4.0 BACTERIA

During the 2003 SWQB sampling monitoring effort in the Rio Hondo watershed, fecal coliform data showed several exceedences of the New Mexico water quality secondary contact use standard for several assessment units. This data was combined with other sources of data to determine overall impairment for these assessment units. As a result, three assessment units in the Rio Hondo watershed are listed on the 2004-2006 Integrated CWA §303(d)/§305(b) list (NMED/SWQB 2004a) with fecal coliform as a pollutant of concern (see summary in Table 4.1 and data in Appendix A). Presence of fecal coliform bacteria is an indicator of the possible presence of other bacteria that may limit beneficial uses and present human health concerns. There are potential nonpoint and point sources of fecal coliform bacteria throughout the basin that could be contributing to the fecal coliform levels.

According to the New Mexico Water Quality Standards (WQS), the fecal coliform standard reads:

> *20.6.4.208 NMAC: The monthly geometric mean of fecal coliform bacteria shall not exceed 200/100mL; no single sample shall exceed 400/100mL.*
>
> *20.6.4.209 NMAC: The monthly geometric mean of fecal coliform bacteria shall not exceed 100/100mL; no single sample shall exceed 200/100mL.*

Per USEPA guidance, SWQB has proposed changes in the contact use criterion from fecal coliform to *E. coli.* This WQS change has not been approved by USEPA at the time these TMDLs were prepared and are therefore not discussed in this TMDL document. However, in the event that new data indicate that the targets used in this analysis are not appropriate and/or if these new standards are adopted, the load capacity will be adjusted accordingly. When water quality standards have been achieved, the reach will be moved to the appropriate category on the Clean Water Act Integrated §303(d)/§305(b) list of waters.

Table 4.1. Summary of Assessment Units Impaired for Bacteria in the Rio Hondo Basin

Assessment Unit	New Mexico Standards Segment	Fecal coliform: # Exceedences/ Total Samples	Fecal coliform[(a)] %Exceedence
Carrizo Creek (Rio Ruidoso to Mescalero Apache boundary)	20.6.4.209	2/8	25%
Rio Bonito (Angus Canyon to headwaters)	20.6.4.209	2/13	15%
Rio Bonito (Rio Ruidoso to Angus Canyon)	20.6.4.208	0/8	0%[(b)]
Rio Hondo (Pecos River to confluence of Rio Bonito and Rio Ruidoso)	20.6.4.208	6/13	46%
Rio Ruidoso (US Highway 70 to Mescalero Apache Boundary)	20.6.4.209	1/19	5%[(b)]
Rio Ruidoso (Rio Bonito to US Highway 70)	20.6.4.208	2/17	12%[(b)]

Notes:

[(a)] Exceedence rates ≥ 15% result in a determination of Non Support based on the assessment protocol (NMED/SWQB 2004b)

[(b)] There are no TMDL calculations for fecal coliform in the Rio Ruidoso or Rio Bonito (Rio Ruidoso to Angus Canyon) in this document because the exceedence rate was <15%. Thus, the determination would be Full Support.

4.1 Target Loading Capacity

Overall, the target values for bacteria TMDLs will be determined based on (1) the presence of numeric criteria, (2) the degree of experience in applying the indicator and (3) the ability to easily monitor and produce quantifiable and reproducible results. For this TMDL document, target values for bacteria are based on the reduction in bacteria necessary to achieve numeric criteria. This TMDL is also consistent with New Mexico's antidegradation policy.

The segment-specific criteria leading to an assessment of use impairment for Carrizo Creek and Rio Bonito is the numeric criteria stating that "The monthly geometric mean of fecal coliform bacteria shall not exceed 100cfu /100 mL; no single sample shall exceed 200cfu /100 mL" for the designated contact use (20.6.4 NMAC). The segment-specific criteria leading to an assessment of use impairment for the Rio Hondo is the numeric criteria stating that "The monthly geometric mean of fecal coliform bacteria shall not exceed 200cfu /100 mL; no single sample shall exceed 400cfu /100 mL" for the designated contact use (20.6.4 NMAC).

4.2 Flow

Bacteria numbers can vary as a function of flow. Exceedences of the criterion occurred at both high and low flows in the impaired assessment units in the Rio Hondo basin. Therefore, the target flow was set at the critical low flow condition or 4Q3, defined as the minimum average four consecutive day flow which occurs with a frequency of once in three years (4Q3). Critical low flow was determined on an annual basis utilizing all available daily flow values rather than on a seasonal basis for these TMDLs because exceedences occurred during both low and high flow conditions.

When available, USGS gage data were used to determine 4Q3s (Table 4.2 and Appendix B). These 4Q3s were estimated through application of USGS gage data to a log Pearson Type III distribution through "*Input and Output for Watershed Data Management*" (IOWDM) software, Version 4.1 (USGS 2002a) and "*Surface-Water Statistics*" (SWSTAT) software, Version 4.1 (USGS 2002b). When necessary, 4Q3s calculated at USGS gaging stations are area weighted according to USGS (1970) to determine 4Q3 values for the ungaged portion (Appendix B).

It is important to remember that the TMDL itself is a value calculated at a defined critical condition, and is calculated as part of planning process designed to achieve water quality standards. Since flows vary throughout the year in these systems, the actual load at any given time will vary based on the changing flow. Management of the load to improve stream water quality should be a goal to be attained.

4.3 Calculations

Bacteria standards are expressed as colony forming units (cfu) per unit volume. The fecal coliform criteria are listed in Table 4.2.

Table 4.2. Criteria concentrations and flow values for allowable load calculations

Assessment Unit	Fecal coliform criterion used in target calculation (cfu/100ml)	Source of selected criterion	4Q3 [(a)]
Carrizo Creek (Rio Ruidoso to Mescalero Apache boundary)	200	NMAC 20.6.4.209 single sample criterion	0.547 cfs 0.354 mgd
Rio Bonito (Angus Canyon to headwaters)	200	NMAC 20.6.4.209 single sample criterion	0.990 cfs 0.640 mgd
Rio Hondo (Pecos River to confluence of Rio Bonito and Rio Ruidoso)	400	NMAC 20.6.4.208 single sample criterion	1.342 cfs 0.867 mgd

Notes:
[(a)] Determined by area-weighting the 4Q3 from USGS Gage 08387000 – Rio Ruidoso at Hollywood, NM (USGS 1970).
cfs = cubic feet per second; mgd = million gallons per day

Target loads for bacteria are calculated based on 4Q3 flow values, current and proposed WQS, and conversion factors (**Equation 1**). The more conservative geometric mean criteria are utilized in TMDL calculations to provide an implicit MOS. In addition, if the single sample criteria were used as targets, the geometric mean criteria may not be reached.

C as cfu/100 mL * 1,000 mL/1 L * 1 L/ 0.264 gallons * Q * 1,000,000 gallons = cfu/day (**Eq. 1**)

Where C = NM state water quality standard criterion for bacteria,
Q = stream flow in million gallons per day (mgd)

The target loads (TMDLs) predicted to attain current and proposed standards were calculated using **Equation 1** and are shown in Table 4.3.

Table 4.3. Calculation of Target Loads for Fecal Coliform

Assessment Unit	4Q3 Flow (mgd)	Fecal Coliform geometric mean criteria (cfu/100mL)	Conversion Factor[(a)]	Bacteria Target Load Capacity (cfu/day)
Carrizo Creek (Rio Ruidoso to Mescalero Apache boundary)	0.354	100	3.79×10^7	1.34×10^9
Rio Bonito (Angus Canyon to headwaters)	0.640	100	3.79×10^7	2.42×10^9
Rio Hondo (Pecos River to confluence of Rio Bonito and Rio Ruidoso)	0.867	200	3.79×10^7	6.57×10^9

Notes:
[(a)] Based on equation 1.

4.4 Waste Load Allocations and Load Allocations

4.4.1 Waste Load Allocation

There are no point source contributions associated with this TMDL. The WLA is therefore zero for all three of the impaired assessment units.

4.4.2 Load Allocation

In order to calculate the LA, the WLA and MOS were subtracted from the target capacity (TMDL), as shown below in **Equation 2**.

$$WLA + LA + MOS = TMDL \qquad \textbf{(Eq. 2)}$$

The MOS was developed using a combination of conservative assumptions and explicit recognition of potential errors in flow calculations. Results using an explicit MOS of 5% (see Section 4.7 for details) are presented in Table 4.4.

Table 4.4. Calculation of TMDLs for Fecal Coliform

Assessment Unit	WLA (cfu/day	LA (cfu/day)	MOS (5%) (cfu/day)	TMDL (cfu/day)
Carrizo Creek (Rio Ruidoso to Mescalero Apache boundary)	0	1.27×10^9	6.70×10^7	1.34×10^9
Rio Bonito (Angus Canyon to headwaters)	0	2.30×10^9	1.21×10^8	2.42×10^9
Rio Hondo (Pecos River to confluence of Rio Bonito and Rio Ruidoso)	0	6.24×10^9	3.29×10^8	6.57×10^9

The extensive data collection and analyses necessary to determine background fecal coliform loads for the Rio Hondo watershed were beyond the resources available for this study. It is therefore assumed that a portion of the load allocation is made up of natural background loads.

Measured loads were also calculated using **Equation 1**. In order to achieve comparability between the target capacity (i.e., TMDL values) and measured loads, the same flow rates were used for both calculations. Results are presented in Table 4.5.

Table 4.5. Calculation of Measured Loads for Fecal Coliform

Assessment Unit	4Q3 Flow (mgd)	Measured FC Concentrations[(b)] (cfu/100mL)	Conversion Factor[(a)]	Measured Load (cfu/day)
Carrizo Creek (Rio Ruidoso to Mescalero Apache boundary)	0.354	210	3.79×10^{7}	2.82×10^{9}
Rio Bonito (Angus Canyon to headwaters)	0.640	802	3.79×10^{7}	1.95×10^{10}
Rio Hondo (Pecos River to confluence of Rio Bonito and Rio Ruidoso)	0.867	1040	3.79×10^{7}	3.42×10^{10}

Notes:
[(a)] Based on equation 1.
[(b)] The measured concentration is the arithmetic mean of the measured values used to make the impairment determination (see Appendix A)

The nonpoint source and background load reductions necessary to meet the target loads were calculated to be the difference between the target load allocation and the measured load, and are shown in Table 4.6.

Table 4.6. Calculation of Load Reduction for Fecal Coliform

Assessment Unit	Target Load[(a)] (cfu/day)	Measured Load (cfu/day)	Load Reduction (cfu/day)	Percent Reduction[(b)]
Carrizo Creek (Rio Ruidoso to Mescalero Apache boundary)	1.27×10^{9}	2.82×10^{9}	1.55×10^{9}	55%
Rio Bonito (Angus Canyon to headwaters)	2.30×10^{9}	1.95×10^{10}	1.72×10^{10}	88%
Rio Hondo (Pecos River to confluence of Rio Bonito and Rio Ruidoso)	6.24×10^{9}	3.42×10^{10}	2.80×10^{10}	82%

Note: 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

It is important to note that load allocations are estimates based on a specific flow condition (i.e., low flow in this case). Under differing hydrologic conditions, the loads will change. For this reason the load allocations given here are less meaningful than are the relative percent reductions. Successful implementation of this TMDL will be determined based on achieving the fecal coliform water quality standards.

4.5 Identification and Description of Pollutant Sources

Based on measured loads and potential contributions from existing point sources, probable point and nonpoint pollutant sources that may be contributing to observed fecal coliform loads are displayed in Table 4.7. Probable source lists for *E. coli* would be similar.

Table 4.7. Pollutant Source Summary for Fecal Coliform

Pollutant Sources	Magnitude (cfu/day)	Assessment Unit	Potential Sources[(a)]
Point:			
Fecal coliform	None	Carrizo Creek (Rio Ruidoso to Mescalero Apache boundary)	0%
	None	Rio Bonito (Angus Canyon to headwaters)	0%
	None	Rio Hondo (Pecos River to confluence of Rio Bonito and Rio Ruidoso)	0%
Nonpoint:			
Fecal coliform	2.82×10^{9}	Carrizo Creek (Rio Ruidoso to Mescalero Apache boundary)	100% Drought-related Impacts, Flow Alterations from Water Diversions, Municipal (Urbanized High Density Area), On-site Treatment Systems (Septic Systems and Similar Decentralized Systems), Source Unknown, Loss of Riparian Habitat, Streambank Modifications/destabilization
	1.95×10^{10}	Rio Bonito (Angus Canyon to headwaters)	100% Drought-related Impacts, Flow Alterations from Water Diversions, Loss of Riparian Habitat, On-site Treatment Systems (Septic Systems and Similar Decentralized Systems), Rangeland Grazing, Streambank Modifications/ destabilization
	3.42×10^{10}	Rio Hondo (Pecos River to confluence of Rio Bonito and Rio Ruidoso)	100% Drought-related Impacts, Flow Alterations from Water Diversions, Loss of Riparian Habitat, On-site Treatment Systems (Septic Systems and Similar Decentralized Systems), Rangeland Grazing, Streambank Modifications/ destabilization

Notes:
[(a)] From the 2004-2006 Integrated 303(d)/305(b) list. This list of probable sources is based on staff observation and known land use activities in the watershed. These sources are not confirmed or quantified at this time.

4.6 Linkage Between Water Quality and Pollutant Sources

SWQB fieldwork includes an assessment of the potential sources of impairment (NMED/SWQB 1999). The Pollutant Source(s) Documentation Protocol form and Potential Sources Summary Table in Appendix C provides an approach for a visual analysis of a pollutant source along an impaired reach. Although this procedure is subjective, SWQB feels that it provides the best available information for the identification of potential sources of impairment in this watershed. Table 4.7 (Pollutant Source Summary) identifies and quantifies potential sources of nonpoint source impairments along the reach as determined by field reconnaissance and assessment.

Additional bacteria sampling would need to be conducted to more fully characterize probable sources of bacteria in the Rio Hondo watershed. However, sufficient data exist to support development of a fecal coliform TMDL to address the stream standards violations.

Among the potential sources of bacteria are poorly maintained or improperly installed (or missing) septic tanks, livestock grazing of valley pastures and riparian areas, upland livestock grazing, and wildlife. Very high fecal coliform concentrations have been measured in water sampled from both SWQB monitoring stations along the Rio Hondo. According to SWQB field discharge data, this reach seems to have a considerable ground water input with discharge increasing up to an order of magnitude along the river gradient depending on the season. In addition, the region along this river reach is sparsely vegetated with little permanent settlement and some livestock grazing. Howell et. al. (1996) found that fecal coliform concentrations in underlying sediment increase when cattle (*Bos taurus*) have direct access to streams, such as the Rio Hondo. Natural sources of bacteria are also present in the form of other wildlife such as elk, deer, and any other warm-blooded mammals. In addition to direct input from grazing operations and wildlife, fecal coliform concentrations may be subject to elevated levels as a result of re-suspension of bacteria laden sediment during storm events. Temperature can also play a role in fecal coliform concentrations. Howell et. al. (1996) observed that fecal coliform re-growth increases as water temperature increases, which is a concern along this assessment unit.

The bacteria loading from Carrizo Creek and Rio Bonito probably originate from a combination of drought-related impacts, increasing municipal demands on surface and ground water, septic systems and similar decentralized systems, and livestock and wildlife wastes that are transported downstream during runoff events. The Potential Sources Summary Table (Appendix C) also identifies recreational activities and road maintenance and runoff as potential sources of bacteria.

In order to determine exact sources and relative contributions, further study is needed. One method of characterizing sources of bacteria is a Bacterial, or Microbial, Source Tracking (BST) study. The extensive data collection and analyses necessary to determine bacterial sources were beyond the resources available for this study. However, sufficient data exist to support development of a fecal coliform TMDL to address the stream standards violations.

4.7 Margin of Safety (MOS)

TMDLs should reflect a MOS based on the uncertainty or variability in the data, the point and nonpoint source load estimates, and the modeling analysis. For these bacteria TMDLs, the MOS was developed using a combination of conservative assumptions and explicit recognition of potential errors in flow calculations. Therefore, this MOS is the sum of the following two elements:

- *Conservative Assumptions*

  Treating fecal coliform as a conservative pollutant, that is a pollutant that does not readily degrade in the environment, was used as a conservative assumption in developing these loading limits.

  A more conservative limit of the geometric mean value, rather than the current and proposed standards which allow for higher concentrations in individual grab samples, was used to calculate loading values.

- *Errors in calculating flow*

  4Q3s low flow values were determined based on USGS gaging data. There is inherent error in all flow measurements. A conservative MOS for this element is therefore **5 percent**.

4.8 Consideration of Seasonal Variability

During the 2003 water quality survey, bacteria exceedences occurred during both summer and fall months. Data indicated no link between flow and exceedences. Therefore, although a target was chosen for the TMDL, it may not represent a true critical condition. Higher flows may flush more nonpoint source runoff containing fecal coliform. It is also possible the criterion may be exceeded under a low flow condition when there is insufficient dilution of a point source. Evaluation of seasonal variability for potential nonpoint sources is difficult due to limited available data. Because of the uncertainty involved, there will be no seasonal allocations for fecal coliform in these TMDLs.

4.9 Future Growth

According to the calculations, the overwhelming source of bacteria loading is from nonpoint sources. Estimates of future growth are not anticipated to lead to a significant increase in bacteria concentrations that cannot be controlled with BMP implementation in this watershed.