6.0 TURBIDITY

During the 2001 SWQB intensive water quality survey in the Upper Rio Grande (Part 2) Watershed, several exceedences of the NM water quality criteria for turbidity were documented in the following assessment units:

- Embudo Creek (Rio Grande to Canada de Ojo Sarco) (20.6.4.114 NMAC)
- Rio Grande (non-pueblo Santa Clara to Embudo Creek) (20.6.4.114 NMAC)
- Rio Santa Barbara (Picuris Pueblo bnd to USFS bnd) (20.6.4.123)

According to the NM WQS the segment specific standards for turbidity reads:

> *20.6.4.114 NMAC: In any single sample: turbidity shall not exceed 50 NTU.*
> *20.6.4.123 NMAC: In any single sample: turbidity shall not exceed 25 NTU.*

The following subsections present the turbidity TMDLs for these assessment units.

6.1 Target Loading Capacity

Target values for this turbidity TMDL 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 turbidity are based on numeric criteria. This TMDL is also consistent with New Mexico's antidegradation policy.

According to the New Mexico Water Quality Standards (20.6.4 NMAC), the general narrative standard for turbidity reads:

> *Turbidity: Turbidity attributable to other than natural causes shall not reduce light transmission to the point that the normal growth, function, or reproduction of aquatic life is impaired or that will cause substantial visible contrast with the natural appearance of the water.*

The total suspended solids (TSS) analytical method is a commonly used measurement of suspended material in surface water. This method was originally developed for use on wastewater samples, but has widely been used as a measure of suspended materials in stream samples because it is acceptable for regulatory purposes and is an inexpensive laboratory procedure. Since there are no wastewater treatment plants discharging into either Embudo Creek, the Rio Grande, or the Rio Santa Barbara in the impaired assessment units, it is assumed that TSS measurements in these ambient stream samples are representative of erosional activities and thus comprised primarily of suspended sediment vs. any potential biosolids from wastewater treatment plant effluent.

Turbidity levels can be inferred from studies that monitor suspended sediment concentrations. Extrapolation from these studies is possible when a site-specific relationship between

concentrations of suspended sediments and turbidity is confirmed. Activities that generate varying amounts of suspended sediment will proportionally change or affect turbidity (USEPA 1991). The impacts of suspended sediment and turbidity are well documented in the literature. An increased sediment load is often the most important adverse effect of activities on streams, according to a monitoring guidelines report (USEPA 1991). This impact is largely a mechanical action that severely reduces the available habitat for macroinvertebrates and fish species that utilize the streambed in various life stages. An increase in suspended sediment concentration will reduce the penetration of light, decreases the ability of fish or fingerlings to capture prey, and reduce primary production (USEPA 1991). As stated in Relyea (2000) "increased turbidity by sediments can reduce stream primary production by reducing photosynthesis, physically abrading algae and other plants, and preventing attachment of autotrouphs to substrate surfaces".

TSS and turbidity were measured in Embudo Creek (Table 6.1), the Rio Grande (Table 6.2), and the Rio Santa Barbara (Table 6.3) during the 2001 survey. The TSS target was derived using a regression equation developed using measured turbidity as the independent variable and measured TSS dependent variable. The equation and regression statistics are displayed below in Figures 6.1, 6.2, and 6.3. Correlations of r^2=0.99, 0.77, and 0.98 were found between TSS and turbidity for Embudo Creek, Rio Grande, and Rio Santa Barbara, respectively.

Table 6.1 TSS and Turbidity Data for Embudo Creek (Rio Grande to Canada de Ojo Sarco)

Sample Date	TSS (mg/L)	Turbidity (NTU)
Embudo Creek at Hwy 68 bridge near Dixon at USGS gage		
5/22/2001	27	30.1
5/23/2001	20	23.2
5/24/2001	15	20.6
8/14/2001	71	72*
8/15/2001	183	240*
10/2/2001	3	0.4
10/3/2001	5	0.01
10/4/2001	3	0.01

Notes:
*Exceedence of turbidity water quality criterion.
NTU = Nephelometric turbidity units

Table 6.2 TSS and Turbidity Data for Rio Grande (non-pueblo Santa Clara to Embudo Creek)

Sample Date	TSS (mg/L)	Turbidity (NTU)
Rio Grande at Embudo Station		
5/22/2001	76	73.2*
5/23/2001	79	72*
5/24/2001	81	77*
8/14/2001	60	72*
8/15/2001	399	295*
10/02/2001	14	17.4
10/03/2001	15	17.7
10/04/2001	8	14.7
Rio Grande at Hwy 74 near San Juan Pueblo		
5/22/2001	81	86.8*
5/23/2001	89	75.7*
5/24/2001	100	78*
8/14/2001	91	94*
8/15/2001	3450	999+
10/02/2001	3	28.3
10/03/2001	18	28.9
10/04/2001	24	24
Rio Grande above Espanola at Valdez Bridge		
5/22/2001	78	54.6*
5/23/2001	80	42.4
5/24/2001	91	51.1*
8/21/2001	144	119.8*
8/22/2001	115	133.4*
9/25/2001	131	146.2*
9/26/2001	41	138.9*
9/27/2001	56	133.5*

Notes: *Exceedence of turbidity water quality criterion.
+ This TSS and turbidity reading was excluded from TMDL calculations because the turbidity reading indicates that the actual turbidity measurement exceeded the range of the turbidity meter.

Table 6.3 TSS and Turbidity Data for Rio Santa Barbara (Picuris Pueblo bnd to USFS bnd)

Sample Date	TSS (mg/L)	Turbidity (NTU)
Rio Santa Barbara at mouth		
5/23/2001	16	14.2
5/24/2001	12	13.5
8/14/2001	32	36*
8/15/2001	29	37*
10/2/2001	3	0.4
10/3/2001	3	0.5
10/4/2001	3	1.5

Notes:
*Exceedence of turbidity water quality criterion.

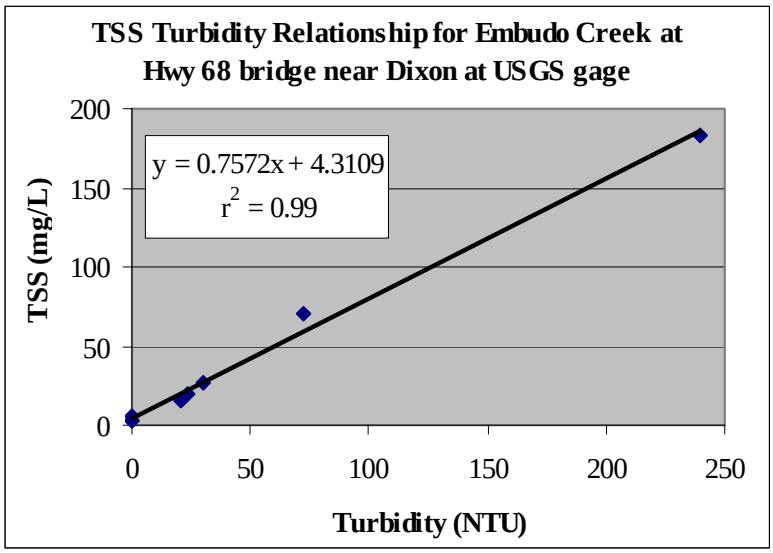

Figure 6.1 Relationship between TSS and Turbidity at Embudo Creek at Hwy 68 Bridge near Dixon at USGS Gage

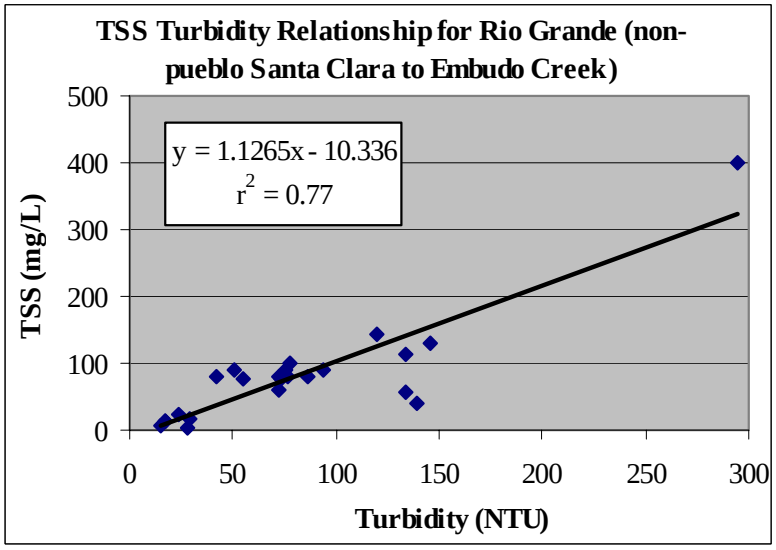

Figure 6.2 Relationship between TSS and Turbidity for the Rio Grande (non-pueblo Santa Clara to Embudo Creek)

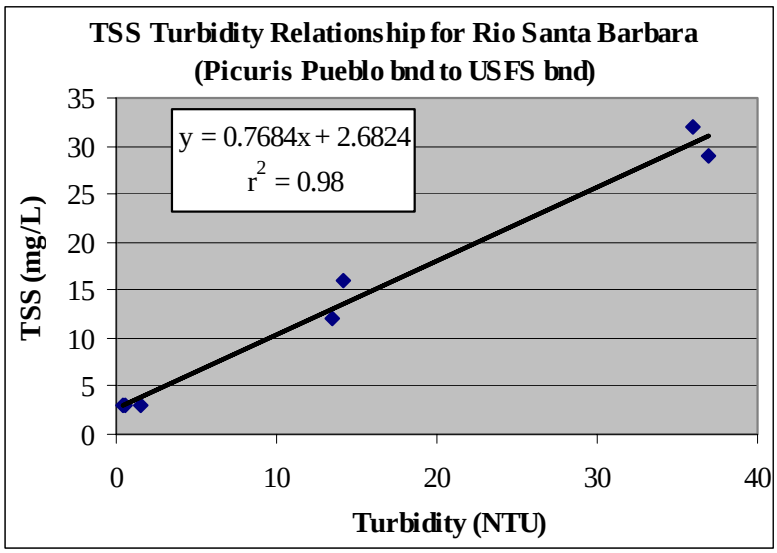

Figure 6.3 Relationship between TSS and Turbidity for the Rio Santa Barbara (Picuris Pueblo bnd to USFS bnd)

6.2 Flow

Sediment transport in a stream varies as a function of flow. As flow increases, the amount of sediment being transported increases. These TMDLs are calculated for each reach at specific flows. When available, USGS gages are used to estimate flow. Gaged streamflow data is available for both Embudo Creek and the Rio Grande, but not for the Rio Santa Barbara. Therefore, USGS gage data was used to determine the average flow when the turbidity water quality criterion was exceeded in Embudo Creek and the Rio Grande. Where gages are absent, geomorphologic cross section field data are collected at each site and flows are modeled or actual flow measurements are taken. In this case, flow was measured on the Rio Santa Barbara at SWQB station 39 during the each sampling run using standard USGS procedures (NMED/SWQB 2001a). For Embudo Creek exceedences were observed on 8/14/2001 and 8/15/2001 and discharge at USGS gage 0827900 (Embudo Creek at Dixon, NM) was recorded on these two days at 103 cfs and 92 cfs, respectively.

The turbidity water quality criterion at the Rio Grande (non-pueblo Santa Clara to Embudo Creek) was exceeded at least one sampling station during the majority of the sampling dates. A USGS gage is located at the upstream sampling location, "Rio Grande at Embudo Station", and an average flow of 1,607 cfs was calculated for this location for the five days where turbidity exceedences were recorded at this location. Since no flow measurements were recorded at either of the downstream sampling locations in this reach, flow for these two locations was calculated using the following equation (Maidment 1993):

$$Q_{(u)} = Q_{(g)} \times (A_u/A_g)$$

Where,
$Q_{(u)}$ = discharge, in cubic feet per second, at ungaged site
$Q_{(g)}$ = discharge, in cubic feet per second, at gaged site
A_u = drainage area, in square miles, at ungaged site
A_g = drainage area, in square miles, at gaged site

Using this equation, a flow of 1,632 cfs was calculated at the Rio Grande at Hwy 74 near San Juan Pueblo station and 2,130 cfs at the Rio Grande above Espanola at Valdez Bridge station. These three flows were averaged to get a flow of 1,789 for the Rio Grande (non-pueblo Santa Clara to Embudo Creek) reach.

Turbidity exceedences in the Rio Santa Barbara were recorded on 8/14/2001 and 8/15/2001 and discharge was measured on these two days at 18.12 cfs and 21.5 cfs, respectively.

Therefore the critical flows for these TMDLs were:

- Embudo Creek critical flow = 97.5 cfs
- Rio Grande critical flow = 1,789 cfs
- Rio Santa Barbara critical flow = 19.81 cfs

The flow value for Embudo Creek was converted from cfs to units of mgd as follows:

$$97.5\,\frac{ft^3}{\sec} \times 1{,}728\,\frac{in^3}{ft^3} \times 0.004329\,\frac{gal}{in^3} \times 86{,}400\,\frac{\sec}{day} \times 10^{-6} = 63.0\,mgd$$

Using the above equation the flow value for the Rio Grande was converted from 1,789 cfs to 1,156 mgd and the flow value for the Rio Santa Barbara was converted from 19.81 cfs to 12.8 mgd.

6.3 Calculations

Target loads for turbidity (expressed as TSS) are calculated based on a flow, the current water quality standards, and a conversion factor (8.34) that is a used to convert mg/L units to lbs/day (see Appendix B for Conversion Factor Derivation). The target loading capacity is calculated using **Equation 1**. The results are shown in Table 6.4.

Critical Flow (mgd) x Standard (mg/L) x 8.34 = Target Loading Capacity (Eq. 1)

Table 6.4 Calculation of target loads for turbidity (expressed as TSS)

Location	Flow (mgd)	TSS (mg/L)	Conversion Factor	Target Load Capacity (lbs/day)
Embudo Creek (Rio Grande to Canada de Ojo Sarco)	63.0	42.2+	8.34	22,173
Rio Grande (non-pueblo Santa Clara to Embudo Creek)	1,156	45.99*	8.34	443,391
Rio Santa Barbara (Picuris Pueblo bnd to USFS bnd)	12.8	21.89±	8.34	2,337

Notes:
+ The TSS value was calculated using the relationship established between TSS and turbidity in Figure 6.1 (y=0.7572x + 4.3109, R^2=0.99) using the turbidity standard of 50 NTU for the X variable.
*The TSS value was calculated using the relationship established between TSS and turbidity in Figure 6.2 (y=1.1265x – 10.336, R^2=0.77) using the turbidity standard of 50 NTU for the X variable.
±The TSS value was calculated using the relationship established between TSS and turbidity in Figure 6.3 (y=0.7684x + 2.6824, R^2=0.98) using the turbidity standard of 25 NTU for the X variable.

It is important to remember that the TMDL is a planning tool to be used to achieve water quality standards. Since flows vary throughout the year in these systems the target load will vary based on the changing flow. Management of the load should set a goal at water quality standards attainment versus meeting the calculated target load.

The measured loads for turbidity (expressed as TSS) were similarly calculated. In order to achieve comparability between the target and measured loads, the flows used were the same for both calculations. The arithmetic mean of corresponding TSS values when turbidity exceeded the standard was substituted for the standard in **Equation 1**. The same conversion factor of 8.34 was used. Results are presented in Table 6.5.

Table 6.5 Calculation of measured loads for turbidity (expressed as TSS)

Location	Flow (mgd)	TSS Arithmetic Mean * (mg/L)	Conversion Factor	Measured Load Capacity (lbs/day)
Embudo Creek (Rio Grande to Canada de Ojo Sarco)	63.0	127	8.34	66,728
Rio Grande (non-pueblo Santa Clara to Embudo Creek)	1,156	107	8.34	1,031,591
Rio Santa Barbara (Picuris Pueblo bnd to USFS bnd)	12.8	30.5	8.34	3,256

Notes: * Arithmetic mean of TSS values when measured turbidity exceeded the standard (see Tables 6.1, 6.2, and 6.3).

6.4 Waste Load Allocations and Load Allocations

6.4.1 Waste Load Allocation

There are no individually permitted point source facilities or MS4 storm water permits in this assessment unit. Sediment may be a component of some (primarily construction) storm water discharges that contribute to suspended sediment impacts, and should be addressed.

In contrast to discharges from other industrial storm water and individual process wastewater permitted facilities, storm water discharges from construction activities are transient because they occur mainly during the construction itself, and then only during storm events. Coverage under the NPDES CGP requires preparation of a SWPPP that includes identification and control of all pollutants associated with the construction activities to minimize impacts to water quality. In addition, the current CGP also includes state specific requirements to implement BMPs that are designed to prevent to the maximum extent practicable, an increase in sediment, or a parameter that addresses sediment (e.g., total suspended solids, turbidity, siltation, stream bottom deposits, etc.) and flow velocity during and after construction compared to pre-construction conditions. In this case, compliance with a SWPPP that meets the requirements of the CGP is generally assumed to be consistent with this TMDL.

Other industrial storm water facilities are generally covered under the current NPDES MSGP. This permit also requires preparation of an SWPPP that includes identification and control of all

pollutants associated with the industrial activities to minimize impacts to water quality. In addition, the current MSGP also includes state specific requirements to further limit (or eliminate) pollutant loading to water quality impaired/water quality limited waters from facilities where there is a reasonable potential to contain pollutants for which the receiving water is impaired. In this case, compliance with a SWPPP that meets the requirements of the MSGP is generally assumed to be consistent with this TMDL.

Individual wasteload allocations for the General Permits were not possible to calculate at this time in this watershed using available tools. Loads that are in compliance with the General Permits from facilities covered are therefore currently calculated as part of the watershed load allocation.

6.4.2 Load Allocation

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

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

The MOS is estimated to be 25% of the target load calculated in Table 6.4. Results are presented in Table 6.6. Additional details on the MOS chosen are presented in Section 6.7 below.

Table 6.6 Calculation of TMDL for turbidity

Location	WLA (lbs/day)	LA (lbs/day)	MOS (25%) (lbs/day)	TMDL (lbs/day)
Embudo Creek (Rio Grande to Canada de Ojo Sarco)	0	16,630	5,543	22,173
Rio Grande (non-pueblo Santa Clara to Embudo Creek)	0	332,544	110,847	443,391
Rio Santa Barbara (Picuris Pueblo bnd to USFS bnd)	0	1,753	584	2,337

The extensive data collection and analyses necessary to determine background turbidity loads for the Embudo and Rio Grande watersheds was 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.

The NPS and background load reductions that would be necessary to meet the target loads were calculated to be the difference between the load allocation (Table 6.6) and the measured load (Table 6.5), and are shown in Table 6.7.

Table 6.7 Calculation of load reduction for turbidity (expressed as TSS)

Location	LA (lbs/day)	Measured Load (lbs/day)	Load Reduction (lb/day)
Embudo Creek (Rio Grande to Canada de Ojo Sarco)	16,630	66,728	50,098
Rio Grande (non-pueblo Santa Clara to Embudo Creek)	332,544	1,031,591	699,047
Rio Santa Barbara (Picuris Pueblo bnd to USFS bnd)	1,753	3,256	1,503

6.5 Identification and Description of pollutant source(s)

Pollutant sources that could contribute to each segment are listed in Table 6.8.

6.6 Linkage of Water Quality and Pollutant Sources

Turbidity is an expression of the optical property in water that causes incident light to be scattered of absorbed rather than transmitted in straight lines. It is the condition resulting from suspended solids in the water, including silts, clays, and plankton. Such particles absorb heat in the sunlight, thus raising water temperature, which in turn lowers dissolved oxygen levels. It also prevents sunlight from reaching plants below the surface. This decreases the rate of photosynthesis, so less oxygen is produced by plants. Turbidity may harm fish and their larvae. Turbidity exceedences, historically, are generally attributable to soil erosion, excess nutrients, various wastes and pollutants, and the stirring of sediments up into the water column during high flow events. Turbidity increases, as observed in SWQB monitoring data, show turbidity values along these reaches that exceed the State Standards for the protection of aquatic habitat, namely the marginal coldwater fishery and High Quality Coldwater Fishery (HQCWF) designed uses. Through monitoring, and pollutant source documentation, it has been observed that the most probable cause for these exceedences are due to the alteration of the stream's hydrograph and grazing impacts. Alterations can be historical or current in nature.

Table 6.8 Pollutant source summary for turbidity

Pollutant Sources	**Magnitude** (Measured Load [lbs/day])	**Location**	**Potential Sources** (% from each)
Point: None	0	--------	0%
Nonpoint: Turbidity (expressed as TSS in lbs/day)	66,728	Embudo Creek	100% Range Grazing -- Riparian or Upland, Removal of Riparian Vegetation Road Maintenance and Runoff Flow Regulation/Modification Agriculture
	1,031,591	Rio Grande	100% Loss of Riparian Habitat Highway, road, bridge runoff (non-construction) Natural causes Irrigated crop production Rangeland grazing
	3,256	Rio Santa Barbara	100% Loss of Riparian Habitat Source unknown Rangeland grazing Streambank modifications/destabilization Site clearance (Land development or Redevelopment)

The components of a watershed continually change through natural ecological processes such as vegetation succession, erosion, and evolution of stream channels. Intrusive human activity often affects watershed function in ways that are inconsistent with the natural balance. These changes, often rapid and sometimes irreversible, occur when people:

- cut forests
- clear and cultivate land
- remove stream-side vegetation
- alter the drainage of the land
- channelize watercourses
- withdraw water for irrigation
- build towns and cities
- discharge pollutants into waterways.

Possible effects of these practices on aquatic ecosystems include:

1. Increased amount of sediment carried into water by soil erosion which may

- increase turbidity of the water
- reduce transmission of sunlight needed for photosynthesis
- interfere with animal behaviors dependent on sight (foraging, mating, and escape from predators)
- impede respiration (e.g., by gill abrasion in fish) and digestion
- reduce oxygen in the water
- cover bottom gravel and degrade spawning habitat cover eggs, which may suffocate or develop abnormally; fry may be unable to emerge from the buried gravel bed

2. Clearing of trees and shrubs from shorelines which may

    - destabilize banks and promote erosion
    - increase sedimentation and turbidity
    - reduce shade and increase water temperature which could disrupt fish metabolism
    - cause channels to widen and become more shallow

3. Land clearing, constructing drainage ditches, straightening natural water channels which may

    - create an obstacle to upstream movement of fish and suspend more sediment in the water due to increased flow
    - strand fish upstream and dry out recently spawned eggs due to subsequent low flows
    - reduce baseflows

Where data gaps exist or 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.

SWQB fieldwork includes an assessment of the potential sources of impairment (NMED/SWQB 1999). The completed *Pollutant Source(s) Documentation Protocol* forms in **Appendix B** provide documentation of a visual analysis of probable sources 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. Staff completing these forms identify and quantify potential sources of NPS impairments along each reach as determined by field reconnaissance and assessment. It is important to consider not only the land directly adjacent to the stream, which is predominantly privately held, but also to consider upland and upstream areas in a more holistic watershed approach to implementing this TMDL.

The main sources of impairment along the Embudo Creek (Rio Grande to Canada de Ojo Sarco) reach appear to be from livestock grazing, channelization, removal of riparian vegetation, natural causes, and off-road vehicles. Agricultural practices such as grazing appear to have contributed to the removal of riparian vegetation and streambank destabilization. This assessment unit goes through episodes of heavy sedimentation and then scouring. During previous surveys, the

cobble was 100% embedded with sand. Heavy sediment inputs in Dixon come from roads running perpendicular to the river. Also, dry watercourses in Dixon are used as roads.

The main sources of impairment to the Rio Grande (non-pueblo Santa Clara to Embudo Creek) reach are considered to be highway/road/bridge runoff (non-construction), loss of riparian habitat, natural causes, irrigated crop production, and rangeland grazing. The sources of impairment for the Rio Santa Barbara (Picuris Pueblo bnd to USFS bnd) are considered to be loss of riparian habitat, rangeland grazing, site clearance (land development or redevelopment), stream modification/stabilization, and unknown sources.

6.7 Margin of Safety (MOS)

TMDLs should reflect a MOS based on the uncertainty or variability in the data, the point and NPS load estimates, and the modeling analysis. For this TMDL, there will be no MOS for point sources since there are none in either Embudo Creek, Rio Santa Barbara, or this reach of the Rio Grande. However, for the NPS the MOS is estimated to be an addition of **25%** of the TMDL. This MOS incorporates several factors:

•Errors in calculating NPS loads

A level of uncertainty does exist in the relationship between TSS and turbidity. In this case, the TSS measure does not include bedload and therefore does not account for a complete measure of sediment load. This does not influence the MOS because we need only be concerned with the turbidity portion of the sediment load, which is the basis for the standard. However, there is a potential to have errors in measurements of NPS loads due to equipment accuracy, time of sampling, etc. Accordingly, a conservative MOS increases the TMDL by **15%**.

•Errors in calculating flow

Flow estimates were based on USGS gages on each of the reaches. There is a potential to have errors in measurements of flow due to equipment accuracy, time of sampling, etc. To be conservative, an additional MOS of **10%** will be included to account for accuracy of flow computations.

6.8 Consideration of Seasonal Variation

Data used in the calculation of this TMDL were collected during spring, summer, and fall in order to ensure coverage of any potential seasonal variation in the system. Since the critical condition is set to estimate high stream discharge, only data that exceeded the water quality criterion were used in determining the target capacities. Therefore, it is assumed that if critical conditions are met, coverage of any potential seasonal variation will also be met.

6.9 Future Growth

Estimations of future growth are not anticipated to lead to a significant increase for turbidity that cannot be controlled with best management practice implementation in this watershed.