5.0 DISSOLVED OXYGEN

During the 2002 SWQB intensive water quality survey in the San Juan River Watershed, exceedences of the New Mexico water quality standard for dissolved oxygen were documented at the La Plata sampling station on the La Plata River (SWQB Station 14). Consequently, the La Plata River from McDermott Arroyo to Colorado Border was listed on the 2004-2006 Clean Water Act Integrated §303(d)/§305(b) list for dissolved oxygen.

Based on USEPA's TMDL guidance and requirements, development of the dissolved oxygen TMDL for the La Plata River was conducted for critical low-flow conditions using a modeling program called QUAL2K (Chapra and Pelletier 2003). QUAL2K (Q2K) is a river and stream water quality model that is intended to represent a modernized version of USEPA's QUAL2E model (Brown and Barnwell 1987). Q2K is similar to QUAL2E in the following respects:

- The channel is well-mixed vertically and laterally (i.e. one dimensional).
- Steady flow is simulated.
- The heat budget and temperature are simulated as a function of meteorology on a diurnal time scale.
- All water quality variables are simulated on a diurnal time scale.
- Point and non-point loads and abstractions are simulated.

Q2K differs from QUAL2E in several ways. Q2K is implemented within the Microsoft Windows environment and is programmed in the Windows macro language with Visual Basic for Applications. Microsoft Excel is used as the graphical user interface. The following are additional features of the Q2K model listed on the USEPA's Support Center Q2K webpage:

- Model segmentation. QUAL2E segments the system into river reaches comprised of equally spaced elements. In contrast, Q2K uses unequally spaced reaches. In addition, multiple loadings and abstractions can be input into any reach.
- Carbonaceous Biological Oxygen Demand (CBOD) speciation. Q2K uses two forms of CBOD to represent organic carbon. These forms are a slowly oxidizing form (slow CBOD) and a rapidly oxidizing form (fast CBOD). In addition, non-living particulate organic matter (detritus) is simulated. This detrital material is composed of particulate carbon, nitrogen and phosphorus in a fixed stoichiometry.
- Anoxia. Q2K accommodates anoxia by reducing oxidation reactions to zero at low oxygen levels. In addition, denitrification is modeled as a first-order reaction that becomes pronounced at low oxygen concentrations.
- Sediment-water interactions. Sediment-water fluxes of dissolved oxygen and nutrients are simulated internally rather than being prescribed. That is, oxygen, sediment oxygen demand (SOD) and nutrient fluxes are simulated as a function of settling particulate organic matter, reactions within the sediments, and the concentrations of soluble forms in the overlying waters.
- Bottom algae. The model explicitly simulates attached bottom algae.
- Light extinction. Light extinction is calculated as a function of algae, detritus and inorganic solids.

- pH. Both alkalinity and total inorganic carbon are simulated. The river's pH is then simulated based on these two quantities.
- Pathogens. A generic pathogen is simulated. Pathogen removal is determined as a function of temperature, light, and settling.

Additional information on the Q2K program including model parameters and specific input values can be found in Appendix E.

5.1 Target Loading Capacity

Target values for this dissolved oxygen 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 loads that translate New Mexico's numeric dissolved oxygen criterion are based on total ultimate biological oxygen demand (TBODu). This TMDL is also consistent with New Mexico's antidegradation policy.

According to the New Mexico water quality standards (20.6.4.900.M NMAC) for a marginal coldwater fishery (MCWF), the dissolved oxygen shall not be less than 6.0 mg/L.

Grab sample data for the La Plata River (McDermott Arroyo to Colorado border) were collected from the La Plata station (SWQB station 14) six times between April 16 and July 16, 2002 and eight times at the NM-Colorado State Line station (SWQB station 13) between April 17 and October 22, 2002. Samples were not collected at Station 14 after July 16, 2002 because river levels were too low to allow for sample collection. Only one dissolved oxygen reading from the grab sample events at Station 14 was below the 6.0 mg/L criteria. No grab samples collected from Station 13 at the NM-Colorado State Line were below the dissolved oxygen criteria. Data were also collected June 19 – 21, 2002 at Station 14 using a data sonde. Approximately 63% of the dissolved oxygen measurements were below the 6.0 mg/L criteria at the La Plata Station 14 during the June 2002 sonde deployment sampling.

The pollutant of concern, based on the QK2 modeling, is biochemical oxygen demand, both carbonaceous (CBODu) and nitrogenous (NBODu), which is expressed in terms of TBODu. The equations below show this relationship. The TMDL will be expressed in terms of TBODu, based on the waterbody's assimilative capacity for oxygen-demanding substances.

$$\text{TBODu} = \text{CBOD} + \text{NBOD} \qquad \textbf{(Eq. 4)}$$

Where:

$$\text{NBODu} = \text{Total Kjedahl Nitrogen (TKN)} * 4.57 \qquad \textbf{(Eq. 5)}$$

Over the time scale of years, stream bottom sediments act as sinks for oxygen (Chapra 1997, Thomann and Mueller 1987). Oxygen is consumed by the oxidation of organic carbon (CBOD) and by the nitrification of ammonia (NBOD) in the bottom sediment. This process is known as SOD. The role of sediments in the system-wide nutrient budget is especially important during

the summer when seasonal low flows diminish tributary nutrient loads. During the summer, warm temperatures enhance biological processes in the sediments, increasing SOD (USEPA 1993a).

There have been numerous studies for establishing a SOD/TBODu relationship. According to the Streeter-Phelps SOD model, SOD is approximately 130 percent of the downward flux of TBODu (Chapra 1997) and the TMDL will employ the following relationship to link TBODu and SOD.

$$SOD = 1.3 * TBODu \qquad \textbf{(Eq. 6)}$$

5.2 Flow

TMDLs are calculated for the La Plata River at a specific flow. Dissolved oxygen concentrations in a stream vary as a function of flow. As flow decreases, the concentration of dissolved oxygen can decrease. Therefore the critical flow for this TMDL is low-flow which corresponds to June 2002 when the lowest dissolved oxygen measurements were collected. When available, USGS gages are used to estimate flow. 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 in the field at both SWQB stations 13 and 14. The flow measurement at SWQB station 14 for June 2002 (0.005 cubic feet per second [cfs]) was determined to be the critical flow for this TMDL based on dissolved oxygen measurements at this site, therefore this flow was used in the Q2K model (see Appendix E for more detail).

This flow value was converted for cfs to units of mgd as follows:

$$0.005\,\frac{ft^3}{\sec} \times 7.48\frac{gal}{ft^3} \times 86{,}400\,\frac{\sec}{day} \times 10^{-6} = 0.0032\,mgd \qquad \textbf{(Eq. 7)}$$

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.

5.3 Calculations

The determination of the TMDL value was performed using the Q2K model (see Appendix E for a detailed description of this model and the process involved in determining the TMDL). The calibration or baseline model run for dissolved oxygen is shown in Figure 5.1. This dissolved oxygen curve, calculated by Q2K, corresponds to a CBODu input value of 18.28 mg/L . TBODu can then be calculated based on the following:

$$NBODu = TKN * 4.57 \quad \textbf{(Eq. 5)}$$

Where: TKN at Station 14 for 6/17/02 = 0.276 mg/L
Therefore NBODu = 0.276 mg/L * 4.57 = 1.26 mg/L

$$TBODu = NBOD + CBOD \quad \textbf{(Eq. 4)}$$

Therefore TBODu = 1.26 mg/L + 18.28 mg/L = 19.54 mg/L

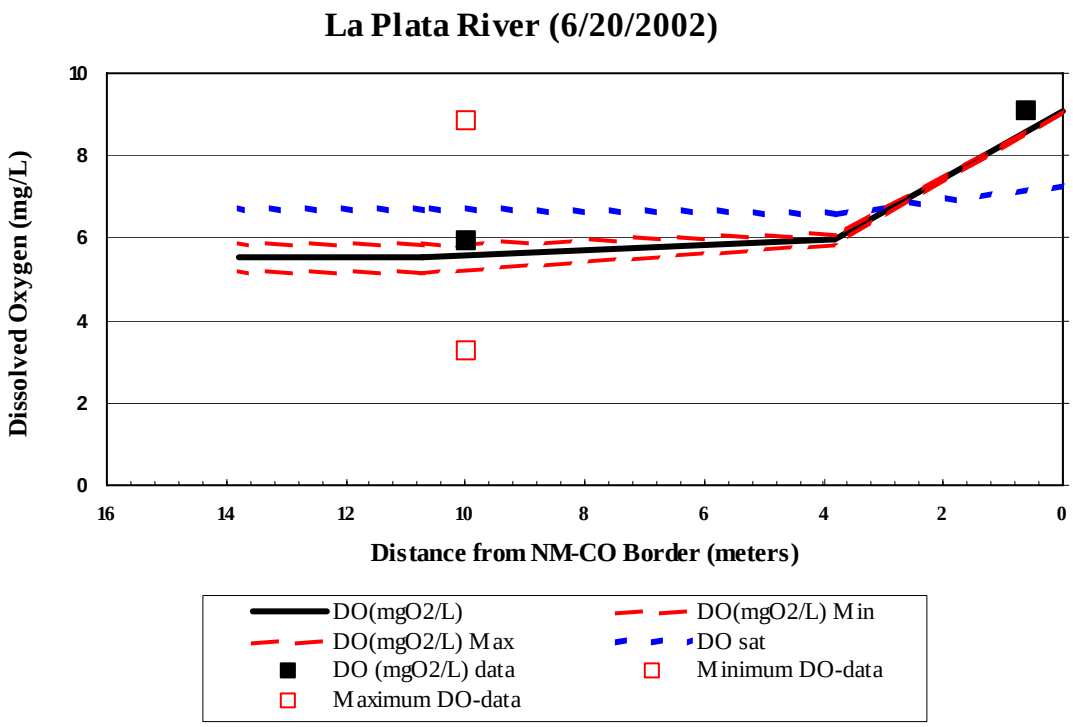

Figure 5.1 Model-Predicted Dissolved Oxygen Based on Existing Conditions for the La Plata River

The baseline condition model was then run adjusting the CBOD (while keeping the rest of the calibrated parameters the same), to bring the modeled in-stream dissolved oxygen concentration at or above 6.0 mg/L (representing the state criterion). This involved an iterative process to determine the CBODu value that would not violate water quality standards for dissolved oxygen (Figure 5.2). This value was determined to be 10.83 mg/L CBODu or 12.09 mg/L of TBODu.

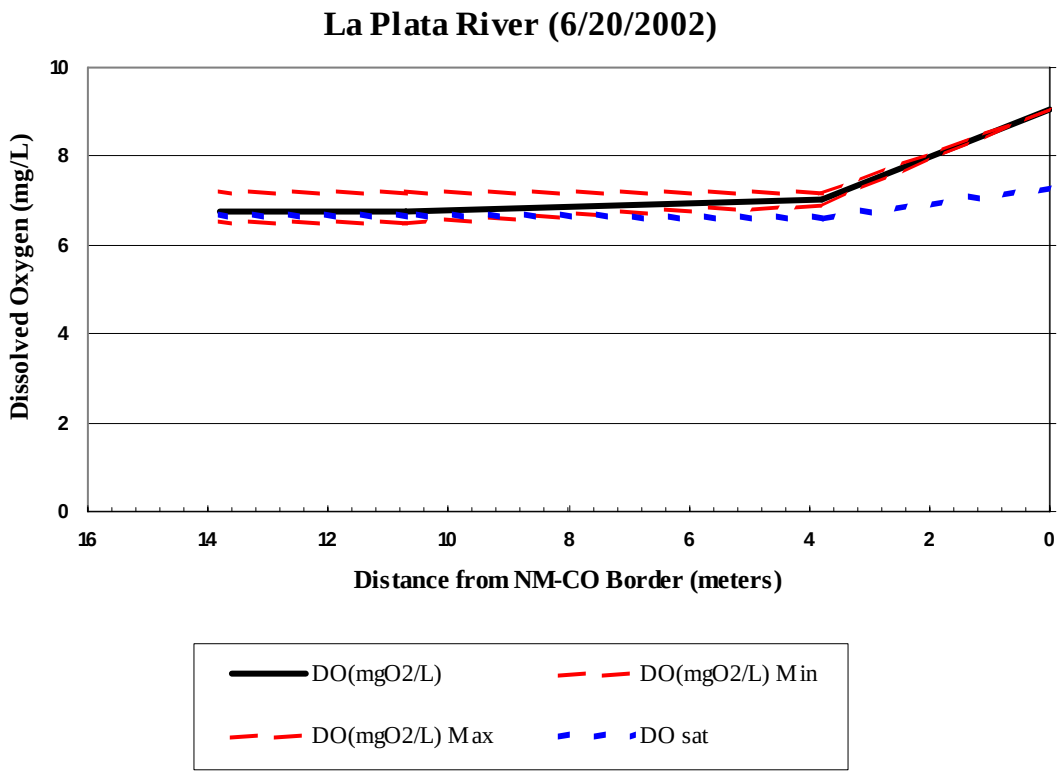

Figure 5.2 Model-predicted Dissolved Oxygen Concentrations in the La Plata River for the TMDL Scenario

A target load for TBODu is calculated based on a flow, the TBODu concentration at which the dissolved oxygen standard will be meet, and a conversion factor (8.34) that is a used to convert mg/L units to lbs/day (see Appendix C for Conversion Factor Derivation). The target loading capacity is calculated using **Equation 1**. The results are shown in Table 5.1.

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

Table 5.1 Calculation of Target Loads for TBODu

Location	Flow[(a)] (mgd)	TBODu (mg/L)	Conversion Factor	Target Load Capacity (lbs/day)
La Plata River (McDermott Arroyo to Colorado Border)	0.0032	12.09	8.34	0.323

NOTES: (a) Flow is based on field measurements at SWQB station 14 on 6/19/02.

The measured loads for TBODu were similarly calculated using the model-calculated load of 19.54 mg/L. The same conversion factor of 8.34 was used. Results are presented in Table 5.2.

Table 5.2 Calculation of Measured Loads for TBODu

Pollutant sources	Flow[(a)] (mgd)	TBODu (mg/L)	Conversion Factor	Measured Load Capacity (lbs/day)
La Plata River (McDermott Arroyo to Colorado Border)	0.0032	19.54	8.34	0.521

NOTES: (a) Flow is based on field measurements at SWQB station 14 on 6/19/02.

5.4 Waste Load Allocations and Load Allocations

5.4.1 Waste Load Allocation

There are no point source contributions associated with this TMDL. Therefore, the WLA is zero.

5.4.2 Load Allocation

In order to calculate the LA, the WLA and MOS were subtracted from the target capacity (TMDL) following **Equation 6**.

$$WLA + LA + MOS = TMDL \qquad \textbf{(Eq. 3)}$$

The MOS is estimated to be 20% of the target load calculated in Table 5.2. Results are presented in Table 5.3. Additional details on the MOS chosen are presented in Section 5.7 below.

Table 5.3 Calculation of TMDL for TBODu

Location	WLA (lbs/day)	LA (lbs/day)	MOS (20%) (lbs/day)	TMDL (lbs/day)
La Plata River (McDermott Arroyo to Colorado Border)	0	0.258	0.0646	0.323

The extensive data collection and analyses necessary to determine background TBODu loads for the La Plata River watershed 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 calculated target load allocation (Table 5.2) and the measured load (Table 5.3) shown in Table 5.4.

Table 5.4 Calculation of Load Reduction for TBODu

Location	Target Load[(a)] (lbs/day)	Measured Load (lbs/day)	Load Reduction (lb/day)
La Plata River (McDermott Arroyo to Colorado Border)	0.258	0.521	0.263

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

5.5 Identification and Description of Pollutant Sources

Pollutant sources that could contribute to this assessment unit are listed in Table 5.5.

Table 5.5 Pollutant Source Summary for TBODu

Pollutant Sources	Magnitude (Measured Load [lbs/day])	Location	Potential Sources (% from each)
Point: None	0	--------	0%
Nonpoint:	0.521	La Plata River (McDermott Arroyo to Colorado Border)	100% Drought-related Impacts Flow Alterations from Water Diversions Loss of Riparian Vegetation On-site Treatment Systems (septic systems and similar decentralized systems) Range Grazing - Riparian or Upland

5.6 Linkage Between Water Quality and Pollutant Sources

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 D 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 primary sources of dissolved oxygen impairment in the La Plata River are drought-related impacts, flow alterations from water diversions, loss of riparian vegetation, on-site treatment systems (septic systems and similar decentralized systems), and range grazing (riparian or upland). Field notes indicate that this river went dry in places during the 2002 survey year. Upstream activities, such as grazing, water diversions for agricultural use, residential runoff and wastewater systems, clearing of vegetation from streambanks may be contributing to the dissolved oxygen impairment.

Oxygen-consuming constituents from NPS pollution are delivered to the stream during storm events. Sources can include runoff from agricultural fields and leaf litter or plant material from riparian zones. These constituents settle out of the stormwater and become a part of the stream bottom. In slow flowing streams with a high bed-to-channel-volume ratio, large portions of the organic material will settle to the sediment surface and thus increase the TBODu and SOD. A stream impacted by heavy loads of oxygen-consuming pollutants, either natural or man-made, will exhibit low dissolved oxygen concentrations during warm low flow periods (Wood 2001; Thomann et al. 1994; Thomann and Mueller 1987; Congalton 1998; Chapra 1997).

The above-mentioned watershed activities increase nutrient rich and organic enriched substances in the stream. It results in high TBODu and SOD and low dissolved oxygen. Reduction/control of watershed activities associated with nutrient rich and organic enriched substances will result in lower TBODu and SOD and higher dissolved oxygen. The lack of riparian vegetation along many areas of the streambank can lead to increasing water temperatures which will also cause a decrease in the dissolved oxygen saturation potential of the water.

The U.S. Department of Interior Bureau of Reclamation is presently constructing the Animas-La Plata Project, which includes the building of the Ridges Basin Reservoir in the Animas River drainage near Durango, Colorado. The Project pumping station will divert high flows of the Animas River to Ridges Basin Reservoir, an off-stream impoundment, where the stored water may be diverted directly for use or released back to the Animas River during low-flow periods for delivery of use. This Project will potentially affect water quality in the La Plata River in

Colorado and New Mexico downstream of the confluence of the La Plata with Long Hollow, depending on whether any water is eventually diverted from Ridges Basin Reservoir into the La Plata River drainage for use. If so, the La Plata River channel could be used to convey the imported water or to collect return flow from the use of imported water. Importation of Project water thus may potentially increase base flows in the La Plata River during summer months.

5.7 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. For NPS loads, the MOS is estimated to be an addition of **20%** for dissolved oxygen in this case, excluding background. This MOS incorporates several factors:

- Errors in calculating NPS loads

  A level of uncertainty exists in sampling NPSs of pollution. Techniques used for measuring dissolved oxygen concentrations in stream water can lead to inaccuracies in the data and several assumptions had to be made in running the Q2K model. Therefore, a conservative MOS for dissolved oxygen increases the TMDL by **10%.**

- Errors in calculating flow

  Some flow estimates used in the Q2K model were based on a visual measurement at SWQB station 14 during the June sampling run because of the extremely low flow in the river. Instrument and operator error can also lead to inaccuracy in flow measurements. Accordingly, a conservative MOS increases the TMDL by an additional **10%.**

5.8 Consideration of Seasonal Variability

Data was collected during spring, summer, and fall on the La Plata River in order to ensure coverage of any potential seasonal variation in the system. Data used in the calculation/modeling of this TMDL were collected mainly during the summer of 2002. The critical condition for dissolved oxygen is set to low flow during summer months because the lowest dissolved oxygen values were recorded during June 2002 at low flows. This flow condition was determined to have the most severe impacts on the aquatic life use. The low flow period has a reduced nutrient assimilative capability due to less stream flow available for dilution. Increases in stream temperatures resulting in lower dissolved oxygen levels are also common during summer month at low flow conditions coupled with increased air temperatures. If this stream segment is protected during this critical period, then other flow conditions under seasonal variations (e.g. under higher flow with stormwater or spring runoff) are protected as well.

5.9 Future Growth

Estimations of future growth are not anticipated to lead to a significant increase for dissolved oxygen that cannot be controlled with BMP implementation in this watershed. The majority of the land area along the La Plata River (McDermott Arroyo to Colorado Border) is agricultural or rangeland with a low population density and large growth is not anticipated for the area. Therefore, a growth allocation was not included in the load allocation for this TMDL. The Animas-La Plata Reservoir Project discussed in Section 5.6 has the potential to change the water quality of the La Plata River, but exact changes to the condition of the river is unknown at this time. The SWQB is scheduled to perform intensive monitoring of the San Juan Watershed in 2010 and effects of the reservoir will be included in this monitoring.