TNRCC

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One Total Maximum Daily Load for Dissolved Oxygen in Salado Creek

For Segment 1910

Prepared by the:
Strategic Assessment Division, TMDL Team

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Introduction

Section 303(d) of the Clean Water Act requires all states to identify waters that do not meet, or are not expected to meet, applicable water quality standards. For each listed water body that does not meet a standard, states must develop a total maximum daily load (TMDL) for each pollutant that has been identified as contributing to the impairment of water quality in that water body. The Texas Natural Resource Conservation Commission (TNRCC) is responsible for ensuring that TMDLs are developed for impaired surface waters in Texas.

In simple terms, a TMDL is a quantitative plan that determines the amount of a particular pollutant that a water body can receive and still meet its applicable water quality standards. In other words, TMDLs are the best possible estimates of the assimilative capacity of the water body for a pollutant under consideration. A TMDL is commonly expressed as a load, with units of mass per time period, but may also be expressed in other ways. TMDLs must also estimate how much the pollutant load needs to be reduced from current levels in order to achieve water quality standards.

The Total Maximum Daily Load Program, a major component of Texas' statewide watershed management approach, addresses impaired or threatened streams, reservoirs, lakes, bays, and estuaries (water bodies) in or bordering the state of Texas. The primary objective of the TMDL Program is to restore and maintain the beneficial uses (such as drinking water, recreation, support of aquatic life, or fishing) of impaired or threatened water bodies.

Section 303(d) of the Clean Water Act and the U.S. Environmental Protection Agency's (EPA) implementing regulations (40 Code of Federal Regulations, Section 130) describe the statutory and regulatory requirements for acceptable TMDLs. The TNRCC guidance document, *Developing Total Maximum Daily Load Projects in Texas* (GI-250, 1999), further refines the process for Texas. This TMDL document has been prepared in accordance with these guidelines, and is composed of the following six elements:

- Problem Definition
- Endpoint Identification
- Source Analysis
- Linkage Between Endpoint and Sources
- Margin of Safety
- Load Allocation

This TMDL document was prepared by:

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- TMDL Team in the Strategic Assessment Division of the Office of Environmental Policy, Analysis, and Assessment of the Texas Natural Resource Conservation Commission.

It was adopted by the Texas Natural Resource Conservation Commission on October 12, 2001. Upon adoption, the TMDL became part of the state Water Quality Management Plan. The Texas Natural Resource Conservation Commission will use this document in reviewing and making determinations on applications for storm water permits and in its nonpoint source pollution abatement programs.

Background Information

The San Antonio River Basin, covering 4,180 square miles, is located in the south central portion of Texas, as shown in Figure 1. The basin's headwaters are located northwest of the City of San Antonio, and the basin extends southeast to the confluence of the San Antonio and Guadalupe Rivers near San Antonio Bay. The largest population center in the basin is the City of San Antonio area, with a population in excess of 1,000,000.

The San Antonio River Basin encompasses two physiographic regions, the Edwards Plateau in the Great Plains Province and the West Gulf Coastal Plain of the Coastal Plains Province. Historically, the majority of streams in the basin emerged from springs supplied by the Edwards Aquifer, but increased water demands and pumping from the aquifer have curtailed the flow of most springs (SARA, 1992).

The upper portion of the basin is comprised mainly of intermittent hill country streams traversing limestone formations. The greatest population density is located in the upper middle portion of the basin. Below the City of San Antonio, flow in the principal streams is augmented by substantial discharges of treated municipal wastewater effluent. The San Antonio River valley narrows in the lower basin, and channels become more steeply entrenched with high muddy banks and increased water depth (SARA, 1992).

The San Antonio River originates within the north-central area of the City, fed by the tributary Olmos Creek and water pumped from the Edwards Aquifer. The Medina River is the uppermost tributary located within the northwest segment of the basin. The Medina flows west of the City of San Antonio to a confluence with the San Antonio River downstream of the City. Cibolo Creek originates in the upper northern portion of the basin and flows east of the City to a confluence with the San Antonio River in the lower reach of the basin. Leon Creek and Salado Creek originate north of the City and flow along the western and eastern areas, respectively, of the metropolitan area. Leon Creek joins with the Medina prior to its confluence with the San Antonio River. Salado Creek has a confluence with the San Antonio River south of the City.

Salado Creek is located in the upper portion of the San Antonio River Basin with its headwaters in extreme north central Bexar County. Salado Creek runs north to south for 35 miles along the north and east side of the City of San Antonio through the San Antonio International Airport and Fort Sam Houston. Salado Creek joins the San Antonio River south of the City between Losoya and Elmendorf. The Salado Creek watershed is 218 square miles in size. The upper portion of the watershed is largely undeveloped and the terrain is characterized by limestone hills and sparse vegetation typical of the Texas Hill Country. Dense urban development is located in the lower portion of the Salado Creek watershed. The upper portion of Salado Creek is normally dry except during rain events and provides recharge to the Edwards Aquifer. The Salado Creek watershed is depicted in Figure 2.

Problem Definition

Salado Creek is identified as Segment 1910 in the Texas Surface Water Quality Standards (TSWQS). The uses designated for Salado Creek are Contact Recreation, High Aquatic Life, Public Water Supply, and Aquifer Protection. The site-specific water quality criteria necessary to support the designated uses for Salado Creek in accordance with the TSWQS are presented in the following table.

CONSTITUENT	WATER QUALITY CRITERION
Chloride	140 mg/L
Sulfate	200 mg/L
Total Dissolved Solids	600 mg/L
Dissolved Oxygen (1)	5.0 mg/L
pH Range	6.5 - 9.0 Standard Units
Fecal Coliform Bacteria	200 # /100 ml
Temperature	90 Degrees Fahrenheit

Notes: (1) 24-Hour Average

Water quality in Salado Creek is monitored by the San Antonio River Authority, the TNRCC, the US Geological Survey, and others. The TNRCC uses this water quality data to assess water quality conditions in Salado Creek for compliance with the TSWQS. The water quality assessments performed by the TNRCC are in accordance with procedures set forth in *Guidance* *for Screening and Assessing Texas Surface and Finished Drinking Water Quality Data* (TNRCC, 2000).

303(d) Listings

Salado Creek was included in the 1998, 1999, and the draft 2000 303(d) lists for the State of Texas based upon the assessment of water quality data. The water quality problems identified in Salado Creek are low dissolved oxygen concentrations and elevated bacterial levels. This TMDL addresses only the low dissolved oxygen concentrations which have been observed in Salado Creek.

The 1998 303(d) list contained the following entry for Salado Creek:

> Dissolved oxygen concentrations are sometimes lower than the standard established to assure optimum habitat conditions for aquatic life in a 2-mile portion from 1 mile downstream of Rigsby Avenue to Southcross Boulevard, and in a 5-mile portion from NE Loop 410 to Pershing Road.

The reach of Salado Creek between Rigsby Avenue and Southcross Boulevard was assessed with data from three monitoring stations. Seventeen dissolved oxygen measurements were made at these three stations and five of the measurements (29%) were below the screening criteria. The reach of Salado Creek between NE Loop 410 and Pershing Road was assessed with data from three monitoring stations. Fifty one dissolved oxygen measurements were made at these three stations and six of the measurements (11.8%) were below the screening criteria.

The 1999 and draft 2000 303(d) list contained the following entry for Salado Creek:

> In 1.25 miles near SH 368, dissolved oxygen concentrations are sometimes lower than the criterion established to assure optimum conditions for aquatic life, and are occasionally lower than the criterion in short portions near NE Loop 410, Pletz Park, and MLK Park (a total of 5.5 miles).

In the portion of Salado Creek around SH 368, a total of 64 dissolved oxygen measurements were made. Eighteen of the 64 dissolved oxygen measurements (28%) were below the screening criteria. The mean value of the dissolved oxygen measurements which were below the screening criteria in this portion of Salado Creek was 4.08 mg/L. In the portion of Salado Creek around NE Loop 410, Pletz Park, and MLK Park, a total of 240 dissolved oxygen measurements were made. Fifty of the 240 dissolved oxygen measurements (21%) were below the screening criteria. The mean value of the dissolved oxygen measurements which were below the screening criteria in this portion of Salado Creek was 4.03 mg/L.

The dissolved oxygen data from Salado Creek used by the TNRCC to evaluate compliance with applicable water quality standards were predominately obtained from grab samples. Grab samples are individual samples of water collected from the creek and represent the water quality conditions that exist at the specific time the sample was collected. The dissolved oxygen criteria specified in the state water quality standards, however, is based upon the average conditions that should exist over a 24-hour period. Comparing instantaneous dissolved oxygen levels obtained from grab samples to 24-hour average levels specified in the water quality standards introduces some uncertainty into the water quality assessment process. Grab sample dissolved oxygen data which falls below the criterion is considered to be an indication of a possible water quality problem warranting further evaluation.

Additional Water Quality Assessments

The TMDL project for Salado Creek evaluated the water quality data used by the TNRCC as well as additional water quality data available from Salado Creek. This additional water quality assessment was performed to further define water quality conditions in Salado Creek and guide the data collection and modeling to be conducted under the TMDL project. The analysis conducted by the TMDL project identified three reaches, positioned within the lower segment of Salado Creek, as potential problem reaches:

- above Loop 410 to Eisenhauer Road, a distance of approximately 2 miles;
- a short reach from Pletz Park to Gembler Road, covering a distance of approximately 0.5 miles; and,
- the reach extending from MLK Park to Rigsby Avenue.

The data used to perform these assessments were obtained from grab samples collected from Salado Creek. As stated above, comparing instantaneous dissolved oxygen levels obtained from grab samples to 24-hour average levels specified in the water quality standards introduces some uncertainty into the water quality assessment process. Grab sample dissolved oxygen data which falls below the criterion is considered to be an indication of a possible water quality problem warranting further evaluation.

USGS Data from Loop 13

The most thorough representation of the extant water quality condition in Salado Creek is provided by the extensive data base available at the USGS monitoring station at Loop 13. This station monitors dissolved oxygen on a continuous basis and thus allows a daily average dissolved oxygen concentration to be calculated. Thirty four mean daily dissolved oxygen values measured at stream flow rates above the minimum specified for evaluating compliance with state water quality standards were below the segment criteria. These 34 values represent only 1% of the total number of observations obtained over a ten-year period. Ten of the 34 values were only 0.3 mg/l or less below the 5.0 mg/l criterion, representing only minimal evidence of a contravention. The rate of non-compliance demonstrated in this database is not sufficient to result in an impairment of designated uses under the state water quality standards. It is however, an indication of a potential problem that warrants further evaluation.

Non-Steady State Flow Conditions

Of the 34 daily average dissolved oxygen values from the Loop 13 monitoring stations which were below the segment criteria, two appeared to be associated with steady-state conditions in the receiving stream. The remaining 32 values appeared to be associated with nonsteady-state conditions in the stream. All of the nonsteady-state contraventions were encountered with relatively small flows, with the maximum mean daily flow observed at 69 cfs for this data set. Therefore, the contraventions under nonsteady-state conditions appeared to be associated with relatively small or localized storm events that produced washoff of pollutants from only a portion of the watershed, without the benefit of large volumes of flushing runoff that would be produced by a larger storm. The rate of non-compliance under non-steady state conditions is not sufficient to result in an impairment of designated uses under the state water quality standards. It is however, an indication of a potential problem that warrants further evaluation.

Separate from the USGS data base at Loop 13, there are occasional incidences in the historical data base of dissolved oxygen below 5.0 mg/l under nonsteady state conditions. However, these incidences are comprised of instantaneous dissolved oxygen measurements. There is no data that indicates a systematic problem throughout the study segment with mean daily dissolved oxygen under nonsteady state conditions. This assessment is further evaluated in the TMDL modeling exercises presented below.

Endpoint Identification

Dissolved oxygen, in this context, is not a pollutant, rather it is an indicator parameter for water quality. The pollutant of concern is the material that exerts a demand upon the instream dissolved oxygen resources. In this case, it was postulated that carbonaceous material (as represented by BOD_5) and nitrogenous material (as represented by ammonia nitrogen) would be the pollutants that were likely responsible for oxygen demand in the study segment.

The desired target, or endpoint, is compliance with Texas Water Quality Standards (TNRCC, 1995). For Salado Creek, therefore, the target is maintenance of a mean daily dissolved oxygen concentration of 5.0 mg/l. Associated with the mean criterion is a daily instantaneous minimum criterion of 4.0 mg/l.

Source Analysis

Historically, there have been no permitted municipal or industrial waste water point source discharges into Salado Creek. All constituent loadings were attributable to storm water runoff and non-point sources. Salado Creek is located within the city limits of the City of San Antonio. Storm water discharges from the City of San Antonio are regulated under the Phase I NPDES Storm Water Permit program.

The San Antonio Water System (SAWS) began discharging reclaimed water into Salado Creek in March of 2001 under a permit issued by the TNRCC (Permit No. 10137, Outfall 004). The reclaimed water is treated domestic wastewater with a flow limit of 3.0 MGD and effluent limits of 10 mg/l of BOD_5 , 2 mg/l of NH_3-N, and 5.0 mg/l dissolved oxygen. The reclaimed water is being discharged into Salado Creek to augment flows in the creek.

Land use for Salado Creek has been obtained using the Anderson Level I land use classification system. The total land area was estimated to be 52,777 acres. The predominant land use classification is urban land, estimated at 30,370 acres, covering approximately 57% of the watershed. The next largest land use classification is agricultural land, estimated to be 14,684 acres (28%). The majority of the agricultural land is located in the Rosillo Creek subwatershed which enters Salado Creek in its lowermost point, downstream of the portions of Salado Creek which have been identified as having low dissolved oxygen concentrations. If the land use areas of the Rosillo Creek subwatershed are not considered, the urban land use category would represent approximately 73% of the watershed.

For the purposes of water quality modeling, it was assumed that urban land uses in the Salado Creek watershed have a 50% level of impervious cover. Thus, approximately 29% of the watershed is impervious, or approximately 36% of the watershed above the Rosillo Creek subwatershed is impervious.

Linkage Between Sources and Receiving Water

Dissolved oxygen, in this context is not a pollutant, rather it is an indicator parameter for water quality. Instead, the constituents of concern is the materials which exert a demand upon the instream dissolved oxygen resources. In this case, it was postulated that organic material (as represented by BOD) and nitrogenous material (as represented by organic and ammonia nitrogen) would be the pollutants that were likely responsible for oxygen demand in the study segment.

Since the dissolved oxygen problems are predominantly steady-state, the analytical approach focused upon steady-state, low-flow, warm-weather conditions in the watercourse. The QUAL-TX model was applied to simulate water quality under steady-state conditions. The focus of the modeling is on the SAWS discharge, background loadings of pollutant materials, the role of sediment oxygen demand, and other factors. With this approach, it is assumed that development of TMDLs to satisfy the steady-state condition would also likely result in improvements under nonsteady-state conditions.

Additionally, since there exists some indication of dissolved oxygen problems under nonsteady-state conditions, analysis of that scenario is also included. For that aspect, a watershed-receiving stream model was applied to simulate nonpoint source loadings from the watershed and the receiving stream under quasi-dynamic water quality conditions.

To support the modeling analysis, two types of water quality data collection activities were conducted. First, baseline water quality conditions were determined to identify dissolved oxygen and pollutant concentrations along the study reach under steady-state flow regimes. This requirement was met by analysis of historical data, supplemented by conducting baseline surveys with sampling at several stations positioned at strategic locations along the stream. In addition, runoff-related water quality conditions were examined to determine dissolved oxygen and pollutant concentrations under nonsteady-state flow regimes. This type of information was provided by available historical data and by stormwater sampling at selected stations along Salado Creek.

Steady State Analysis

The calibration exercise addressed application of QUAL-TX under steady-state low flow conditions. The most comprehensive data sets available for support of the steady-state calibration are the low flow baseline sampling surveys conducted by SARA in 1999. For the present study, results from the sampling survey of 7-8 June 1999 were employed for the calibration effort. This survey was conducted under low flow conditions in the receiving stream. The measured flow at the lower USGS station at Loop 13 was 3.1 cfs. The flow recorded at the USGS station at Loop 410 NE, the headwater flow in the model segmentation, was 0.0 cfs. For the baseline condition, the SAWS discharge was not present and storm-related runoff does not occur, so flow in the stream is derived from tributary inflow and groundwater exfiltration. No actual measurements of tributary flow were available for the survey, so tributary inflow was estimated at 0.5 cfs from Beitel Creek, 0.5 cfs from Walzem Creek, 0.5 cfs from the unnamed tributary in J Street Park, and 1.6 cfs from groundwater inflow. The existence of groundwater inflow was documented during flow measurements conducted for the present study in conjunction with the baseline sampling surveys. It was observed that the stream gains significant flow in a short reach beginning near Pershing Road at Fort Sam Houston. At one time, there was an uncapped free-flowing artesian well near this location that fed the stream. The well has been capped, but it appears that the artesian flow continues to feed the stream. The flow does exhibit some correspondence to water level in the Edward's Aquifer. For the June 1999 survey, the exfiltration has been estimated at 1.6 cfs, as described above. For comparison, exfiltration was estimated to be approximately 6.5 cfs for the April 1999 survey and 10 cfs for the February 1999 survey.

The June 1999 data set was characterized by low flow conditions and warm temperatures. Oxygen-demanding material, as measured by BOD_5, was low, as was ammonia nitrogen.

Dissolved oxygen throughout the study reach was above 5.0 mg/l, with the lowest mean value (5.78 mg/l) observed at Loop 13.

Results of the calibration simulation of the June 1999 baseline data set are displayed in Figure 3. Predicted dissolved oxygen is in general conformance with observed concentrations. The minimum mean dissolved oxygen value of 5.78 mg/l observed at the Loop 13 station is well replicated, and a sag is also predicted for the pooled area in the vicinity of Rigsby Avenue. Simulated dissolved oxygen is below the observed mean values in the middle reaches, which is a possible indication that additional photosynthesis is occurring.
The most significant parameters that affect the predicted dissolved oxygen are the hydraulic coefficients, the sediment oxygen demand, and the chlorophyll-a. The relatively low concentrations of BOD_5 and ammonia-nitrogen and the attendant decay rates also affect the results, but to a lesser extent.

Sensitivity analysis for the calibration exercise entailed adjustment of the sediment oxygen demand, chlorophyll-a, assumed influent BOD5, and BOD decay rate, at a level of plus or minus 50 percent.

Model calibration is typically followed by verification exercises. In the verification process, the calibrated model is applied to an independent stream quality data set, preferably collected under a different set of environmental conditions. If the predicted dissolved oxygen appears to be reasonable, the model is deemed to be "verified".

Another one of the baseline data sets collected by the SARA in conjunction with the present study was used for model verification. The data set collected 8-9 February 1999 was selected. This data set represented relatively cool weather conditions, compared to the 7-8 June 1999 data set that was used for calibration.

The February survey was conducted under typical low flow conditions in the receiving stream. The measured flow at the lower USGS station at Loop 13 was 13.4 cfs. The flow recorded at the USGS station at Loop 410 NE, the headwater flow in the model segmentation, was 0.08 cfs. Measurements of tributary flow were available that indicated flow of 0.0 cfs in Beitel Creek, 0.5 cfs in Walzem Creek, and approximately 10 cfs from groundwater inflow.

The February 1999 data set was characterized by typical low flow conditions and relatively cool temperatures. As with the June 1999 data set, low concentrations of BOD_5 and ammonia nitrogen were observed. Dissolved oxygen throughout the study reach was above 5.0 mg/l, with a mean value of 7.8 mg/l observed at Loop 13.

Results of simulation of the February 1999 baseline data set are displayed in Figure 4. Predicted dissolved oxygen exhibits conformance with observed conditions. For the present study, then, the model can be assumed to be verified.

The calibration and verification exercises demonstrated that dissolved oxygen in Salado Creek is not dominated by loadings of carbonaceous or nitrogenous material. This is consistent with the fact that there were no point source discharges of oxygen-demanding material present at the time of the data collection activities.

Instead, it appears that dissolved oxygen in Salado Creek is affected principally by hydraulics, sediment oxygen demand, and photosynthesis. The extant hydraulics are attributable to the unique physiographic and hydrographic characteristics of the stream channel, i.e., the variable depths and widths, and the limited sources of inflow. To a certain extent, the sediment oxygen demand and, to a lesser extent, photosynthesis, are linked to the introduction of nonpoint source loadings associated with stormwater runoff events. Nonpoint source loadings of organic material that enter the stream during a runoff event are, for the most part, conveyed downstream out of the study segment. However, a portion of the introduced loading can be expected to settle out of the water column and be deposited on the stream channel bottom, particularly in regions with reduced velocity. The material that is deposited can ultimately exert an effect on the water column as sediment oxygen demand. In the same manner, loadings of nutrient material can be incorporated into the benthal material for support of periphyton growth. The QUAL-TX model does not contain a mathematical linkage of nonpoint source loadings introduced under nonsteady state, stormwater runoff conditions and the sediment oxygen demand or photosynthesis affect that exists under steady-state conditions. Therefore, this phenomenon can be described in general terms but can not be treated analytically.

Nonsteady State Analysis

Modeling exercises were also conducted to evaluate nonsteady state conditions in the receiving stream. The BASINS modeling system was obtained from EPA and applied to the Salado Creek study area. Specifically, the NPSM/HSPF model, one of the components of the BASINS system, was applied to the study area. Hydrologic calibration of the model was accomplished using historical precipitation records and streamflow recorded at the USGS gaging station located near the lower end of the study area at Loop 13. A multi-year long term simulation was employed for calibration, along with detailed examination of discrete storm events. The hydrologic calibration illustrated the sensitivity of the model output to various algorithm parameters, and most importantly, to precipitation itself.

The next step in the nonsteady-state analysis was calibration of the watershed mass loading using NPSM. This was accomplished using limited data for runoff concentration and streamflow. For the present analysis, washoff of BOD from the land surface was simulated using the algorithms incorporated within the model. Algorithm parameters were adjusted in order to obtain concentrations of BOD in runoff consistent with the limited available data base. The model was employed to calculate mass loadings of BOD, in terms of both concentration and load, from each subwatershed delineated in the study area for two example storm events that had at least minimal water quality data available.

NPSM was next applied for modeling of the receiving stream and its response to mass loadings. The NPSM model was executed for simulation of a three-year period of precipitation, namely, 1996-1999. The modeling results did not indicate the existence of dissolved oxygen problems in the receiving stream under nonsteady-state conditions.

As was the case with the steady-state analysis, the results for nonsteady-state conditions are consistent with the historical data base. The historical USGS data base for Loop 13 indicated only occassional dissolved oxygen problems associated with nonsteady-state conditions. In addition, the problems appeared to be specifically associated with relatively small, non-flushing storm runoff events that introduced pollutant loadings to the receiving stream. The magnitude and frequency of occurrence of the dissolved oxygen problems under these nonsteady-state conditions was not sufficient to constitute a significant water quality problem under TNRCC screening criteria.

Margin of Safety

As with all mathematical modeling exercises, there is a certain amount of uncertainty in the determination of assimilative capacity for Salado Creek. This analysis includes an implicit margin of safety that is significant but is not quantifiable. The implicit margin of safety is derived from two major aspects of the technical analysis.

First, the analysis was based upon a large amount of water quality data. An extensive dissolved oxygen data base was available from the USGS. In addition, the historical data base was supplemented by baseline and stormwater data collected in conjunction with the present study. The availability and the analysis of a comprehensive data base contributes to the minimization of the uncertainty in the analysis.

Second, the QUAL-TX model that was used in the analysis was applied in a conservative manner. For the present analysis, the calibration of the model was such that predicted dissolved oxygen was generally lower than observed dissolved oxygen over most of the study segment. Therefore, it can be assumed that the model predictions are environmentally conservative. This margin of safety was incorporated into the analysis through specification of input hydraulic and kinetic parameters that provided conservative results.

Pollutant Load Allocation

For the present analysis, a determination of assimilative capacity of the receiving stream was required. The assimilative capacity is the constituent mass load that can be introduced into the stream that will still allow the stream to maintain compliance with an applicable criterion or standard. Definition of this mass load is not necessarily a straightforward process, since it will be affected by the point of introduction, the temperature, and the underlying flow condition.

In accordance with the problem definition for Salado Creek, the assimilative capacity would require definition principally for low flow conditions. The calibrated and verified QUAL-TX model was applied to the receiving stream for determination of assimilative capacity, as described below.

For the low flow scenario, a specific flow condition should be specified for analysis with the model. The seven-day, two-year low flow (7Q2) is commonly applied by the TNRCC for waste load analysis, in accordance with Texas Surface Water Quality Standards (TNRCC, 1995), and this flow was employed for the low flow condition. The TNRCC defines the 7Q2 for Salado Creek, Segment 1910, as 0.1 cfs at USGS St. 08178700 at Loop 410 NE and 9.4 cfs at USGS St. 08178800 at Loop 13.

The QUAL-TX model was exercised for the 7Q2 flow conditions and summer temperatures which should constitute the worst-case scenario for dissolved oxygen in the receiving stream. The critical temperature was set at 29.4^{0}C, which was determined by the TNRCC from analysis of the historical temperature data. At the low flow regime, nonpoint source runoff loads are introduced into the receiving stream via the headwater inflow, tributary inflow, and groundwater inflow. Point source loads are introduced into the receiving stream via the SAWS wastewater discharge. The principal tributary streams were assumed to be Beitel Creek and Walzem Creek, both located in the upper reach of the study area, and the unnamed tributary in J Street Park, located in the lower reach.

Existing Conditions

The existing baseline condition represents Salado Creek under critical steady-state conditions, with existing loadings. The existing loadings include the SAWS reclaimed water discharge at full permitted flow. Simulation of dissolved oxygen under the existing baseline conditions with the QUAL-TX model displayed the results shown in Figure 5. The results indicated that dissolved oxygen remains above the minimum stream criterion of 5.0 mg/l throughout the study reach under these critical conditions.

The study reach was subdivided into an upper reach (the reach above Interstate 35) and a lower reach (the reach below Interstate 35) in the loading inventory because of the location of tributary inputs and downstream effects. The loadings associated with the existing baseline condition were calculated for each nonpoint source (headwater, tributaries, and groundwater) and for each point source (the SAWS discharge) as described below:

Reach	Source	Q MGD	Q cfs	BOD mg/L	NH_3 mg/L	BOD lb/d	NH3 lb/d
Upper	Headwater	0.0646	0.1	3	0.1	1.6	0.05
	Beitel Creek	0.646	1.0	3	0.1	16.2	0.5
	Walzem Creek	0.646	1.0	3	0.1	16.2	0.5
	Groundwater	4.07	6.3	3	0.1	101.8	3.4
	SAWS	3.0	4.6	10	2	250.2	50.0
	SUBTOTAL					386.0	54.4
Lower	J St. Trib	0.646	1.0	3	0.1	16.2	0.5
	SUBTOTAL					16.2	0.5
TOTAL						402.2	54.9

The baseline loadings can also be converted to loadings of ultimate oxygen demand (UOD), which describe the amount of oxygen ultimately consumed in response to the constituent loadings. Conversion entails multiplication of BOD_5 loadings by a factor of 2.3 and ammonia nitrogen loadings by a factor of 4.33. With this exercise, sediment oxygen demand (SOD) can also be included as a background source of oxygen demand, since it is a dissolved oxygen sink analogous to oxidation of organics and nitrification. Sediment oxygen demand is converted to ultimate demand by multiplication of the specified rate (prior to any supplementation by sediment deposition) times the area of the stream bed. The ultimate oxygen demand of baseline loadings is shown in the following tabulation:

Reach	Source	Q MGD	UOD from BOD lb/d	UOD from NH_3 lb/d	Total UOD lb/d
Upper	Headwater	0.0646	3.68	0.22	3.90
	Beitel Creek	0.646	37.26	2.16	39.42
	Walzem Creek	0.646	37.26	2.16	39.42
	Groundwater	4.07	234.14	14.72	248.86
	SAWS	3.0	575.46	216.5	791.96
	Background SOD	0	0	0	398.28
	SUBTOTAL		887.8	235.76	1521.84
Lower	J St. Trib	0.646	37.26	2.16	39.42
	Background SOD	0	0	0	720.75
	SUBTOTAL		37.26	2.16	760.17
TOTAL			925.06	237.92	2,282.01

Future Conditions

The future scenario was evaluated by determination of the ultimate assimilative capacity of Salado Creek under critical conditions. Constituent mass loads were systematically increased to a point where predicted dissolved oxygen became noncompliant with the applicable criterion. Specifically, the BOD and ammonia nitrogen concentration of incoming loads were increased until dissolved oxygen dropped to a minimum of 5 mg/l. A spatial extent of noncompliance of approximately 0.5 mile was arbitrarily required for the 23-mile study segment in order to provide a reasonable assurance of substantive noncompliance.

The results of the assimilative capacity run are displayed in Figure 6, which shows predicted dissolved oxygen along the watercourse. The analysis indicated the following loadings to meet the assimilative capacity:

Reach	Source	Q MGD	Q cfs	BOD mg/L	NH_3 mg/L	BOD lb/d	NH3 lb/d
Upper	Headwater	0.0646	0.1	5	0.2	2.7	0.1
	Beitel Creek	0.646	1.0	5	0.2	26.9	1.1
	Walzem Creek	0.646	1.0	5	0.2	26.9	1.1
	Groundwater	4.07	6.3	3	0.1	101.8	3.4
	SAWS	3.0	4.6	10	2	250.2	50.0
	SUBTOTAL					408.5	55.7
Lower	J St. Trib	0.646	1.0	21	0.7	113.1	3.8
	SUBTOTAL					113.1	3.8
TOTAL						521.6	59.5

The allowable loadings can also be presented in terms of ultimate oxygen demand, as shown in the following table:

Reach	Source	Q MGD	UOD from BOD lb/d	UOD from NH_3 lb/d	Total UOD lb/d
Upper	Headwater	0.0646	6.21	0.43	6.64
	Beitel Creek	0.646	61.87	4.76	66.63
	Walzem Creek	0.646	61.87	4.76	66.63
	Groundwater	4.07	234.14	14.72	248.86
	SAWS	3.0	575.46	216.5	791.96
	Background SOD	0	0	0	398.28
	SUBTOTAL		939.55	241.17	1579
Lower	J St. Trib	0.646	260.13	16.45	276.58
	Background SOD	0	0	0	720.75
	SUBTOTAL		260.13	16.45	997.33
TOTAL			1,199.68	257.62	2,576.33

The allocation of the allowable loadings of the constituents of concern to Salado Creek can be determined based upon a comparison of the existing loads and the assimilative capacity of the stream as presented above. The total existing loadings from point sources are 250.2 lb/d of BOD and 50.0 lb/d of ammonia nitrogen. The total existing loadings from nonpoint sources are 152 lb/d of BOD and 4.95 lb/d of ammonia nitrogen. Subtracting the existing loadings from the assimilative capacity of the stream yields the excess capacity of Salado Creek to assimilate constituent loadings. This calculation results in an excess capacity of 119.4 lb/d of BOD and 4.55 lb/d of ammonia nitrogen. The allocation of constituent loadings to Salado Creek are summarized as follows:

Source	**BOD** lb/d	**NH3** lb/d
Point	250.2	50.0
Nonpoint	152	4.95
Excess Capacity	119.4	4.55
TOTAL	521.6	59.5

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TNRCC, 1999b. State of Texas 1999 Clean Water Act Section 303(d) List and Schedule for Development of Total Maximum Daily Loads. SFR-58. Austin, TX: TNRCC.

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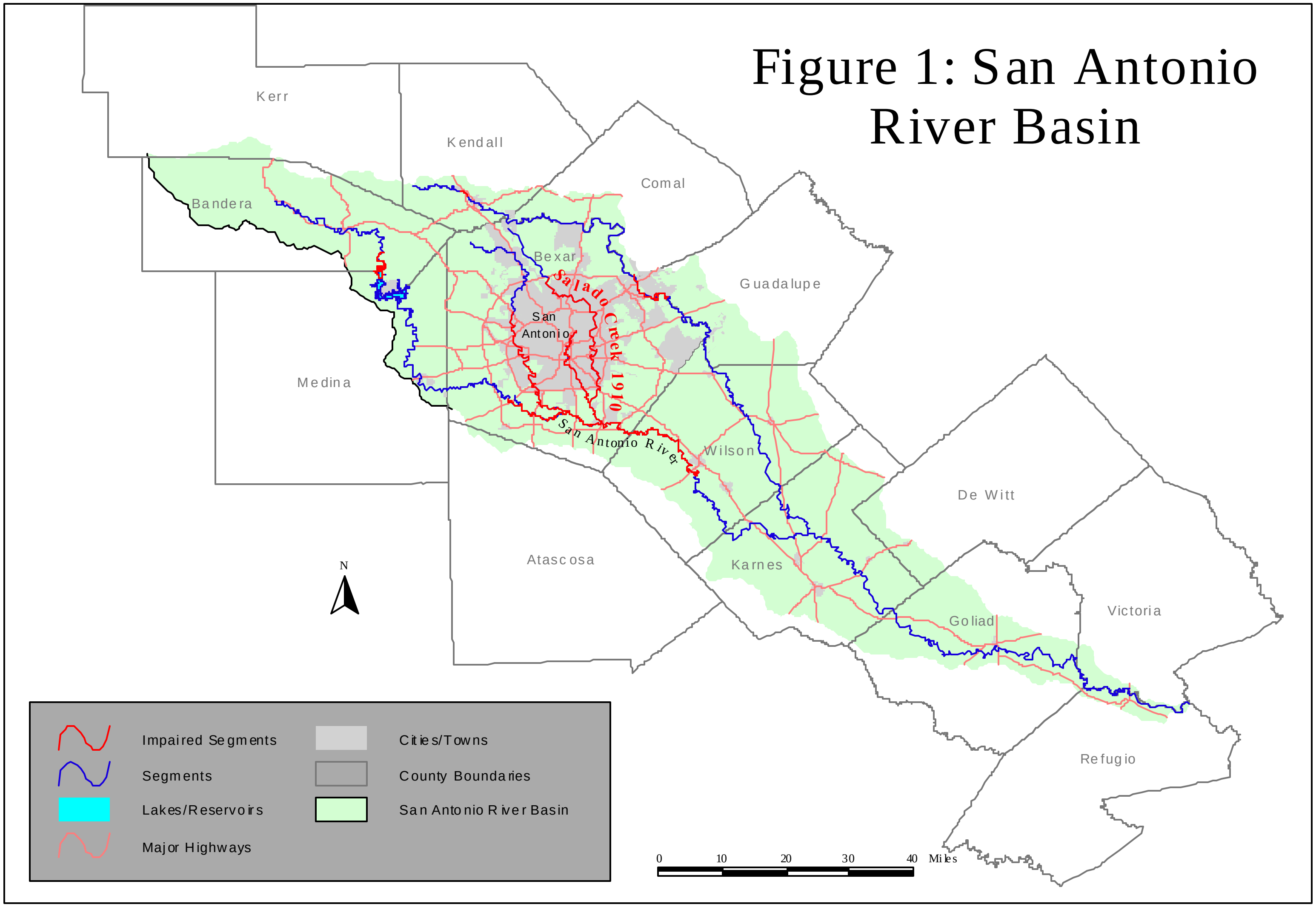


Figure 1: San Antonio River Basin
Kerr
Kendall
Comal
Bandera
Bexar
Guadalupe
San Antonio
Salado Creek 1910
Medina
San Antonio River
Wilson
De Witt
Atascosa
Karnes
Goliad
Victoria
Refugio
N
Impaired Segments
Segments
Lakes/Reservoirs
Major Highways
Cities/Towns
County Boundaries
San Antonio River Basin
0
10
20
30
40
Miles

Figure 2: Salado Creek Watershed

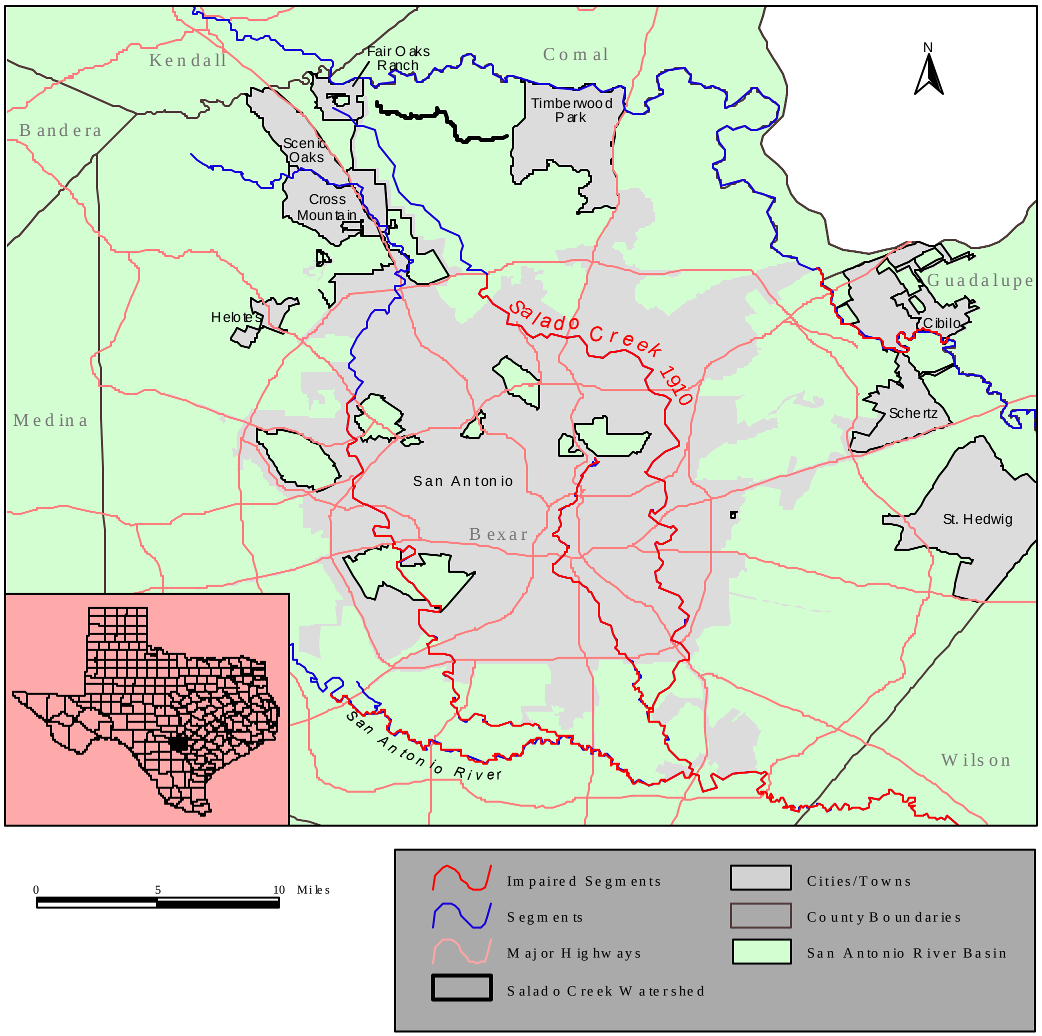
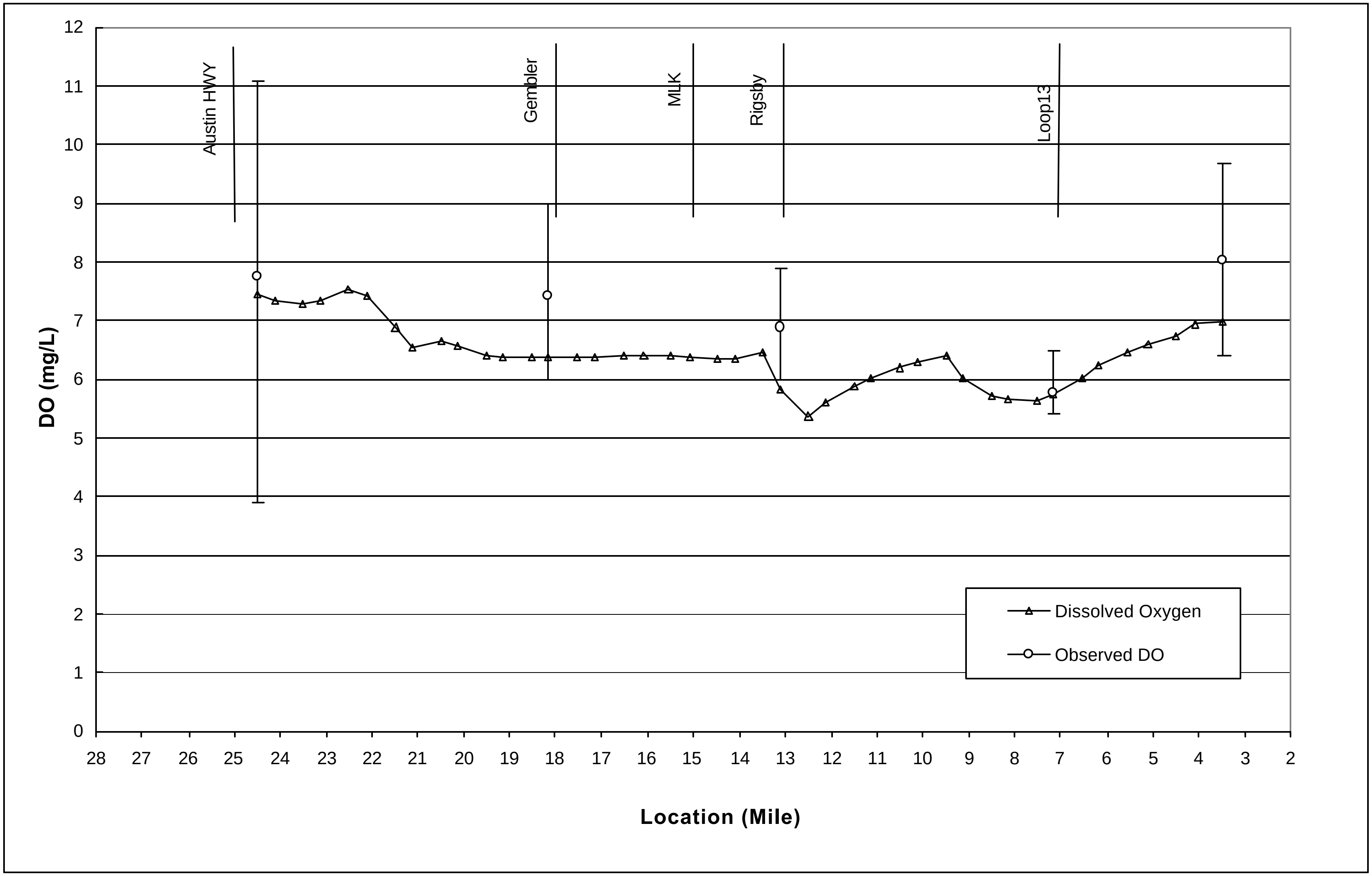


Figure 3 Predicted Dissolved Oxygen For Salado Creek, 8-9 June 99 Calibration



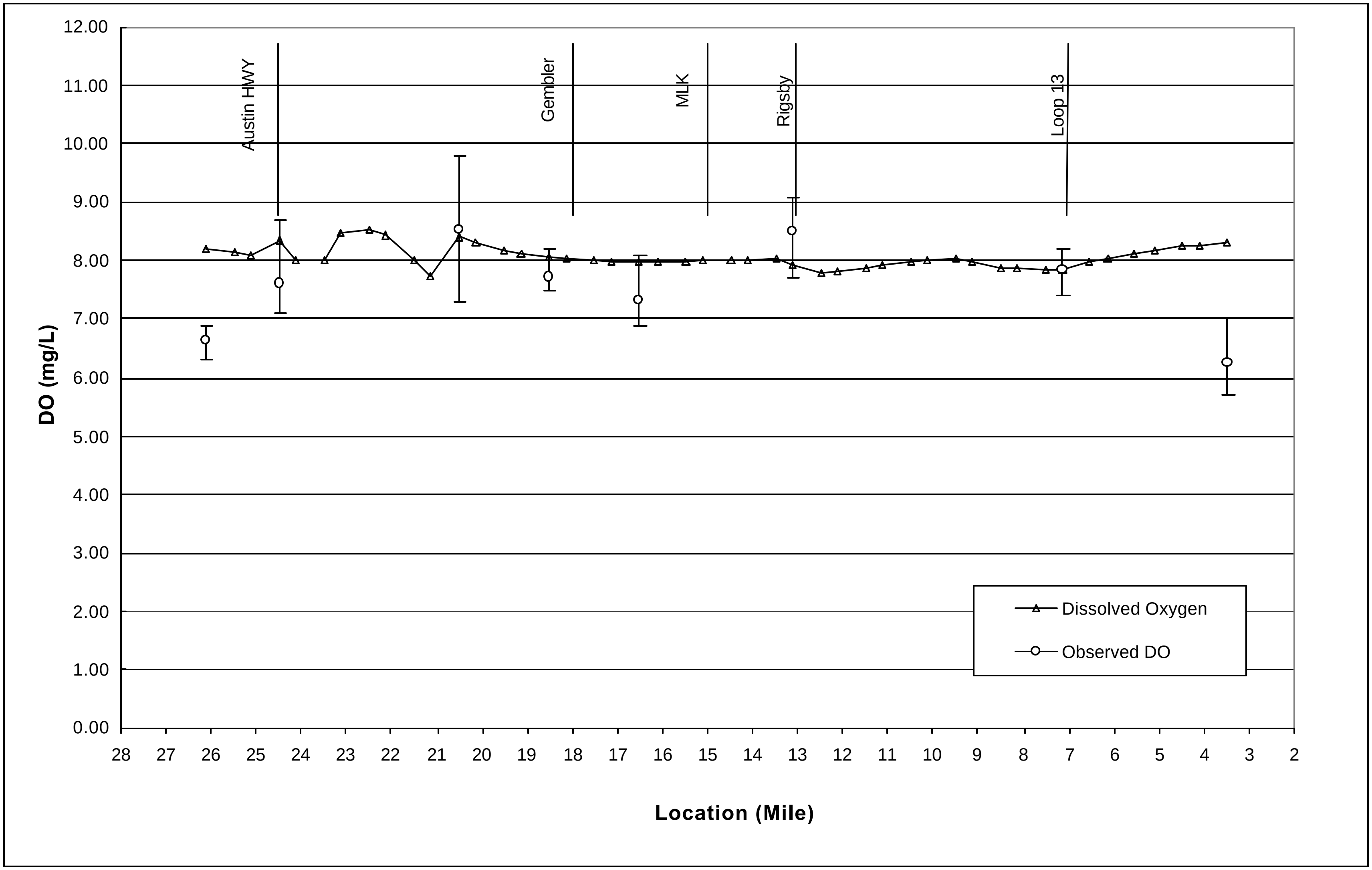


Figure 4 Predicted Dissolved Oxygen For Salado Creek, 8 February 99 Verification

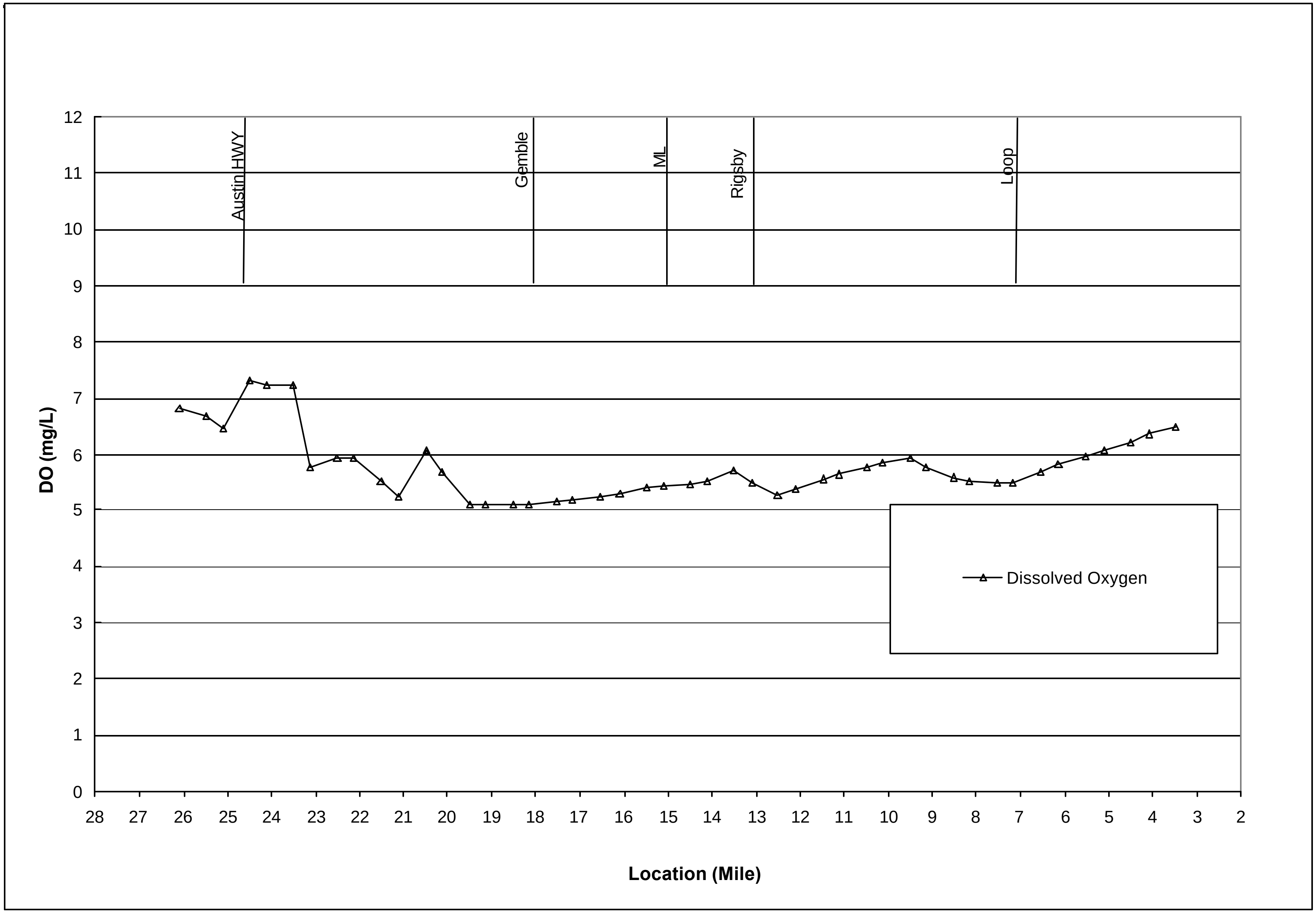


Figure 5 Baseline Loading

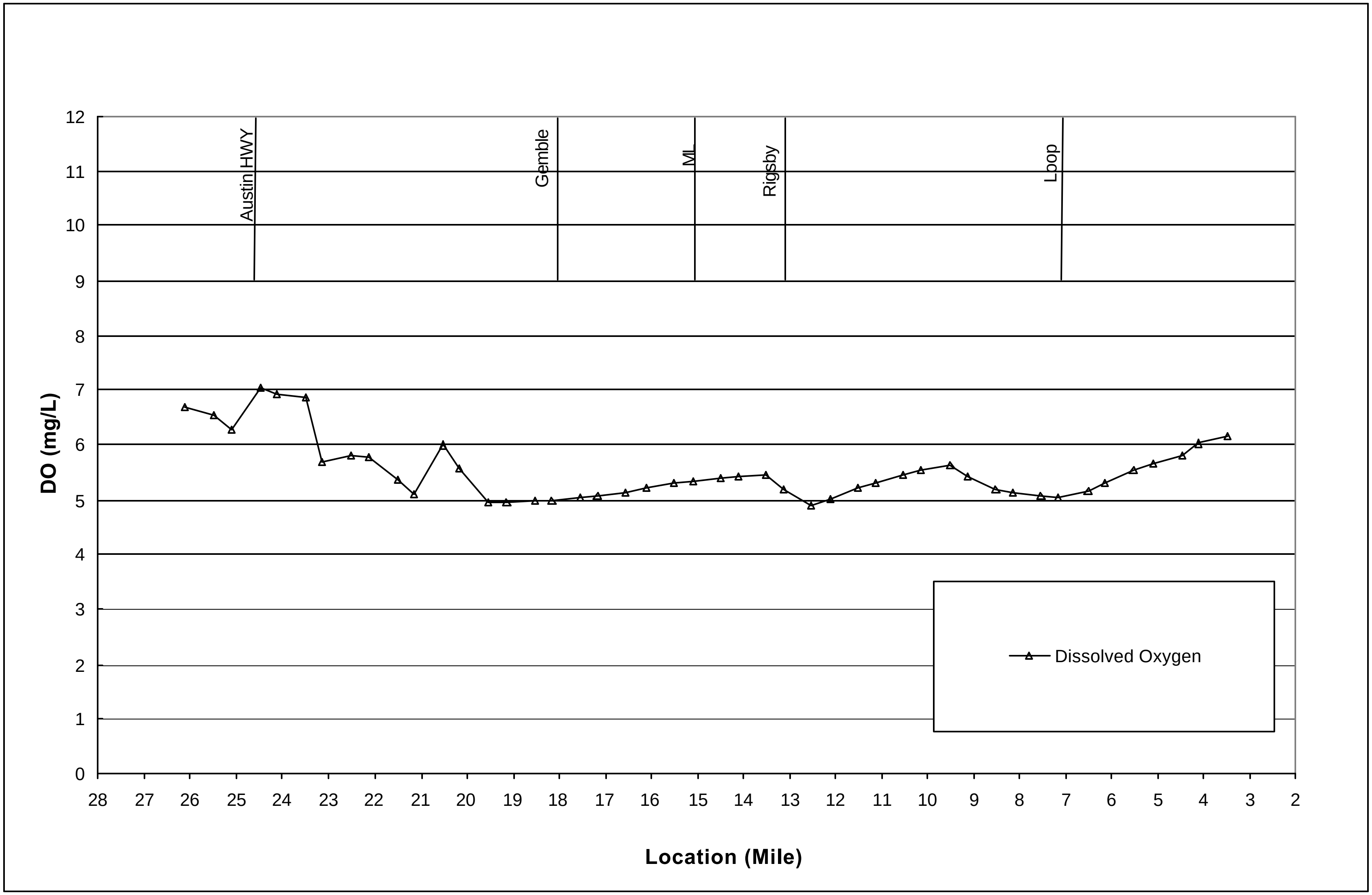


Figure 6 Assimilative Capacity