4.0 BACTERIA

During the 2004 SWQB sampling monitoring effort in the Lower Rio Grande watershed, *E. coli* 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, two assessment units in the Lower Rio Grande watershed were determined to be impaired with *E. coli* as a pollutant of concern (see summary in Table 4.1 and data in Appendix A). Presence of *E. coli* bacteria is an indicator of the possible presence of other bacteria that may limit beneficial uses and present human health concerns. There are probable nonpoint and point sources of *E. coli* bacteria throughout the basin that could be contributing to the *E. coli* levels.

According to the New Mexico Water Quality Standards (WQS), the *E. coli* standard reads:

> *20.6.4.101 NMAC: The monthly geometric mean of E. coli bacteria 126 cfu/100 mL or less; single sample 410 cfu/100 mL or less.*
>
> *20.6.4.102 NMAC: The monthly geometric mean of E. coli bacteria 126/100mL or less; single sample 235/100mL or less.*
>
> *20.6.4.103 NMAC: The monthly geometric mean of E. coli bacteria 548/100mL or less; single sample 2507/100mL or less.*

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 assessed waters.

Table 4.1. Summary of Bacteria Data in the Lower Rio Grande

Assessment Unit	New Mexico Standards Segment	*E. coli*: # Exceedences/ Total Samples	*E. coli*[(a)] %Exceedence
Rio Grande (International Mexico bnd. to Leasburg Dam)	20.6.4.101	16/53	30%
Rio Grande (Leasburg Dam to Percha Dam)	20.6.4.101	4/23	17%
Rio Grande (Percha Dam to Caballo Res.)	20.6.4.102	0/7	0%[(b)]
Rio Grande (Caballo Res. to Elephant Butte Dam)	20.6.4.103	0/7	0%[(b)]

Notes:

[(a)] Exceedence rates ≥ 15% result in a determination of Non Support based on the assessment protocol (NMED/SWQB 2006b)

[(b)] There are no TMDL calculations for *E. coli* in the Rio Grande (Percha Dam to Elephant Butte Dam) 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 the Rio Grande (International Mexico Boundary to Leasburg Dam) and the Rio Grande (Leasburg Dam to Percha Dam) is the numeric criteria stating that "The monthly geometric mean of *E. coli* bacteria 126cfu /100 mL or less; single sample 410cfu /100 mL or less" for the designated contact use (20.6.4.101 NMAC).

4.2 Flow

Flow duration curve analysis looks at the cumulative frequency of historic flow data over a specified period. A flow duration curve relates flow values to the percent of time those values have been met or exceeded. The use of *"percent of time"* provides a uniform scale ranging between 0 and 100. Thus, the full range of stream flows is considered. Low flows are exceeded a majority of the time, while floods are exceeded infrequently.

A basic flow duration curve runs from high to low along the x-axis. The x-axis represents the duration amount, or *"percent of time"*, as in a cumulative frequency distribution. The y-axis represents the flow value (e.g., cubic feet per second) associated with that *"percent of time"* (or duration). Flow duration curve development typically uses daily average discharge rates, which are sorted from the highest value to the lowest (Figures 4.1 and 4.2). Using this convention, flow duration intervals are expressed as a percentage, with zero corresponding to the highest stream discharge in the record (i.e., flood conditions) and 100 to the lowest (i.e., drought conditions). Thus, a flow duration interval of sixty associated with a stream discharge of 312 cubic feet per second (cfs) implies that sixty percent of all observed daily average stream discharge values equal or exceed 312 cfs (Figure 4.1).

Duration curve analysis identifies intervals, which can be used as a general indicator of hydrologic condition (i.e., wet versus dry and to what degree). Flow duration curve intervals can be grouped into several broad categories or zones. These zones provide additional insight about conditions and patterns associated with the impairment. A common way to look at the duration curve is by dividing it into five zones, as illustrated in Figures 4.1 and 4.2: one representing *high flows (0-10%)*, another for *moist conditions (10-40%)*, one covering *mid-range flows (40-60%)*, another for *dry conditions (60-90%)*, and one representing *low flows (90-100%)* (Cleland 2003). This particular approach places the midpoints of the moist, mid-range, and dry zones at the 25^{th}, 50^{th}, and 75^{th} percentiles respectively (i.e., the quartiles). The high zone is centered at the 5^{th} percentile, while the low zone is centered at the 95^{th} percentile.

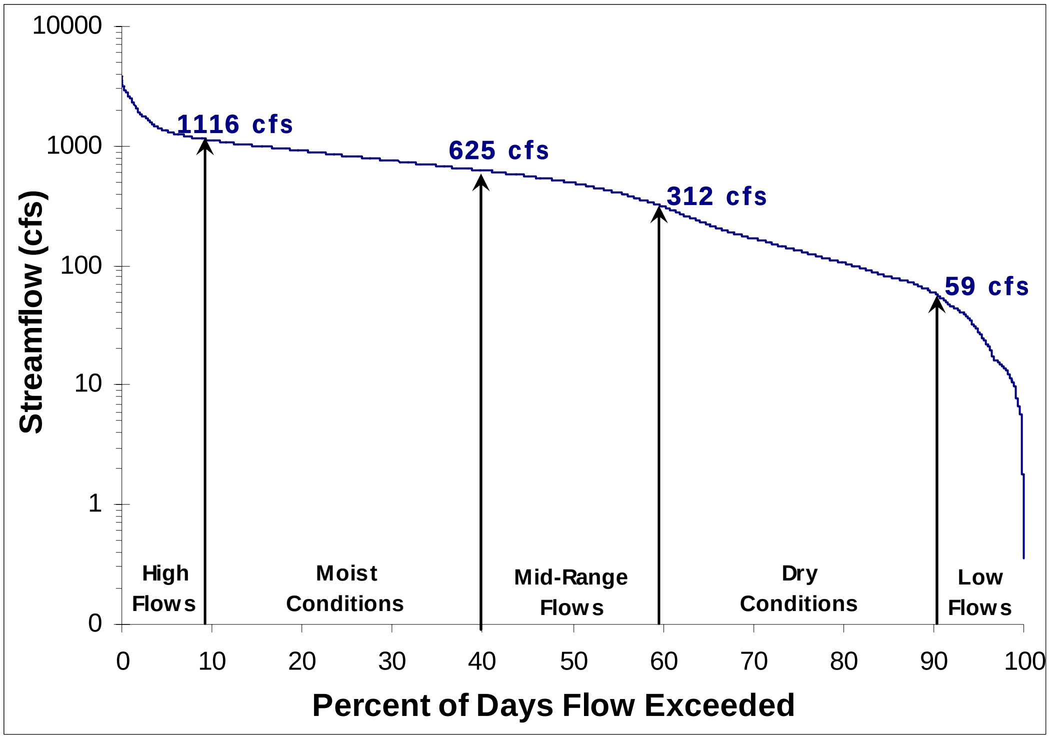

Figure 4.1 Flow Duration Curve: IBWC 08364000 Rio Grande at El Paso, TX (1966-2006)

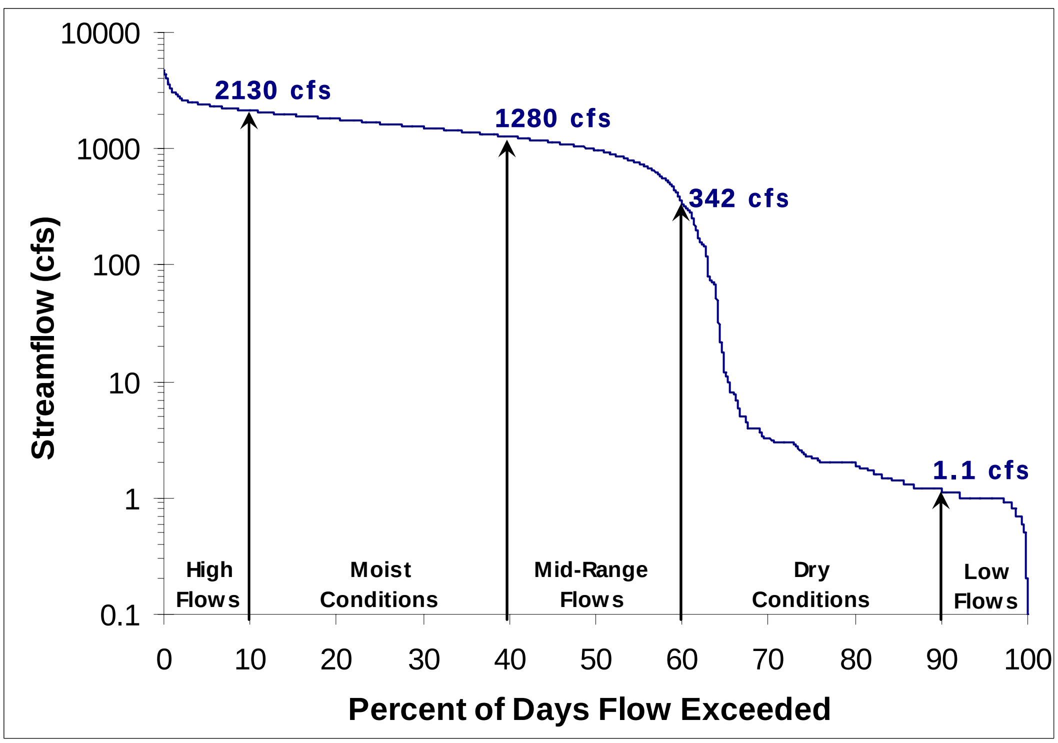

Figure 4.2 Flow Duration Curve: USGS 08362500 Rio Grande blw Caballo Dam (1965-2005)

The use of duration curves provides a technical framework for identifying *"daily loads"* in TMDL development, which accounts for the variable nature of water quality associated with different stream flow rates. Specifically, a maximum daily concentration limit can be used with basic hydrology and a duration curve to identify a TMDL that covers the full range of flow conditions. With this approach, ambient water quality data, taken with some measure or estimate of flow at the time of sampling, can be used to compute an instantaneous load. Using the relative percent exceedence from the flow duration curve that corresponds to the stream discharge at the time the water quality sample was taken, the computed load can be plotted in a duration curve format (Figures 4.3 and 4.4).

By displaying instantaneous loads calculated from ambient water quality data and the daily average flow on the date of the sample (expressed as a flow duration curve interval), a pattern develops, which describes the characteristics of the water quality impairment. Loads that plot above the curve indicate an exceedence of the water quality criterion, while those below the load duration curve show compliance. The pattern of impairment can be examined to see if it occurs across all flow conditions, corresponds strictly to high flow events, or conversely, only to low flows. Impairments observed in the low flow zone typically indicate the influence of point sources, while those further left generally reflect probable nonpoint source contributions. This concept is illustrated in Figures 4.3 and 4.4.

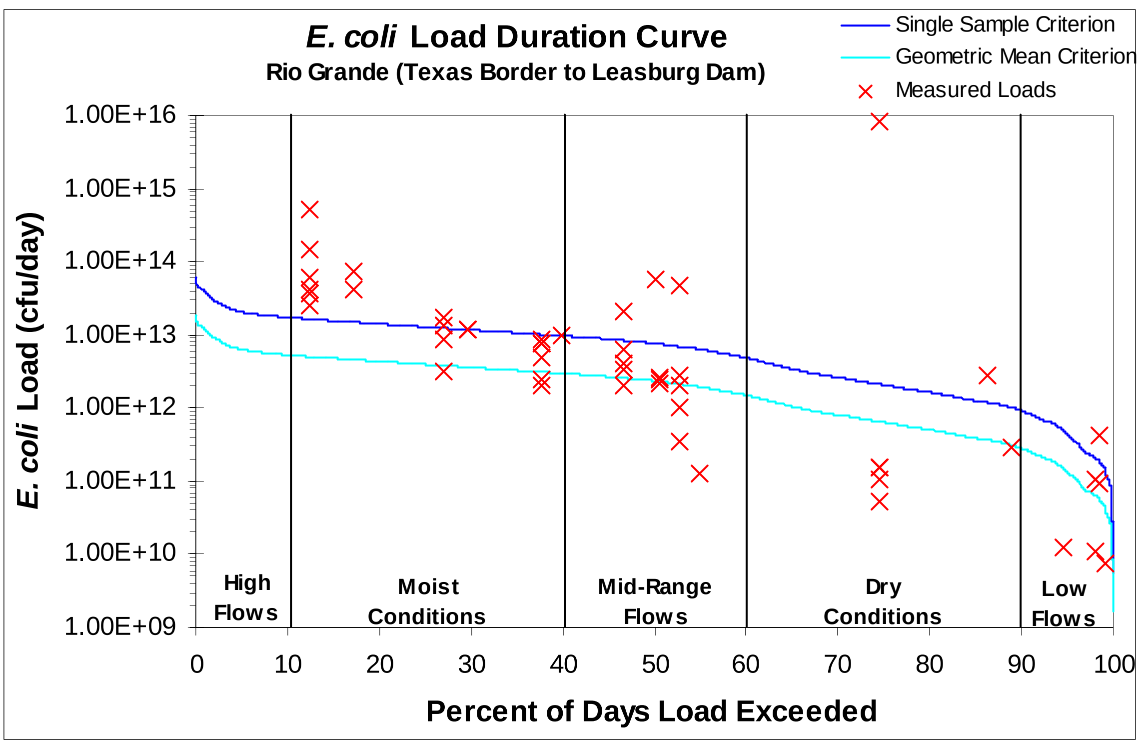

Figure 4.3 ***E. coli*** **Load Duration Curve – Rio Grande (International Mexico Boundary to Leasburg Dam)**

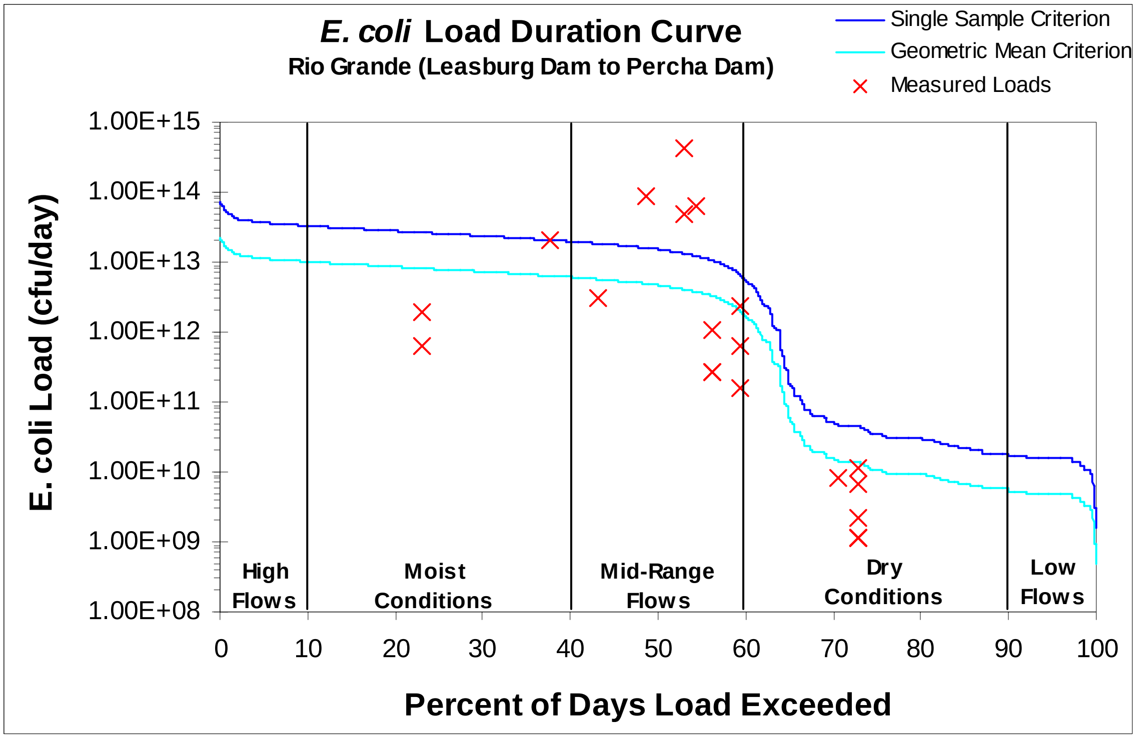

Figure 4.4 ***E. coli*** **Load Duration Curve – Rio Grande (Leasburg Dam to Percha Dam)**

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 processes 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 *E. coli* criteria are listed in Tables 4.2 and 4.3. Target loads for bacteria are calculated based on flow values, current and proposed WQS, and conversion factors (**Equation 1**). The more conservative monthly 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)

Under the duration curve framework, the loading capacity is essentially the curve itself. The loading capacity, which sets the target load on any given day, is determined by the flow on the particular day of interest. However, a continuous curve that represents the loading capacity has some logistical drawbacks. It is often easier to communicate information with a set of fixed targets. Critical points along the curve can be used as an alternative method to quantify the loading capacity, such as the mid-point of each hydrologic zone (e.g., the 5^{th}, 25^{th}, 50^{th}, 75^{th}, and 95^{th} percentiles). A unique loading capacity for each hydrologic zone allows the TMDL to reflect changes in dominant watershed processes that may occur under different flow regimes. The target loads (TMDLs) predicted to attain current standards were calculated using **Equation 1** and are shown in Tables 4.2 and 4.3.

Table 4.2. Calculation of Target Loads: Rio Grande (Int'l Mexico bnd. to Leasburg Dam)

Rio Grande (International Mexico boundary to Leasburg Dam)	FLOW CONDITIONS				
	High	**Moist**	**Mid-Range**	**Dry**	**Low**
***E. coli* geometric mean criterion (cfu/100mL)**	126	126	126	126	126
Mid-point Flow (mgd)	860	534	317	86	18
Conversion Factor[(a)]	3.79×10^7	3.79×10^7	3.79×10^7	3.79×10^7	3.79×10^7
TMDL	$\mathbf{4.11 \times 10^{12}}$	$\mathbf{2.55 \times 10^{12}}$	$\mathbf{1.52 \times 10^{12}}$	$\mathbf{4.10 \times 10^{11}}$	$\mathbf{8.64 \times 10^{10}}$

[(a)] Conversion factor is based on Equation 1.

Table 4.3. Calculation of Target Loads: Rio Grande (Leasburg Dam to Percha Dam)

Rio Grande (Leasburg Dam to Percha Dam)	FLOW CONDITIONS				
	High[(b)]	**Moist**[(b)]	**Mid-Range**	**Dry**[(b)]	**Low**[(b)]
***E. coli* geometric mean criterion (cfu/100mL)**	-	-	126	-	-
Mid-point Flow (mgd)	-	-	635	-	-
Conversion Factor[(a)]	-	-	3.79×10^7	-	-
TMDL	**-**	**-**	$\mathbf{3.03 \times 10^{12}}$	**-**	**-**

[(a)] Conversion factor is based on Equation 1.
[(b)] There are no TMDL calculations for High, Moist, Dry, or Low flow conditions because there were no observed exceedences during these flow regimes (refer to Figure 4.4).

4.4 Waste Load Allocations and Load Allocations

4.4.1 Waste Load Allocation

Excess bacteria levels may be a component of some storm water discharges so these discharges should be addressed. On September 29, 2006, EPA Region 6 issued general permits for discharges from regulated small municipal separate storm sewer system (sMS4s) in New Mexico and on Indian Country lands in New Mexico and Oklahoma. Notice of availability of the general permits will be published in the Federal Register in the near future. The general permits offer coverage for discharges of storm water from sMS4s that are regulated under Phase II of the National Pollutant Discharge Elimination System (NPDES) Storm Water Program to various waters of the United States in New Mexico and Oklahoma. The permits will be effective January 1, 2007, and Notices of Intent to be covered will generally be due by April 1, 2007. In New Mexico, some of the major impacts to small MS4s are as follows: operators of MS4s located in urbanized areas (UAs) must develop, implement, and enforce a storm water management program to reduce the discharge of pollutants from its MS4 to the "maximum extent practicable" and protect water quality; operators of "regulated" MS4s must obtain NPDES permit coverage; the permit application (Notice of Intent [NOI]) must include six "minimum control measures" (using Best Management Practices, or BMPs) and measurable goals; the BMPs must be fully implemented within 5 years of permit issuance; and, operators must submit yearly progress reports to EPA.

There are seven municipalities along the Rio Grande (International Mexico Boundary to Leasburg Dam) that are eligible for coverage under the statewide, general sMS4 permit (#NMR040000). The municipalities include Anthony, Doña Ana, Las Cruces, Mesilla, Santa Teresa, Sunland Park, and University Park. In addition to the general sMS4 permit, there are eight NPDES permitted municipal wastewater treatment facilities (WWTF) in the region.

The waste load allocation (WLA) for sMS4s was based on the percent jurisdictional area approach. For each zone, the amount available for nonpoint source load allocations (LAs) and the sMS4 WLA was the TMDL for that zone minus the margin of safety (MOS) and the WLAs for WWTFs. In the case of the Lower Rio Grande, two percent of the watershed falls within the jurisdiction of sMS4 communities. Thus, the sMS4 WLA is two percent of the available allocation for each zone. The remaining ninety-eight percent was designated for nonpoint sources and natural background as the LA for each zone. Individual waste load allocations for all NPDES permits in the impaired assessment units are shown in Table 4.4.

In contrast to discharges from other industrial storm water and individual process wastewater permitted facilities, storm water discharges are transient because they occur during storm events. Coverage under Phase II of the NPDES Storm Water Program requires preparation of a Storm Water Pollution Prevention Plan (SWPPP) that includes identification and control of all pollutants associated with urban activities to minimize impacts to water quality. In the case of the Lower Rio Grande, compliance by those municipalities within the terms of their individual MS4 permits will fulfill any obligations they have toward implementing this TMDL.

Table 4.4. Waste Load Allocations for *E. coli*

Assessment Unit	Facility	Design Capacity Flow (mgd)	Proposed *E. coli* Effluent limits[(a)] (cfu/100mL)	Conversion Factor[(b)]	Waste Load Allocations (cfu/day)
Rio Grande (International Mexico boundary to Leasburg Dam)	**NM0029629** Anthony Water and Sanitation District WWTP	0.9	126	3.79×10^{7}	4.30×10^{9}
	NM0028487 Gadsden Independent School District	0.088	126	3.79×10^{7}	4.20×10^{8}
	NM0023311 City of Las Cruces WWTP	8.9	126	3.79×10^{7}	4.25×10^{10}
	NM0030201 City of Sunland Park (Santa Teresa)	0.53	126	3.79×10^{7}	2.53×10^{9}
	NM0030490 South Central Regional WWTP, Dona Ana Co.	1.05	126	3.79×10^{7}	5.01×10^{9}
	NM0029483 City of Sunland Park WWTP	1.2	126	3.79×10^{7}	5.73×10^{9}
	NMR040000 Municipal Separate Storm Sewer System (MS4) storm water permit	--	--	--	Variable[(c)]
Rio Grande (Leasburg Dam to Percha Dam)	**NM0020010** Village of Hatch WWTP	0.3	126	3.79×10^{7}	1.43×10^{9}
	NM0030457 Village of Salem WWTP	0.2	126	3.79×10^{7}	9.55×10^{8}

Notes:
[(a)] Based on current in-stream New Mexico WQS for segment 20.6.4.101 NMAC (as amended February 16, 2006).
[(b)] Based on equation 1.
[(c)] The waste load allocation for the storm water MS4 permit was based on the percent jurisdictional area approach. Two percent of the watershed fell within the jurisdiction of MS4 communities. Thus, the MS4 waste load allocation is 2% of the available allocation for each hydrologic zone, where the available allocation = TMDL – WLA – MOS.

4.4.2 Load Allocation

In order to calculate the LA, the WLAs listed in table 4.4 and the 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 (see Section 4.7 for details). Results are presented in Tables 4.5 and 4.6.

Table 4.5. TMDLs for *E. coli*: Rio Grande (International Mexico bnd. to Leasburg Dam)

	FLOW CONDITIONS				
	High	**Moist**	**Mid-Range**	**Dry**	**Low**
TMDL	**4.11×10^{12}**	**2.55×10^{12}**	**1.52×10^{12}**	**4.10×10^{11}**	**8.50×10^{10}**
Load Allocation	**3.32×10^{12}**	**1.83×10^{12}**	**8.84×10^{11}**	**1.19×10^{11}**	**2.03×10^{10}**
NM0029629	4.30×10^{9}	4.30×10^{9}	4.30×10^{9}	4.30×10^{9}	4.30×10^{9}
NM0000108	0	0	0	0	0
NM0028487	4.20×10^{8}	4.20×10^{8}	4.20×10^{8}	4.20×10^{8}	4.20×10^{8}
NM0023311	4.25×10^{10}	4.25×10^{10}	4.25×10^{10}	4.25×10^{10}	4.25×10^{10}
NM0030201	2.53×10^{9}	2.53×10^{9}	2.53×10^{9}	2.53×10^{9}	2.53×10^{9}
NM0030490	5.01×10^{9}	5.01×10^{9}	5.01×10^{9}	5.01×10^{9}	5.01×10^{9}
NM0029483	5.73×10^{9}	5.73×10^{9}	5.73×10^{9}	5.73×10^{9}	5.73×10^{9}
NMR040000	6.77×10^{10}	3.74×10^{10}	1.80×10^{10}	2.43×10^{9}	0
Total Waste Load Allocation	**1.28×10^{11}**	**9.79×10^{10}**	**7.85×10^{10}**	**6.29×10^{10}**	**6.05×10^{10}**
Margin of Safety	**6.64×10^{11}**	**6.20×10^{11}**	**5.52×10^{11}**	**2.28×10^{11}**	**4.25×10^{9}**

Table 4.6. TMDLs for *E. coli*: Rio Grande (Leasburg Dam to Percha Dam)

	FLOW CONDITIONS				
	High$^{(a)}$	**Moist**$^{(a)}$	**Mid-Range**	**Dry**$^{(a)}$	**Low**$^{(a)}$
TMDL	**-**	**-**	**3.03×10^{12}**	**-**	**-**
Load Allocation	**-**	**-**	**1.05×10^{12}**	**-**	**-**
NM0020010	-	-	1.43×10^{9}	-	-
NM0030457	-	-	9.55×10^{8}	-	-
Total Waste Load Allocation	**-**	**-**	**2.39×10^{9}**	**-**	**-**
Margin of Safety	**-**	**-**	**1.98×10^{12}**	**-**	**-**

$^{(a)}$ There are no TMDL calculations for High, Moist, Dry, or Low flow conditions because there were no observed exceedences during these flow regimes (refer to Figure 4.4).

The extensive data collection and analyses necessary to determine background *E. coli* loads for the Lower Rio Grande 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. The load reductions necessary to meet the target loads were calculated to be the difference between the target load and the measured load. Results are presented in Tables 4.7 and 4.8.

Table 4.7. Load Reduction: Rio Grande (International Mexico Boundary to Leasburg Dam)

Rio Grande (Int'l Mexico bnd. to Leasburg Dam)	FLOW CONDITIONS				
	High[a]	Moist	Mid-Range	Dry	Low
Measured *E. coli* concentration (cfu/100mL) [b]	--	1308	523	228,732	150
Mid-point Flow (mgd)	--	534	317	86	18
Conversion Factor[c]	--	3.79×10^7	3.79×10^7	3.79×10^7	3.79×10^7
Measured Loads	**--**	**2.65×10^{13}**	**6.29×10^{12}**	**7.45×10^{14}**	**1.01×10^{11}**
Target Loads[d]	**--**	**1.93×10^{12}**	**9.63×10^{11}**	**1.82×10^{11}**	**8.08×10^{10}**
Percent Reduction [e]	**--**	**92.7%**	**84.7%**	**100%**	**20.2%**

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] There were no measured concentrations at high flows, thus measured load and reduction estimate could not be calculated.

[b] The measured concentration is the arithmetic mean of the measured values (see Appendix A)

[c] Based on equation 1.

[d] Target Load = LA + WLA

[e] 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

Table 4.8. Load Reduction: Rio Grande (Leasburg Dam to Percha Dam)

Rio Grande (Leasburg Dam to Percha Dam)	FLOW CONDITIONS				
	High [a]	Moist [a]	Mid-Range	Dry [a]	Low [a]
Measured *E. coli* concentration (cfu/100mL) [b]	--	--	1662	--	--
Mid-point Flow (mgd)	--	--	635	--	--
Conversion Factor[c]	--	--	3.79×10^7	--	--
Measured Load	**--**	**--**	**4.00×10^{13}**	**--**	**--**
Target Load[d]	**--**	**--**	**1.05×10^{12}**	**--**	**--**
Percent Reduction[e]	**--**	**--**	**97.4%**	**--**	**--**

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] There are no calculations for High, Moist, Dry, or Low flow conditions because there were no observed exceedences during these flow regimes (refer to Figure 4.4).

[b] The measured concentration is the arithmetic mean of the measured values (see Appendix A)

[c] Based on equation 1.

[d] Target Load = LA + WLA

[e] 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

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 *E. coli* loads are displayed in Table 4.9.

Table 4.9. Pollutant Source Summary for *E. coli*

Pollutant Sources	Magnitude (cfu/day)	Assessment Unit	Probable Sources[a]
Point: [b]			
E. coli	1.28×10^{11} (High Flow) – 6.05×10^{10} (Low Flow)	Rio Grande (International Mexico bnd. to Leasburg Dam)	**0.3%** (Moist Conditions) **– 59.8%** (Low Flow) Municipal Point Source Discharges
E. coli	2.39×10^{9}	Rio Grande (Leasburg Dam to Percha Dam)	**0.1%** Municipal Point Source Discharges
Nonpoint: [c]			
E. coli *High Flow* *Moist Conditions* *Mid-Range* *Dry Conditions* *Low Flow*	-- 2.64×10^{13} 6.21×10^{12} 7.45×10^{14} 4.07×10^{10}	Rio Grande (International Mexico bnd. to Leasburg Dam)	**99.7%** (Moist Conditions) **– 40.2%** (Low Flow) Impervious Surface/Parking Lot Runoff; Municipal (Urbanized High Density Areas); On-site Treatment Systems (Septic Systems and Similar Decentralized Systems); Permitted Runoff from Confined Animal Feeding Operations (CAFOs); Rangeland Grazing; Wastes from Pets; Waterfowl; Wildlife other than Waterfowl
E. coli *High Flow* *Moist Conditions* *Mid-Range* *Dry Conditions* *Low Flow*	-- -- 4.00×10^{13} -- --	Rio Grande (Leasburg Dam to Percha Dam)	**99.9%** Impervious Surface/Parking Lot Runoff; On-site Treatment Systems (Septic Systems and Similar Decentralized Systems); Rangeland Grazing; Wastes from Pets; Waterfowl; Wildlife other than Waterfowl

[a] From the 2004-2006 Integrated CWA 303(d)/305(b) Report (NMED/SWQB 2004a). 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. Point source percentage calculated as WLA magnitude divided by measured load. Nonpoint source percentage is the remainder when this value is subtracted from 100%.
[b] Current probable point source contributions (based on WLA calculations)
[c] Measured load minus current probable point source contributions

4.6 Linkage Between Water Quality and Pollutant Sources

SWQB fieldwork includes an assessment of the probable sources of impairment (NMED/SWQB 1999). The Source Documentation Sheet and Sources Summary Table in Appendix B provide 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 probable sources of impairment in this watershed. Table 4.9 (Pollutant Source Summary) identifies and quantifies probable sources of nonpoint source impairments along the reach as determined by field reconnaissance and assessment.

Among the probable sources of bacteria are municipal point sources discharges such as wastewater treatment facilities, poorly maintained or improperly installed (or missing) septic tanks, runoff from the numerous confined animal feeding operations (CAFOs), impervious surface/parking lot runoff, livestock grazing of valley pastures and riparian areas, upland livestock grazing, in addition to wastes from pets, waterfowl, and other wildlife. Very high *E. coli* concentrations have been measured in water sampled from SWQB monitoring stations along the Lower Rio Grande. Howell et. al. (1996) found that bacteria concentrations in underlying sediment increase when cattle (*Bos taurus*) have direct access to streams, such as the Lower Rio Grande. Natural sources of bacteria are also present in the form of other wildlife such as waterfowl, elk, deer, and any other warm-blooded mammals. In addition to direct input from dairy farm operations and wildlife, *E. coli* 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 *E. coli* concentrations. Howell et. al. (1996) observed that bacteria re-growth increases as water temperature increases, which definitely is a concern along the Lower Rio Grande.

E. coli Data

E. coli data collected during the 2004 water quality survey are shown in Tables 4.10 and 4.11. Rainfall measurements collected at the NOAA stations in Anthony, NM and Leasburg, NM were used to identify trends between elevated *E. coli* levels and rainfall. The Pearson correlation coefficient was used to assess whether a statistical association existed between *E. coli* and rainfall. The Pearson correlation coefficient, denoted by *r*, measures the strength and direction of a *linear* relationship between *X* and *Y* variables.

$$r = \frac{\sum_{i=1}^{n}(x_i - \bar{x})(y_i - \bar{y})}{\sqrt{\sum_{i=1}^{n}(x_i - \bar{x})^2 \sum_{i=1}^{n}(y_i - \bar{y})^2}}$$

Rio Grande (International Mexico Boundary to Leasburg Dam)

The available data for the Rio Grande (International Mexico Boundary to Leasburg Dam), shows no relationship between *E. coli* and rainfall events (r = -0.07). Data in Table 4.10 and Figure 4.5 show that elevated *E. coli* levels tend to occur during non-rainfall events. This potentially shows that along this segment of the Rio Grande sources of bacteria are delivered to the river during non-rainfall events. Moreover, the Discharge Monitoring Reports revealed that the City of Sunland Park WWTP (NPDES permit #NM0030201) was in violation for fecal coliforms during the weeks of April 8-14, April 15-21, April 22-28, and August 12-18, 2004. The South Central Regional WWTP (NPDES permit #NM0030490) was also in violation for fecal coliforms during the weeks of November 7-13 and November 21-27, 2004.

Table 4.10. *E. coli* concentration in the Rio Grande (International Mexico Boundary to Leasburg Dam)

Date Collected	Average *E. coli* Concentration (cfu/100mL)	Rainfall (inches)
4/6/04	642	0.41
4/20/04*	320,018*	0*
5/5/04	20	0
6/7/04	128	0
6/24/04	222	0.06
8/2/04	397	0.22
8/3/04	345	0.01
8/16/04	1550	0
8/17/04	3413	0.12
8/27/04	400	0
9/20/04	1500	1.06
9/21/04	352	0
10/18/04	10	0
11/8/04	0	0
11/9/04	275	0
11/17/04	110	0

***Note:** The sample from March 20, 2004 was not included on the graph because the *E. coli* concentration was so much higher than the other samples, thus skewing the graph.

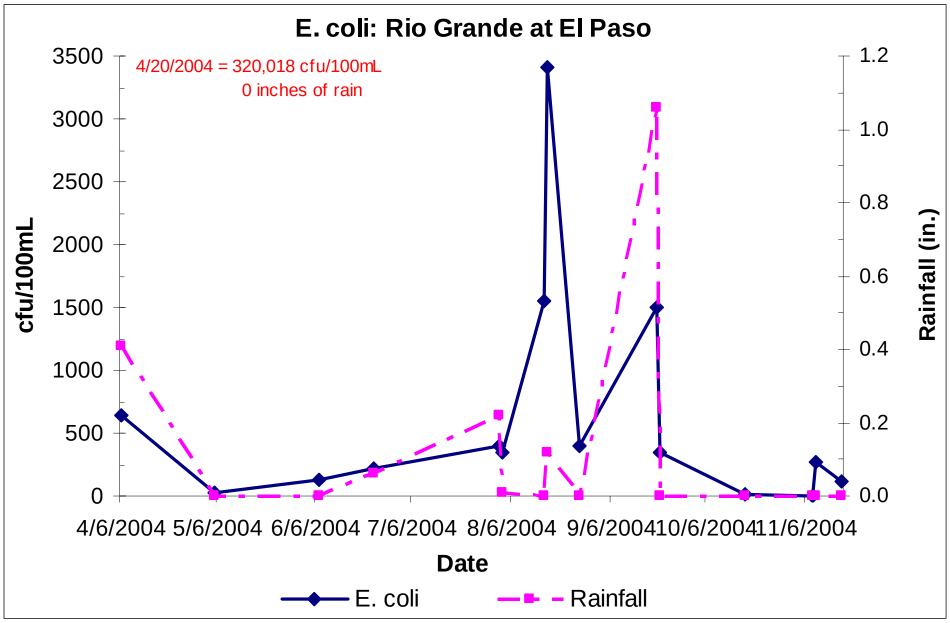

Figure 4.5 ***E. coli*** **Measurements in the Rio Grande (International Mexico Boundary to Leasburg Dam)**

Rio Grande (Leasburg Dam to Percha Dam)

The available data for the Rio Grande (Leasburg Dam to Percha Dam) shows a strong positive association between *E. coli* and rainfall events (Table 4.11 and Figure 4.6; r = 0.75). This potentially shows that along this segment of the Rio Grande sources of bacteria are delivered to the river mostly during rainfall events.

Table 4.11. ***E. coli*** **concentration in the Rio Grande (Leasburg Dam to Percha Dam)**

Date Collected	Average *E. coli* concentration (cfu/100mL)	Rainfall (inches)
4/20/04	13	0
5/5/04	57	0
11/8/04	23	0
9/20/04	65	0.2
4/6/04	20	0.01
8/17/04	7275	1.09
8/2/04	1160	0.34
7/28/04	400	0.15
6/24/04	20	0.14

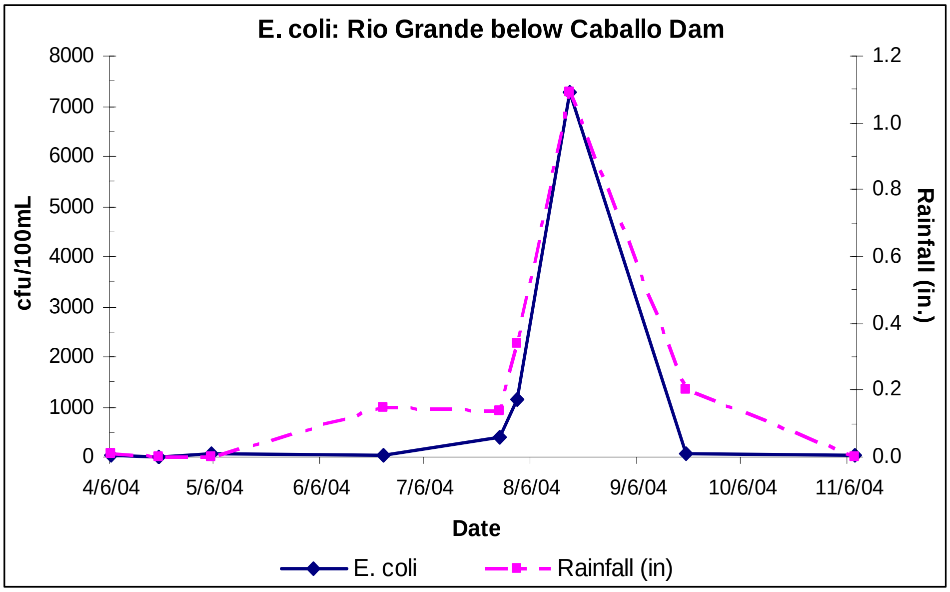

Figure 4.6 ***E. coli*** **Measurements in the Rio Grande (Leasburg Dam to Percha Dam)**

Conclusions

The bacteria loading probably originates 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 duration curve method, by itself, is limited in the ability to track individual source loadings or relative source contributions within a watershed. Additional analysis is needed to identify pollutant contributions from different types of probable sources and activities (i.e., construction zone versus agricultural area) or individual sources of a similar source category (i.e., WWTF #1 versus WWTF #2). Practitioners interested in more precise source characterization should consider supplementing the duration curve framework with a separate analysis. An added analytical tool might aid in evaluating allocation scenarios and tracking individual sources or source categories. This could allow for improved targeting of restoration activities.

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 *E. coli* TMDLs 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 allocations. Therefore, this MOS is the sum of the following two elements:

- *Implicit Margin of Safety*

  Treating *E. coli* 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 single sample criterion which allows for higher concentrations in individual grab samples, was used to calculate loading values.

- *Explicit Margin of Safety*

  Using a duration curve framework, an explicit MOS can be identified for each listed reach and corresponding set of flow zones. In this TMDL, the MOS was based on the difference between the loading capacity as calculated at the mid-point of each of the four higher flow zones (high, moist, mid-range, and dry), and the loading capacity calculated at the minimum flow in each zone. Given that the loading capacity is typically much less at the minimum flow of a zone as compared to the mid-point, a substantial MOS is provided. This explicit MOS ensures that allocations will not exceed the load associated with the minimum flow in each zone (USEPA 2006).

  The MOS for the low flow zone was determined using a different method because the lowest flow recorded was only 0.35 cfs. If the MOS was calculated as described above, the MOS would constitute the majority of the target load. In other words, there would not be enough load to allocate to point and nonpoint sources under this flow regime. Similar to previous SWQB bacteria TMDLs which were based on 4Q3 low-flows, there is inherent error in all flow measurements. A conservative MOS of **5 percent** was therefore explicitly allocated to the low flow hydrologic zone.

An explicit MOS identified using a duration curve framework is basically unallocated assimilative capacity intended to account for uncertainty (e.g., loads from tributary streams, effectiveness of controls, etc). As new information becomes available, this unallocated capacity may be attributed to nonpoint sources including tributary streams (which could then be added to the load allocation); or it may be attributed to point sources (and become part of the waste load allocations).

4.8 Consideration of Seasonal Variability

Federal regulations (40 CFR §130.7(c)(1)) require that TMDLs take into consideration seasonal variation in watershed conditions and pollutant loading. Seasonal variation was accounted for in these TMDLs by using 40 years of USGS flow records when estimating flows to develop flow exceedence percentiles.

During the 2004 water quality survey, bacteria exceedences occurred during spring, summer, and fall months. Higher flows may flush more nonpoint source runoff containing *E. coli*. It is also possible the criterion may be exceeded under a low flow condition when there is insufficient dilution of a point source. The use of duration curves provides a technical framework for identifying *"daily loads"* in TMDL development, which accounts for the variable nature of water quality associated with different stream flow rates during different seasons. Allocations within the TMDL are set in a way that reflects dominant concerns associated with appropriate hydrologic conditions.

4.9 Future Growth

According to the calculations, the overwhelming source of bacteria loading is from nonpoint sources in the upper AU (Leasburg Dam to Percha Dam). However, the lower AU (International Mexico Boundary to Leasburg Dam) experienced impacts from both point and nonpoint sources depending on the flow conditions. Estimates of future growth are not anticipated to lead to a significant increase in bacteria concentrations that cannot be controlled with BMP implementation and appropriate NPDES permit limits in this watershed.

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