143.96	226.85	82.89	37
Sixmile Creek (Eagle Nest Lake to headwaters)	171.46	265.36	93.90	35
South Ponil Creek (Ponil Creek to Middle Ponil)	143.09	165.98	22.89	14
Ute Creek (Cimarron River to headwaters)	177.99	232.67	54.68	24

Notes: The MOS is not included in the load reduction calculations because it is a set aside value which accounts for any uncertainty, or variability, in TMDL calculations and therefore should not be subtracted from the measured load.
(a) Target Load = LA + WLA
(b) Percent reduction is the percent the existing measured load must be reduced to achieve the target load, and is calculated as follows: (Measured Load – Target Load) / Measured Load x 100.

6.5 Identification and Description of pollutant source(s)

SWQB fieldwork includes an assessment of the probable sources of impairment (Appendix B). The approach for identifying "Probable Sources of Impairment" was recently modified by SWQB to include additional input from a variety of stakeholders including landowners, watershed groups, and local, state, tribal and federal agencies. Probable Source Sheets are filled out by SWQB staff during watershed surveys and watershed restoration activities. The draft probable source list will be reviewed and modified, as necessary, with watershed group/ stakeholder input during the TMDL public meeting and comment period.

Table 6.13 Pollutant source summary for Temperature

Pollutant Sources	Magnitude[a]	Location	Probable Sources[b] (% from each)
Point:			
None	0	--------	0%
Nonpoint:			
	207.83	**Cieneguilla Creek** (Eagle Nest to headwaters)	100% Loss of Riparian Habitat Rangeland Grazing Streambank Modifications/destablization
	157.05	**Cimarron River** (Cimarron Village to Turkey Creek)	100% Baseflow Depletion from Groundwater Withdrawals Loss of Riparian Habitat Rangeland Grazing
	170.48	**Moreno Creek** (Eagle Nest Lake to headwaters)	100% Rangeland Grazing
	226.85	**Rayado Creek** (Miami Lake Diversion to headwaters)	100% Baseflow Depletion from Groundwater Withdrawals Rangeland Grazing
	265.36	**Sixmile Creek** (Eagle Nest Lake to headwaters)	100% Habitat Modification - other than Hydromodification Livestock (grazing or feeding operations) Rangeland Grazing
	165.98	**South Ponil Creek** (Ponil Creek to Middle Ponil)	100% Rangeland Grazing
	232.67	**Ute Creek** (Cimarron River to headwaters)	100% Loss of Riparian Habitat Rangeland Grazing

Notes:
[a] Measured Load as $j/m^2/s$. Expressed as solar radiation.
[b] From the 2008-2010 Integrated CWA §303(d)/305(b) list unless otherwise noted.

Although this procedure is subjective, SWQB feels that it provides the best available information for the identification of probable sources of impairment in a watershed. The list of "Probable Sources" is not intended to single out any single land owner or particular land management activity and generally includes several sources for each known impairment. Table 6.13 displays pollutant sources that may contribute to each segment as determined by field reconnaissance and evaluation. Probable sources of temperature impairments will be evaluated, refined, and changed as necessary through the Watershed-Based Plan (WBP).

6.6 Linkage of Water Quality and Pollutant Sources

Water temperature influences the metabolism, behavior, and mortality of fish and other aquatic organisms. Natural temperatures of a waterbody fluctuate daily and seasonally. These natural fluctuations do not eliminate indigenous populations, but may affect existing community structure and geographical distribution of species. In fact, such temperature cycles are often necessary to induce reproductive cycles and may regulate other aspects of life history (Mount 1969). Behnke and Zarn (1976) in a discussion of temperature requirements for endangered western native trout recognized that populations cannot persist in waters where maximum temperatures consistently exceed 21-22°C, but they may survive brief daily periods of higher temperatures (25.5-26.7°C). Anthropogenic impacts can lead to modifications of these natural temperature cycles, often leading to deleterious impacts on the fishery. Such modifications may contribute to changes in geographical distribution of species and their ability to persist in the presence of introduced species. Of all the environmental factors affecting aquatic organisms in a waterbody, temperature is always a factor. Heat, which is a quantitative measure of energy of molecular motion that is dependent on the mass of an object or body of water is fundamentally different than temperature, which is a measure (unrelated to mass) of energy intensity. Organisms respond to temperature, not heat.

Temperature increases, as observed in SWQB thermograph data, show temperatures that exceed the State Standards for the protection of aquatic habitat, namely the HQCW and CW aquatic life designated uses. Through monitoring, and pollutant source documentation, it has been observed that the most probable cause for these temperature exceedences are due to the alteration of the stream's hydrograph, removal of riparian vegetation, livestock grazing, and natural causes such as geothermal inputs. Alterations can be historical or current in nature.

A variety of factors impact stream temperature (Figure 6.5). Decreased effective shade levels result from reduction of riparian vegetation. When canopy densities are compromised, thermal loading increases in response to the increase in incident solar radiation. Likewise, it is well documented that many past hydromodification activities have lead to channel widening. Wider stream channels also increase the stream surface area exposed to sunlight and heat transfer. Riparian area and channel morphology disturbances are attributed to past and to some extent current rangeland grazing practices that have resulted in reduction of riparian vegetation and streambank destabilization. These nonpoint sources of pollution primarily affect the water temperature through increased solar loading by: (1) increasing stream surface solar radiation and (2) increasing stream surface area exposed to solar radiation.

Riparian vegetation, stream morphology, hydrology, climate, geographic location, and aspect influence stream temperature. Although climate, geographic location, and aspect are outside of human control, the condition of the riparian area, channel morphology and hydrology can be affected by land use activities. Specifically, the elevated summertime stream temperatures attributable to anthropogenic causes in the Cimarron basin result from the following conditions:

1. Channel widening (i.e., increased width to depth ratios) that has increased the stream surface area exposed to incident solar radiation,
2. Riparian vegetation disturbance that has reduced stream surface shading, riparian vegetation height and density, and
3. Reduced summertime base flows that result from instream withdrawals and/or inadequate riparian vegetation. Base flows are maintained with a functioning riparian system so that loss of a functioning riparian system may lower and sometimes eliminate baseflows. Although removal of upland vegetation has been shown, in some cases, to increase water yield, studies show that removal of riparian vegetation along the stream channel subjects the water surface and adjacent soil surfaces to wind and solar radiation, partially offsetting the reduction in transpiration with evaporation. In losing stream reaches, increased temperatures can result in increased streambed infiltration, which can result in lower base flow (Constantz et al. 1994).

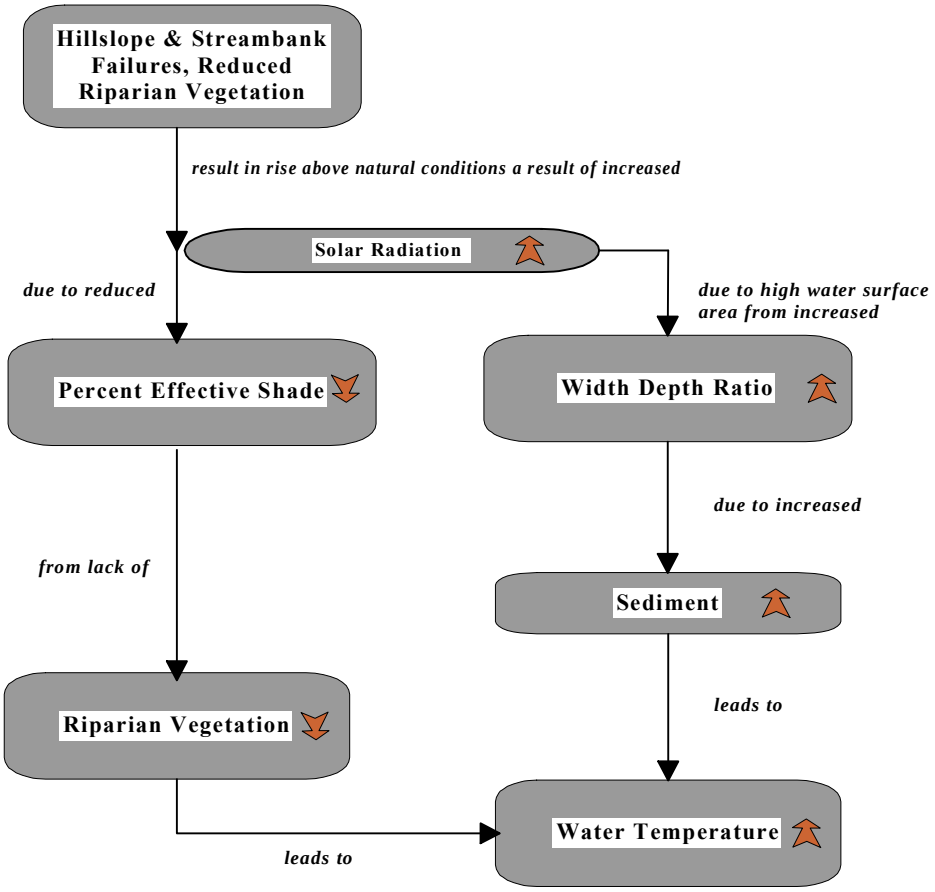

Figure 6.5 Factors That Impact Water Temperature

Through monitoring and pollutant source documentation (Table 6.13) it has been observed that the most probable causes for these temperature exceedences are due to alteration of the stream's hydrograph, removal of riparian vegetation, livestock grazing, and natural causes such as geothermal inputs. Alterations can be historical or current in nature.

Analyses presented in these TMDLs demonstrate that the target loading capacities will result in attainment of New Mexico WQS. Specifically, the relationship between shade and water temperature was demonstrated. Vegetation density increases will provide necessary shading, as well as encourage bank-building processes in severe hydrologic events. However, the presentation of percent total shade in Tables 6.4 – 6.10 is only one avenue which may be pursued to decrease water temperature and ultimately meet WQS. Changes in geomorphological paramters might also prove useful. SWQB encourages stakeholders to pursue whichever options seem to be the best fit for each particular watershed or project with the ultimate goal being that the stream temperature meets the WQS.

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

6.7 Margin of Safety (MOS)

The CWA requires that each TMDL be calculated with a MOS. This statutory requirement that TMDLs incorporate a MOS is intended to account for uncertainty in available data or in the actual effect controls will have on loading reductions and receiving water quality. A MOS may be expressed as unallocated assimilative capacity or conservative analytical assumptions used in establishing the TMDL (e.g., derivation of numeric targets, modeling assumptions or effectiveness of proposed management actions). The MOS may be implicit, utilizing conservative assumptions for calculation of the loading capacity, WLAs, and LAs. The MOS may also be explicitly stated as an added separate quantity in the TMDL calculation.

For this TMDL, there were no MOS adjustments for point sources since there are none.

In order to develop this temperature TMDL, the following conservative assumptions were used to parameterize the model:

- Data from the warmest time of the year were used in order to capture the seasonality of temperature exceedences.
- Critical upstream and downstream low flows were used because assimilative capacity of the stream to absorb and disperse solar heat is decreased during these flow conditions.
- Low flow was modeled using formulas developed by the USGS. One formula (Thomas et al. 1997) is recommended when the ratio between the gaged watershed area and the ungaged watershed area is between 0.5 and 1.5. When the ratio is outside of this range, a different regression formula is used (Waltemeyer 2002). See **Appendix D** for details.

As detailed in **Appendix D,** a variety of high quality hydrologic, geomorphologic, and meteorological data were used to parameterize the SSTEMP model. Because of the high quality of data and information that was put into this model and the continuous field monitoring data used to verify these model outputs, an explicit MOS of 10% is assigned to this TMDL.

6.8 Consideration of seasonal variation

Section 303(d)(1) of the CWA requires TMDLs to be "…established at a level necessary to implement the applicable WQS with seasonal variations". Both stream temperature and flow vary seasonally and from year to year. Water temperatures are coolest in winter and early spring months.

Thermograph records show that temperatures exceed State of New Mexico WQS in summer and early fall. Warmest stream temperatures corresponded to prolonged solar radiation exposure, warmer air temperature, and low flow conditions. These conditions occur during late summer and early fall and promote the warmest seasonal instream temperatures. It is assumed that if critical conditions are met, coverage of any potential seasonal variation will also be met.

6.9 Future Growth

Growth estimates by county are available from the New Mexico Bureau of Business and Economic Research. These estimates project growth to the year 2035. Growth estimates for Colfax County project a 14% growth rate through 2035. However, as of 2008, the largest incorporated town in the county, Raton, had an estimated population of 6,465 people. This showed a decrease of 11.22 percent from the 2000 census population and Raton's population is not expected to have much growth in the future.

Estimates of future growth are not anticipated to lead to a significant increase in water temperature that cannot be controlled with best management practices (BMPs) in this watershed. However, it is imperative that BMPs continue to be utilized in this watershed to improve road conditions and grazing allotments and adhere to SWPPP requirements related to construction and industrial activities covered under the general permit.