Cibolo Creek
Water Quality Monitoring and Modeling

Prepared for:

City of Boerne

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Executive Summary

ES.1 Background

The purpose of the study is to understand current and potential water quality conditions in Cibolo Creek, particularly with regard to the City of Boerne's permitted wastewater treatment plant (WWTP) discharge into Cibolo Creek. For this project two major tasks were completed: 1) twelve months of stream monitoring of flow and water quality in Cibolo Creek and the WWTP effluent and 2) nutrient (nitrogen and phosphorus) modeling of Cibolo Creek.

ES.1.1 Water Quality Standards

The Texas Commission on Environmental Quality (TCEQ) sets and implements standards for surface water quality in an effort to improve and maintain the quality of water in the state. The 2000 Texas surface water quality criteria for the upper segment of Cibolo Creek, which includes the reach through Boerne, include criteria for chloride, sulfate, total dissolved solids, dissolved oxygen, pH, bacteria and temperature.

As required under Sections 303(d) and 304(a) of the federal Clean Water Act, the "303(d) List" identifies the water bodies in Texas for which effluent limitations are not stringent enough to implement water quality standards. In the past, Cibolo Creek was listed for dissolved oxygen (DO), but was removed in 2006 because the most recent set of data demonstrated that water quality standards are now met and water quality meets the requirements for delisting. For the 2008 Texas 303(d) list, only the most upstream reach of Cibolo Creek from 2 mi upstream of Highway 87 in Boerne to the confluence of Champee Springs was listed for bacteria. In 2008 this same segment of Cibolo Creek was listed by TCEQ as a "concern" for ammonia, and the portion of Cibolo Creek that flows through Boerne was listed as a "concern" for impaired habitat and orthophosphorus.

Although not regulated by explicit surface water quality standards, nutrients (nitrogen and phosphorus) are of concern to state regulators. Excess nutrients in a water body can cause *eutrophication*. As defined by the United States Geological Survey (USGS), eutrophication is a process whereby water bodies, such as lakes, estuaries, or slow-moving streams receive excess nutrients that stimulate excessive plant growth[1]. The enhanced plant growth, often an algal

[1] USGS, 2009. http://toxics.usgs.gov/definitions/eutrophication.html

bloom, can reduce DO in the water as plant material decomposes and can cause other organisms to die. Nutrients can originate from many point and non-point sources, such as:

- Fertilizers applied to agricultural fields, golf courses, and suburban lawns;
- Erosion of soil containing nutrients;
- Septic systems;
- Atmospheric deposition; and
- Wastewater treatment plant discharges.

While phosphorus can be a catalyst for algal blooms, its presence in water bodies does not pose a direct health threat to humans. In fact, the United States Environmental Protection Agency (EPA) does not regulate the amount of phosphorus in drinking water.

ES.1.2 Wastewater Treatment

In 2004, a WWTP needs assessment was completed by the City of Boerne. The assessment identified the wastewater treatment capacity needs based on population projections over a 20-year planning period. A total wastewater treatment capacity of 3.9 MGD was determined to be needed, as well as an immediate need of 2.4 MGD. As a result, the City of Boerne proceeded with expansion of the existing WWTP to 2.4 MGD and with land acquisition plans for a second WWTP.

In 2005, the City of Boerne submitted a draft TPDES permit application to the TCEQ for approval. The draft permit was submitted based on expanding the existing WWTP to 2.4 MGD with no change to the existing permitted discharge limits, which included limits for carbonaceous biochemical oxygen demand (CBOD), total suspended solids (TSS), ammonia (NH3), and DO. The draft permit issued by TCEQ did not change the limits for CBOD at 10 mg/L, TSS at 15 mg/L, and DO at 5 mg/L as compared to the current permit. The draft permit for the new WWTP imposed a more stringent NH3 limit of 2 mg/L and imposed a new limit for total phosphorus (P) of 0.5 mg/L.

ES.2 Cibolo Creek Monitoring

Water samples were collected by San Antonio River Authority (SARA) staff 15 times between December 2007 and November 2008. Samples were collected from Cibolo Creek at one location upstream of Currey Creek, which receives the WWTP permitted discharge from the

City of Boerne, and at two locations downstream of Currey Creek. A monthly 24-hour composite sample set was collected from the wastewater treatment plant effluent by City of Boerne staff and then picked up by SARA staff on the day of stream monitoring.

For each sampling event, field measurements of temperature, DO, conductivity, and pH were made with calibrated electronic instruments during sample collection at each monitoring location, as described in the QAPP[2] and according to SARA laboratory reports. In addition, a nitrogen suite of NH3, nitrate, and total Kjeldahl nitrogen and biochemical oxygen demand (BOD), orthophosphorus, chlorophyll a, and pheophytin also were laboratory analyzed.

ES.3 Water Quality Modeling

Goals of the modeling portion of the project included analysis of receiving water quality and developing a functional model that could be refined and used as a planning tool for the City of Boerne. The EPA water quality model QUAL2K was applied to Cibolo Creek. The resulting calibrated models simulate concentrations of nutrients in Cibolo Creek with ambient conditions and wastewater treatment loads as inputs by calculating the various mechanisms of nutrient transformations and fluxes.

Two base applications of QUAL2K to Cibolo Creek were developed. The first model application, the Summer 2008 model, was developed because low-flow and high-temperature conditions are typically used for water quality investigations to assess periods when water bodies may be most impaired and aquatic biota most stressed. The second base model application is the Winter 2008 model.

The calibrated Summer 2008 and Winter 2008 models were used to assess the permit requirement of 3 mg/L NH3 concentration and the new requirement of 2 mg/L P for the existing WWTP. The models were also used to evaluate water quality in Cibolo Creek if a new WWTP were constructed on Menger Creek just upstream of the confluence with Cibolo Creek. For the proposed WWTP, water quality criteria of 2 mg/L NH3 and 0.5 mg/L P were examined. Several scenarios were tested using the Summer 2008 and Winter 2008 models.

[2] San Antonio River Basin in Cooperation with the Texas Commission on Environmental Quality, 2008. Amendment #1 to the San Antonio River Basin Clean Rivers Program FY 2008/2009 QAPP, Effective Date: January 25, 2008.

ES.3.1 Modeling Results

For most modeling scenarios, Texas surface water quality standards are met. Simulated stream temperatures remain below Texas surface water quality standards of 90°F, and simulated pH values are within the criterion of 6.5 to 9.0. However, DO concentrations for the summer 2008 scenarios occasionally drop below the 5 mg/L DO criterion. This is not to be unexpected as flows in 2008 were extremely low and several DO concentration values in the stream monitoring data were below 5 mg/L.

Although Cibolo Creek has no P or NH3 criteria based on the Texas surface water quality standards, TCEQ screening levels for nutrients exist. The various simulated scenarios for total P and NH3 concentrations reflect the limits that may be required in a permit for a new WWTP and a permit renewal for the existing WWTP. The results show that within the planned and currently permitted discharge limits, nutrients remain within acceptable levels. This is especially important in Cibolo Creek, which for the most part of 2008 was effluent dominated.

ES.4 Conclusions

Conclusions based on this project include the following.

- The water quality modeling represents a conservative case. The third driest year ever on record was 2008 based on rainfall records in San Antonio from 1871 to 2008. In San Antonio, the recorded rainfall was 13.76 inches.
- Using data collected as part of the project, the calibrated nutrient water quality model represents 2008 summer and winter conditions in Cibolo Creek.
- For most modeling scenarios, Texas surface water quality standards are met, including temperature and pH. However, DO concentrations for the summer 2008 scenarios sometimes drop below the 5 mg/L DO criterion.
- When varying the effluent P concentration at the new WWTP, with or without a 2 mg/L effluent P concentration limit at the existing WWTP, the simulations of 0.5 mg/L, 1 mg/L, and 2 mg/L show that downstream of the WWTP, total P concentrations in Cibolo Creek converge to within 0.5 mg/L of each other. These three scenarios, or total P effluent concentration limits, may not be significantly different from each other.

- Because of the extremely low streamflow conditions of 2008, the current models could not be expected to assess the impacts of nonpoint sources on Cibolo Creek. Typically runoff from precipitation events may exhibit an increase in P runoff associated with sediment movement. However, in 2008 no significant rain events occurred.
- The thriving stand of bald cypress trees downstream of the existing WWTP and the abundant aquatic life present in Cibolo Creek, as noted in the Summer 2008 issue of the TCEQ Water Quality Monitoring and Assessment Section's newsletter, *The Water Monitor*[3], suggest that nutrients remain within acceptable levels even for the drought-situation effluent-dominated streamflow to maintain health in Cibolo Creek.

ES.5 Recommendations

Specific recommendations based on this project include the following.

- The City of Boerne should complete additional scenarios with the calibrated Summer 2008 and Winter 2008 models, depending on TCEQ permit requirements. Continued model refinements and discussions with TCEQ are beneficial for the City of Boerne's long-term WWTP planning.
- The City of Boerne should consider necessary additional scenarios with different water quality criteria and flow regimes as plans for and design of a new WWTP solidify.
- The City of Boerne should develop a calibrated water quality model that better reflects non-drought conditions or at least 7Q2 streamflow of 1.1 ft^3/sec if non-drought streamflow and water quality data are available within WWTP permitting and design deadlines. With a calibrated non-drought condition water quality model, it also would be more feasible to determine the impacts of nonpoint sources of P on Cibolo Creek.

[3] Blair, Michele, 2008. Cibolo Creek – A Success Story, The Water Monitor, TCEQ Water Quality Monitoring and Assessment Section newsletter, Vol. 1, Issue 2, Summer 2008.

- The City of Boerne should resume stream monitoring of Cibolo Creek to capture a better representation of water quality in a non-drought situation if the permitting schedule allows when normal streamflow returns.

Section 1
Introduction

1.1 Purpose of Study

The purpose of the study is to understand current and potential water quality conditions in Cibolo Creek, particularly with regard to the City of Boerne's permitted wastewater treatment plant discharges into Cibolo Creek.

1.2 Agreement with HDR

HDR Engineering, Inc. (HDR) contracted with the City of Boerne to provide consulting services related to stream monitoring and modeling of current and potential water quality conditions in Cibolo Creek. HDR's services were initiated in August 2007 and included the following:

- Obtain and review available water quality data;
- Apply a water quality model to Cibolo Creek for the City; and
- Examine the proposed reduction in allowable ammonia concentration from 3 mg/L to 2 mg/L and the proposed requirement of 0.5 mg/L of total phosphorus.

This report provides the results of these analyses.

Section 2
Water Quality Standards and TPDES Permitting

2.1 Texas Surface Water Quality Standards

In 2000, the Texas Commission on Environmental Quality (TCEQ) adopted proposed amendments to the 1997 surface water quality standards, as codified by rule in the Texas Administrative Code (TAC), Title 30, Chapter 307. For the 2000 standards to be used for federal permitting programs, the EPA must approve them. The EPA has not yet taken action on the entire 2000 standards, so both the 1997 and the approved portions of the 2000 standards are used in federal permitting programs, such as the Texas Pollutant Discharge Elimination (TPDES) program. The 1997 standards remain in effect for those portions of the 2000 standards not acted on by EPA. For non-federal programs, the 2000 standards are in effect unless they have been specifically disapproved by EPA. The *Procedures to Implement the Texas Surface Water Quality Standards*[4] explains how the standards are applied in permitting.

Table 2-1 shows the 2000 surface water quality criteria for Segment 1908, defined as Upper Cibolo Creek from the Missouri-Pacific Railroad Bridge west of Bracken in Comal County to a point 1.5 km (0.9 miles) upstream of the confluence of Champee Springs in Kendall County.[5]

Table 2-1. Current (2000) Texas surface water quality criteria for Segment 1908, Upper Cibolo Creek

Chloride (mg/L)	Sulfate (mg/L)	Total Dissolved Solids (mg/L)	Dissolved Oxygen (mg/L)	pH Range (SU)	Indicator Bacteria (#/100mL)	Temperature (^{o}F)
50	100	600	5.0	6.5-9.0	126/200	90

2.1.1 Texas 303(d) List

As required under Sections 303(d) and 304(a) of the federal Clean Water Act, the "303(d) List" identifies the water bodies in or bordering Texas for which effluent limitations are not stringent enough to implement water quality standards, and for which the associated pollutants

[4] Texas Commission on Environmental Quality, 2003. Procedures to Implement the Texas Surface Water Quality Standards, RG-194.
[5] Texas Commission on Environmental Quality, 2000. Surface Water Quality Standards (updated 2008).

are suitable for measurement by maximum daily load[6]. In addition, the TCEQ develops a schedule identifying Total Maximum Daily Loads (TMDLs) that will be initiated in the next two years for priority impaired waters. Issuance of new permits and permit renewals to discharge into 303(d)-listed water bodies is described in the TCEQ regulatory guidance document *Procedures to Implement the Texas Surface Water Quality Standards*[7].

Table 2-2 shows the 303(d) listings for Segment 1908, Upper Cibolo Creek. The first 303(d) list for Texas was published in 1992. In 1999, dissolved oxygen (DO) and bacteria were identified on the 303(d) list for the first time. In 2006, DO was removed from the list because the most recent set of data demonstrated that water quality standards are now met and water quality meets the requirements for delisting[8]. However, two sub-segments of the upper Cibolo Creek were still listed for bacteria. In 2008, only the most upstream reach of Cibolo Creek from 2 mi upstream of Highway 87 in Boerne to the upper end of Segment 1908 at the confluence of Champee Springs was listed for bacteria. For the Upper Cibolo Creek, Segment 1908, listing, a ranking of "D" has been assigned to indicate that additional data and information will be collected before a TMDL is scheduled.

In 2008 the most upstream reach of Cibolo Creek from 2 mi upstream of Highway 87 in Boerne to the upper end of Segment 1908 was listed by TCEQ as a “concern for water quality based on screening levels” for ammonia. In addition the segment from the confluence with Balcones Creek to approximately 2 mi upstream of Highway 87 in Boerne, which includes the portion of Cibolo Creek that flows through Boerne was listed as a “concern for water quality based on screening levels” for impaired habitat and orthophosphorus[9]. Table 2-3 shows TCEQ nutrient screening levels for 2004[10] and for 2008[11], when updates to the screening levels were made.

[6] Texas Commission on Environmental Quality, 2008. Texas Water Quality Inventory, 303(d) List.
[7] Texas Commission on Environmental Quality, 2003. Procedures to Implement the Texas Surface Water Quality Standards, RG-194.
[8] Texas Commission on Environmental Quality, 2006. Texas Water Bodies and Parameters Removed from the 303(d) List
[9] 2008 Texas Commission on Environmental Quality, 2008. Texas Water Quality Inventory, Water Bodies with Concerns for Use Attainment and Screening Levels.
[10] Texas Commission on Environmental Quality, 2004. Guidance for Assessing Texas Surface and Finished Drinking Water Quality Data, 2004.
[11] Texas Commission on Environmental Quality, 2008. Guidance for Assessing and Reporting Water Quality in Texas, 2008.

Table 2-2. 303(d) listings for Segment 1908, Upper Cibolo Creek

303(d) List Year	*Segment/Area*	*Constituent*	*Category/Priority*
1999[12]	1908[1]	Dissolved Oxygen (DO)[2] and Bacteria[3]	Medium
2000[13]	1908[3]	DO	Medium
2002[14]	1908[3]	DO	5c[4]
2004[15]	1908[3]	DO	5c[4]
2006[16]	1908_01[3], 1908_02[5]	Bacteria	5c[4]
2008	1908_02[5]	Bacteria	5c[4]

[1]From confluence with Balcones Creek to approximately 2 mi upstream of Hwy 87 in Boerne.
[2]In a 2-mile reach southeast of Boerne, dissolved oxygen concentrations are occasionally lower than the standard established to assure optimum conditions for aquatic life.
[3]In a 2-mile reach southeast of Boerne, bacteria levels sometimes exceed the criterion established to assure the safety of contact recreation.
[4]Additional data and information will be collected before a TMDL is scheduled
[5]From approximately 2 mi upstream of Hwy 87 in Boerne to upper end of segment.

2.1.2 Ecoregional Nutrient Criteria

In June 1998, EPA published the National Strategy for Development of Regional Nutrient Criteria. EPA published technical guidance for developing criteria for lakes and reservoirs, rivers and streams, and estuaries and coastal waters and recommended nutrient criteria for most streams and lakes in January 2001. In November 2001, EPA issued a memorandum to the States about planning the development and adoption of nutrient criteria into water quality standards based on ecoregions.

The concept of ecological regions, or ecoregions, is the grouping of areas of similar climate, hydrology, geology, physiography, soils, land use, vegetation, and wildlife. EPA divided the US into 14 Level I ecoregions and 104 Level III ecoregions. Using ecoregions, the EPA has established criteria for total phosphorus and total nitrogen for rivers and streams, lakes and reservoirs, and wetlands. Ecoregion criteria are in-stream concentrations, as opposed to effluent limits for point source discharges. The ecoregion criteria instream concentrations are range from 0.12 to 2.18 mg/L total nitrogen and 0.010 to 0.076 mg/L total phosphorus. Table 2-

[12] Texas Commission on Environmental Quality, 1999. 1999 Clean Water Act Section 303(d) List and Schedule for Development of Total Maximum Daily Loads (TMDLs), SFR-58/99.
[13] Texas Commission on Environmental Quality, 2000. Texas Water Quality Inventory 2000, SFR-050/00.
[14] Texas Commission on Environmental Quality, 2002. State of Texas 2002 Clean Water Act Section 303(d) List.
[15] Texas Commission on Environmental Quality, 2004. State of Texas 2004 Clean Water Act Section 303(d) List.

3 shows ambient water quality criteria recommendations for streams in Ecoregion IV (Great Plains Grass and Shrublands), Subecoregion 30 (Edwards Plateau)[17].

Table 2-3. EPA reference conditions and TCEQ screening level criteria for nutrients

Parameter (mg/L)	EPA Ecoregion 25th Percentile Reference Conditions for Ecoregion IV, Subecoregion 30	TCEQ Screening Levels for Nutrient Parameters	
		2004[1]	2008[2]
Total Phosphorus	0.008	0.8	0.69
Orthophosphorus	-	0.5	0.37
Total Nitrogen	0.55	-	-
Ammonia-Nitrogen	-	0.17	0.33
Nitrate-Nitrogen	-	2.76	1.95
Chlorophyll a	0.0002[3]	0.0116	0.0141

[1] Concern basis: Screening level is exceeded greater than 25% of the time. Number of exceedances per sample size given in guidance document.
[2] Concern basis: Screening level is exceeded greater than 20% of the time using the binomial method, based on the number of exceedances for a given sample size.
[3] Chlorophyll a measured by Spectrophotometric method with acid correction

2.2 City of Boerne's Permitted Effluent Discharge Limits

In 2004, a WWTP needs assessment was completed by the City of Boerne[18] with HDR Engineering as its consultant. The assessment identified the wastewater treatment capacity needs based on population projections over a 20-year planning period. A wastewater treatment capacity of 3.9 MGD was determined to be needed from the projections. The assessment also identified an immediate need of 2.4 MGD. As a result, the City of Boerne proceeded with expansion plans for the existing plant to 2.4 MGD and with land acquisition plans for a second WWTP.

In 2005, the City of Boerne submitted a draft TPDES permit application to the TCEQ for approval. The draft permit was submitted based on expanding the existing plant to 2.4 MGD with no change to the existing permitted discharge limits, which included limits for carbonaceous biochemical oxygen demand (CBOD), total suspended solids (TSS), ammonia (NH3-N), and DO. The draft permit issued by TCEQ did not change the limits for CBOD, TSS, and DO as compared to the current permit. The draft permit imposed a more stringent NH3-N limit of 2

[16] Texas Commission on Environmental Quality, 2006. State of Texas 2006 Clean Water Act Section 303(d) List.
[17] EPA, 2001. Ambient Water Quality Criteria Recommendations, Information Supporting the Development of State and Tribal Nutrient Criteria, Rivers and Streams in Nutrient Ecoregion IV, EPA Office of Water, EPA 822-B-01-013.
[18] City of Boerne, 2007. WWTP Preliminary Process and Site Evaluation, July 3, 2007.

mg/L and imposed a new limit for total phosphorus (P) of 0.5 mg/L. The current TPDES permit for the City of Boerne is #10066001 and has an EPA identification number of TX24465.

Section 3
Stream Monitoring

3.1 Existing Flow and Water Quality Data

The headwaters of Cibolo Creek are located northwest of Boerne in Kendall County. In the early 1970s to protect the City of Boerne from flooding, officials applied for a right to impound Cibolo Creek. The Texas Water Commission granted permission to the City of Boerne in 1972 to construct and maintain a dam and reservoir on Cibolo Creek for municipal purposes to aid in flood control and in 1979 for drinking water use[19]. From Boerne City Lake, Cibolo Creek flows through Boerne. Downstream of the city limit of Boerne, Cibolo Creek flows southeast toward its confluence with the San Antonio River in Karnes County.

The TCEQ has data available through the Storage and Retrieval (STORET) database in the upstream reach of Cibolo Creek from as early as 1973. United States Geological Survey (USGS) also maintains streamflow records on Cibolo Creek, which is imperative for calculating stream loads of water quality constituents from measured concentrations.

Table 3-1 shows the available daily streamflow records on Cibolo Creek for TCEQ-defined Segment 1908 and the period of record for each gage. Currently one streamflow gage measures daily data in the study area, which is the gage at the Cibolo Nature Center near Boerne (USGS ID 8183890). The gage has streamflow discharge records beginning in November 2005. Figures 3-2 and 3-3 show streamflow for the period of record of this gage. Figure 3-2 shows the extremely wet conditions during 2007, while the streamflow shown in Figure 3-3 shows the variation in low flows on Cibolo Creek with flow on the y-axis from 0 to 50 ft^3/s.

Through the course of the study, City of Boerne staff communicated[20] that during very low streamflow, as was experienced in summer 2008, Cibolo Creek does not flow over the Boerne City Dam located downstream of the intersection of Hwy 87 and Hwy 46. This dam is approximately 7.5 ft high and 113 ft wide. Flow just downstream of the dam is the result of numerous springs and tributary flow, and further downstream from the City of Boerne's wastewater treatment effluent permitted discharge.

Water quality is available in the STORET database for several stations in the study area. Table 3-2 summarizes water quality monitoring locations. Figure 3-1 shows the streamflow and

[19] City of Boerne, 2009. http://www.ci.boerne.tx.us/Facilities/BoerneCityLakePark/tabid/394/Default.aspx

surface water quality monitoring stations on Cibolo Creek. Selected water quality data at TCEQ Stations 12853, 12854, and 16702, which are the stations that were also chosen for water quality sampling for this study are shown in Figures 3-3 through 3-7. On these figures, the surface water quality criteria for Segment 1908, Upper Cibolo Creek, is shown if a criterion for that constituent has been defined in the Texas surface water quality standards.

Table 3-1. Daily streamflow monitoring locations on upper Cibolo Creek and corresponding period of record

USGS Station ID	Site Name	Start	End
8183850	Cibolo Ck at IH 10 above Boerne, TX	5/23/1996	5/9/2007
8183890	Cibolo Ck at Cibolo Nature Center near Boerne, TX	11/9/2005	12/18/2008
8183900	Cibolo Ck near Boerne, TX	3/1/1962	12/17/1997
8184000	Cibolo Ck near Bulverde, TX	5/1/1946	11/30/1965
8184500	Cibolo Ck above Bracken, TX	4/1/1946	9/30/1951
8185000	Cibolo Ck at Selma, TX	4/1/1946	12/18/2008

Table 3-2. Existing surface water quality monitoring locations on Cibolo Creek in the project area and its tributaries

Station ID	Site Description
12858	Cibolo Creek at Boerne City Lake Discharge
12857	Cibolo Creek at IH 10 – US 87 NW of Boerne
12856	Cibolo Creek at Sparkling Springs in Boerne
12855	Cibolo Creek at Boerne City Park
12854	Cibolo Creek at Herff Road in Boerne
12853	Cibolo Creek 2.5 mi SE of Boerne
12760	Ranger Creek in Boerne
14207	Ranger Creek 33 m upstream from confluence with Cibolo Creek on south bank
15108	Cibolo Creek at Johns Rd in Boerne, TX
15126	Cibolo Creek immediately downstream of Menger Creek confluence SE of Boerne
16702	Cibolo Creek SE of Boerne at downstream end of City Park in the Nature Preserve 1608 m downstream of SH46

[20] Don Burger, City of Boerne. Personal communication, January 21, 2009.

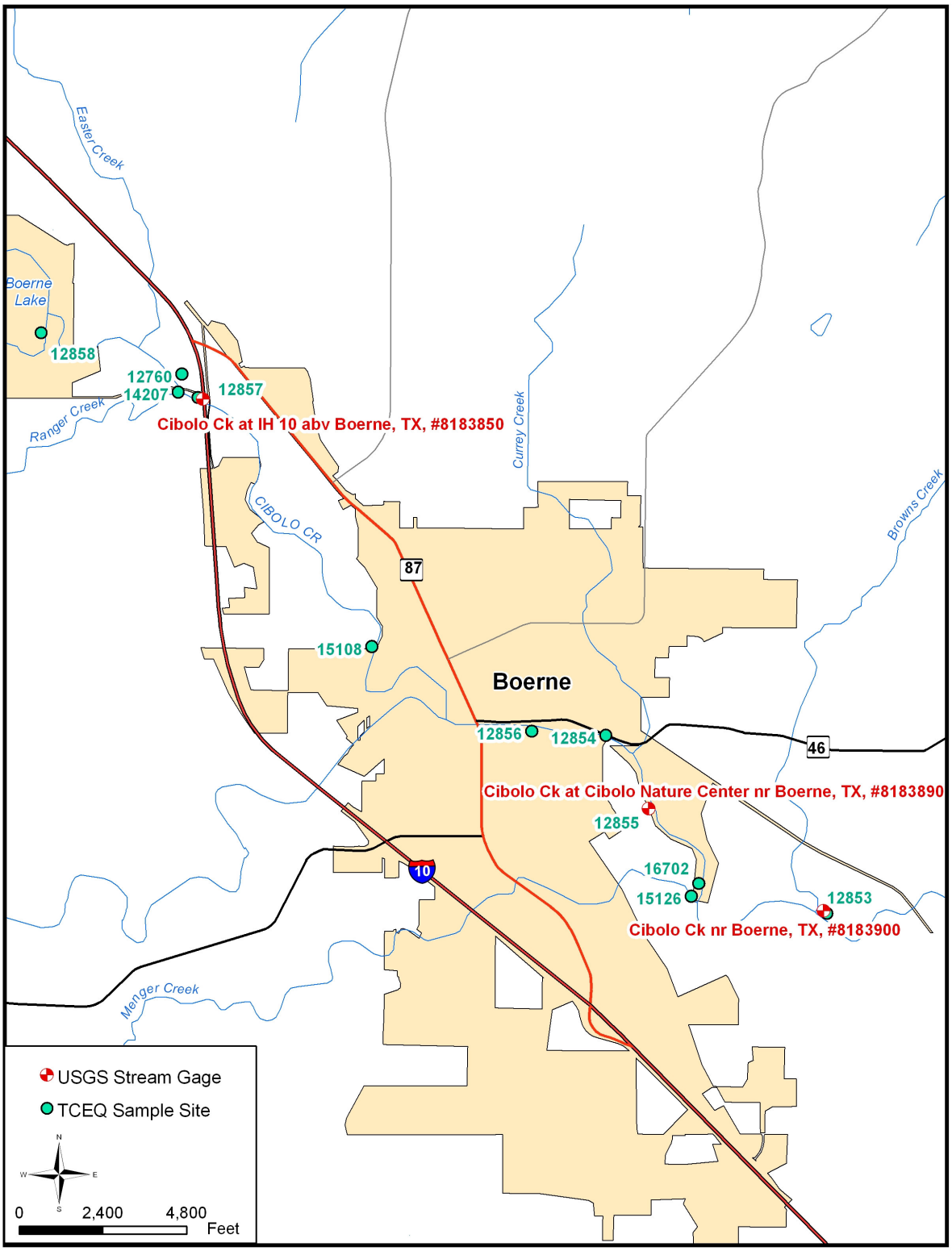


Figure 3-1. Streamflow and surface water quality monitoring stations on Cibolo Creek

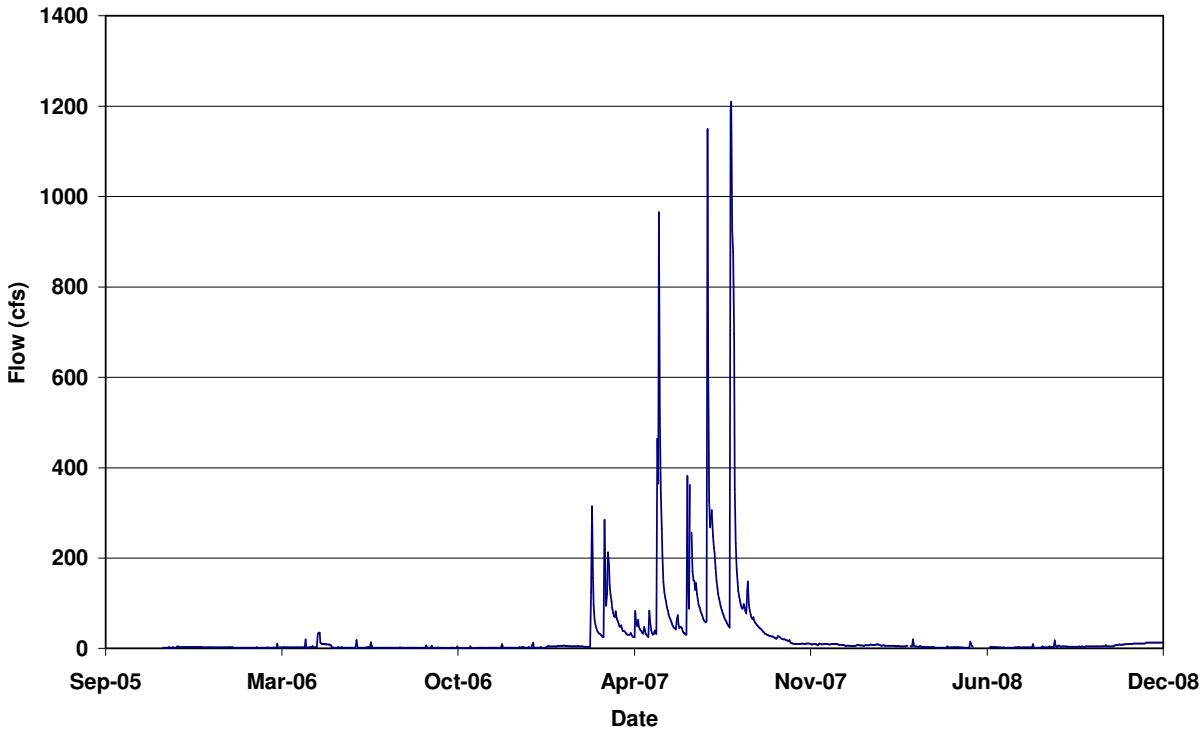


Figure 3-2. Cibolo Creek at Cibolo Nature Center near Boerne (USGS ID 8183890)

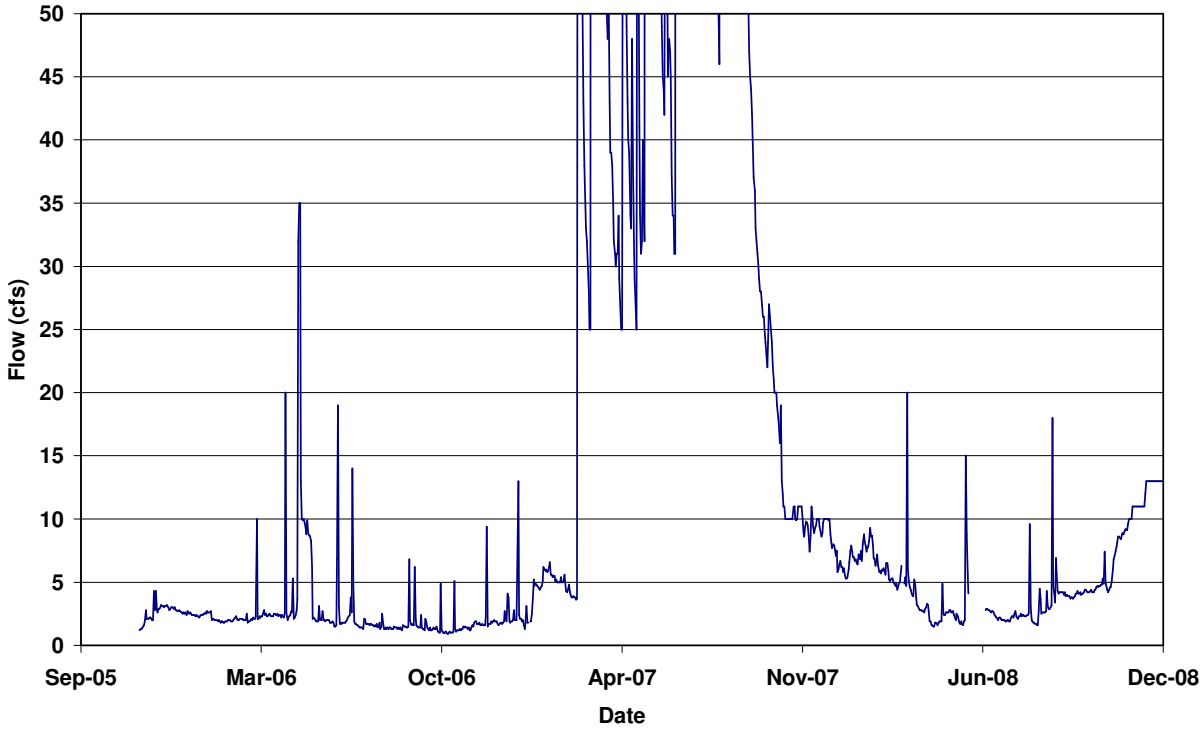


Figure 3-3. Cibolo Creek at Cibolo Nature Center near Boerne (USGS ID 8183890) with y-axis scale from 0 to 50 ft^3/s to show variation in low flow

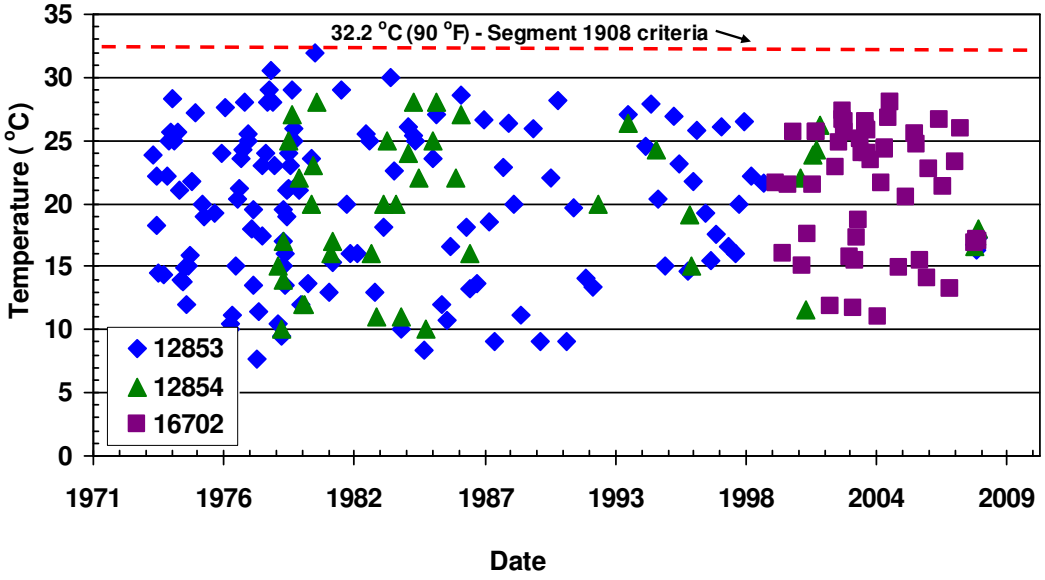


Figure 3-4. Available temperature data at selected stations on Cibolo Creek

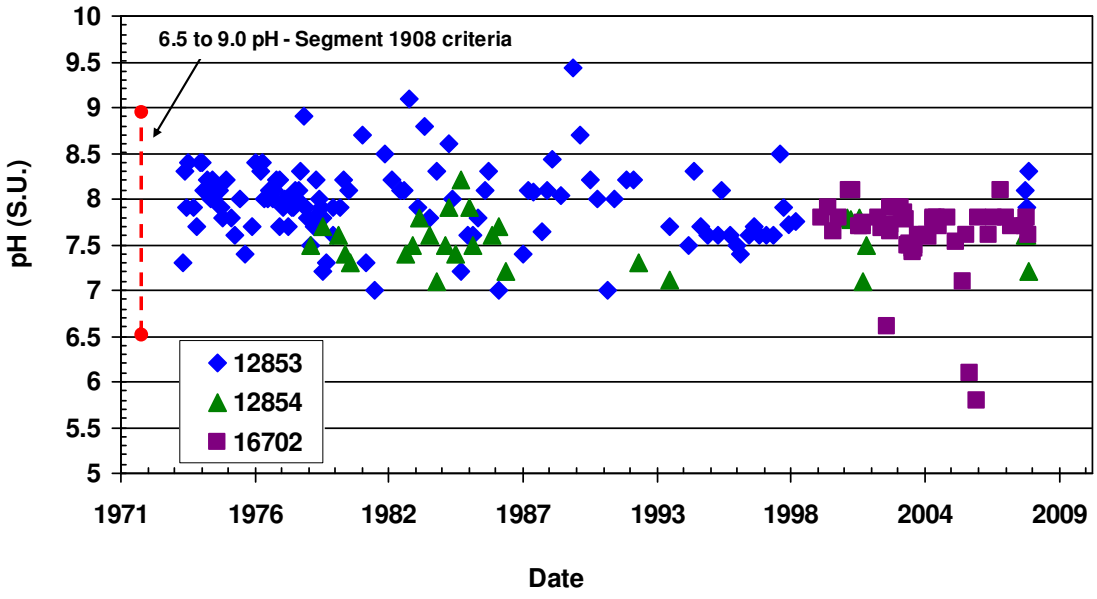


Figure 3-5. Available pH data at selected stations on Cibolo Creek

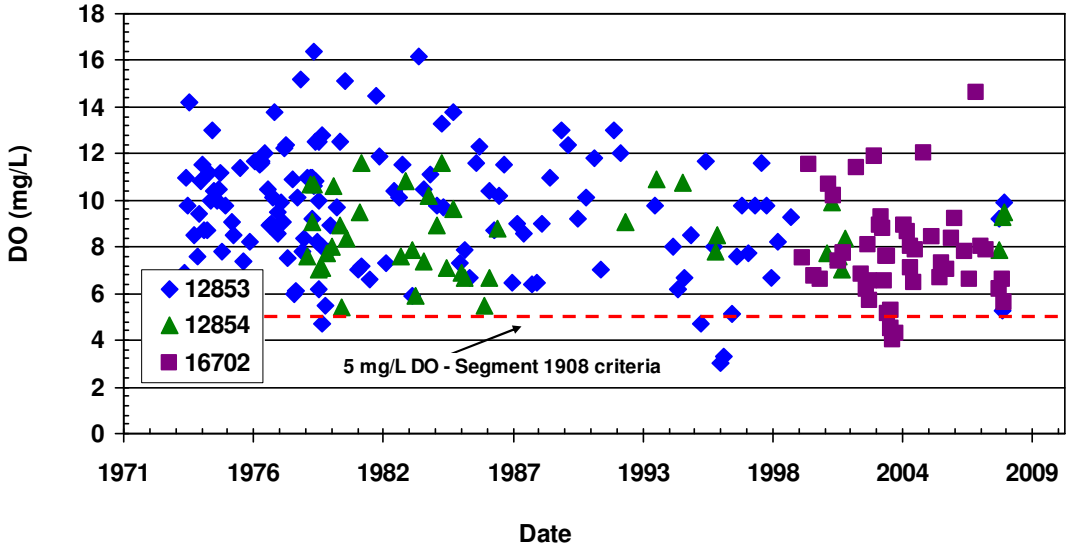


Figure 3-6. Available dissolved oxygen data at selected stations on Cibolo Creek

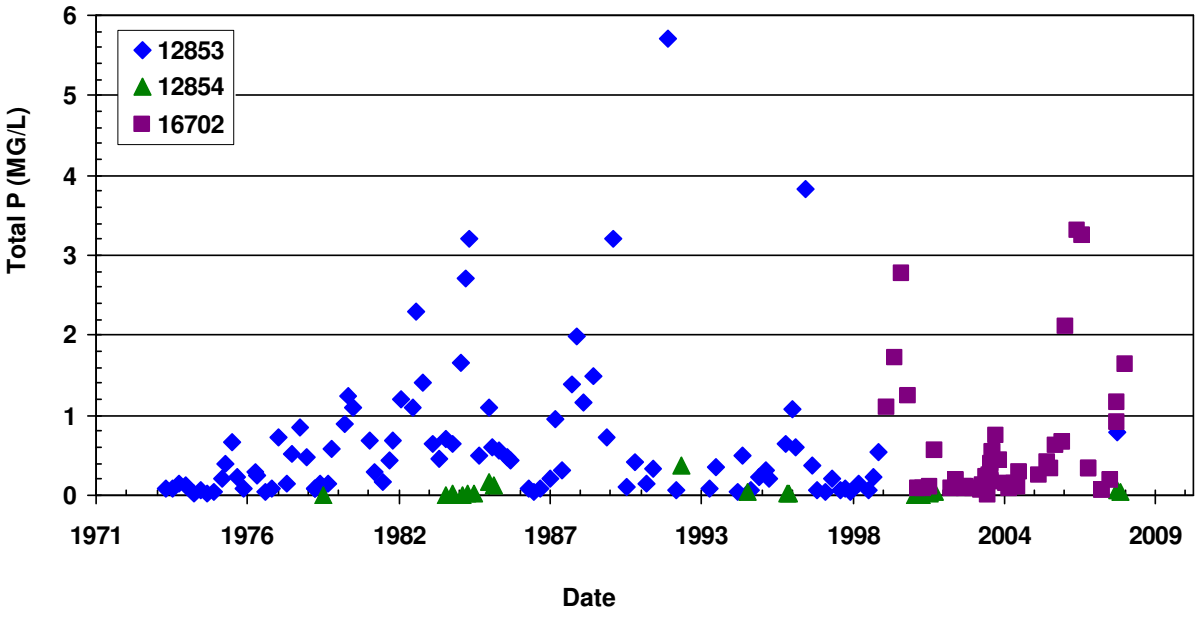


Figure 3-7. Available total phosphorus data at selected stations on Cibolo Creek

3.2 Water Quality Monitoring in Cibolo Creek

The water quality monitoring program for this study was intended to characterize the ambient ammonia and total phosphorus concentrations in the upper reaches of Cibolo Creek. The monitoring program uses methods and procedures consistent with those employed by the

TCEQ and outlined in the 2003 TCEQ Surface Water Quality Monitoring Procedures Manual, Volume1[21].

The data were collected consistent with a Quality Assurance Project Plan (QAPP) approved by TCEQ. Amendment #1 to the San Antonio River Basin Clean Rivers Program FY 2008/2009 QAPP[22] defines the changes to the existing QAPP with the following justification provided.

> *This document details the changes made to the San Antonio River Authority Clean Rivers Program FY2008-2009 Quality Assurance Project Plan to update Section A7 (Quality Objectives and Criteria), Section B2 (Sampling Methods), Appendix B (Sampling Process Design, Sampling Methods and Monitoring Schedule Plan) and Appendix E (SARA Stream Monitoring Program) as a result of the addition of three TCEQ surface water quality sampling stations that originally were not planned for the San Antonio River Basin during the FY2008-2009 contract period. Additional parameters (BOD, Orthophosphate, Chlorophyll-a and Pheophytin-a) are being added to reflect the monitoring for Upper Cibolo Creek (Segment 1908). Field form revisions made to reflect changes and corrections to forms to be consistent with SWQM terminology.*

The data were analyzed in a laboratory accredited as complying with standards established by the National Environmental Laboratory Accreditation Conference (NELAC). Staff and laboratory facilities of the San Antonio River Authority (SARA) were utilized for sample collection and analyses.

3.2.1 Water Quality Parameter Set

For each sampling event, field measurements of temperature, dissolved oxygen, conductivity, and pH were made with calibrated electronic instruments during sample collection at each monitoring location, as described in the QAPP and according to SARA laboratory reports.

Although ammonia and total phosphorus are the constituents of concern, a nitrogen suite (ammonia, nitrate, and total Kjeldahl nitrogen) and biochemical oxygen demand (BOD), orthophosphorus, chlorophyll a, and pheophytin also were analyzed.

[21] Texas Commission on Environmental Quality, 2008. Surface Water Quality Monitoring Procedures, Volume 1: Physical and Chemical Monitoring Methods, RG-415.
[22] San Antonio River Basin in Cooperation with the Texas Commission on Environmental Quality, 2008. Amendment #1 to the San Antonio River Basin Clean Rivers Program FY 2008/2009 QAPP, Effective Date: January 25, 2008.

3.2.2 Sampling Locations and Schedule

Water samples were collected on 15 dates between December 2007 and November 2008. Samples were collected from Cibolo Creek at one location upstream of Currey Creek, which receives the direct permitted discharge of treated wastewater from the City of Boerne, and at two locations downstream of the permitted discharge. One downstream location corresponds to TCEQ Station 16702, Cibolo Creek 1.6 km downstream of SH 46. The other sampling location is located southeast of Boerne at the site of the former USGS streamflow gaging station 08183900 Cibolo Creek 2.5 mi SE of Boerne. The TCEQ identification number for this station is 12853. Figure 3-8 shows the sampling sites for the nutrient monitoring.

A monthly 24-hour composite sample set was collected from the wastewater treatment plant permitted discharge by City staff and then picked up by SARA staff on the day of stream monitoring. In addition, a duplicate discrete sample set (or field split) was collected from one of the stream stations each month for quality control purposes and assessment of variability, resulting in a total monthly collection of five sample sets (three stream samples, WWTP effluent sample, and field split).

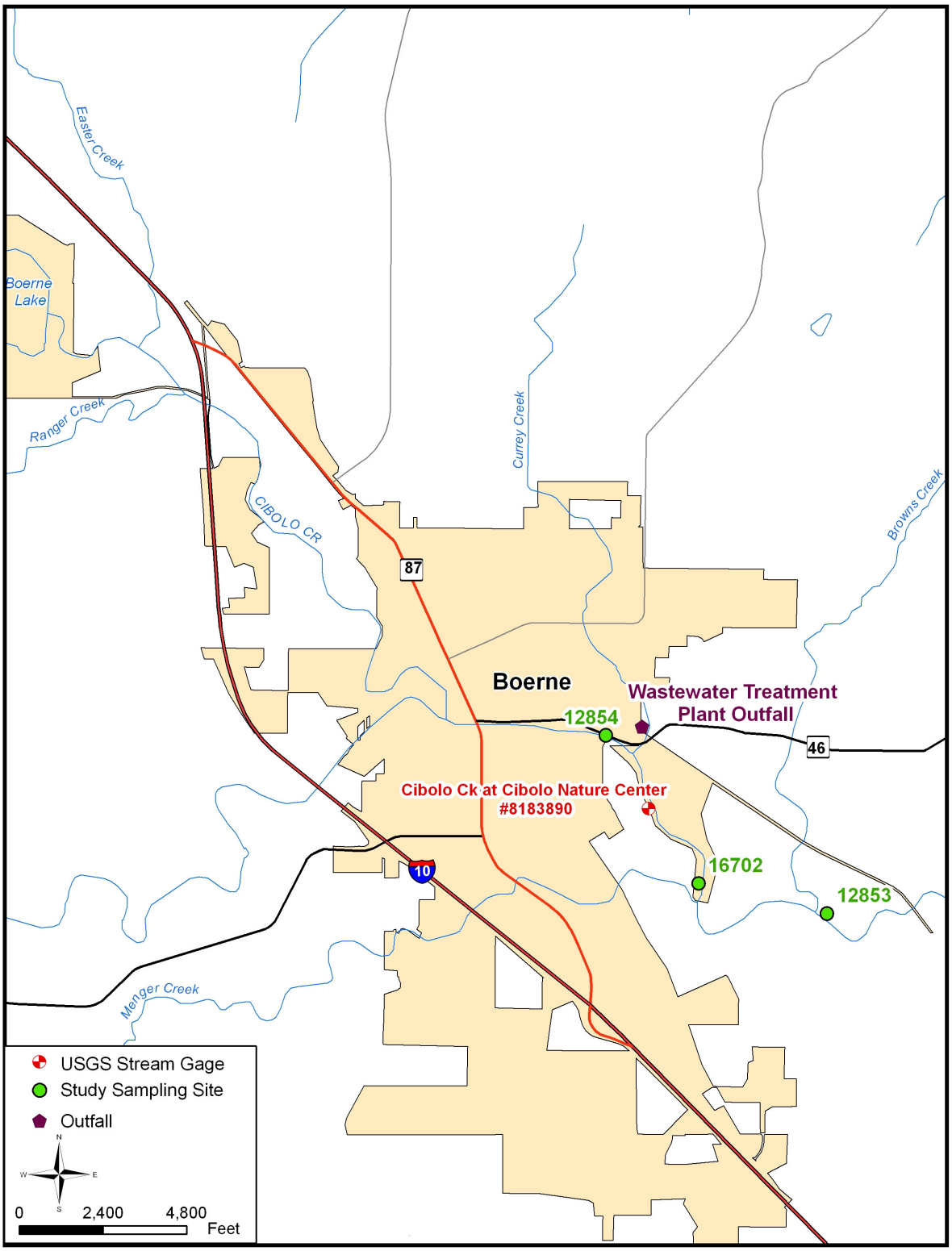


Figure 3-8. Stream sampling sites chosen for project

3.2.3 Analytical Laboratory Results

The field data, including a summary of analytical laboratory analysis results, are presented in Appendix A. Photographs taken by SARA field staff of Cibolo Creek at each sampling location corresponding to sample dates are presented in Appendix B. SARA laboratory and field reports are presented in Appendix C.

Section 4
Water Quality Modeling

4.1 Model Selection

Model selection for this project required consideration of present and future needs of the City of Boerne. Goals of the modeling included analysis of receiving water quality and developing a functional model that could be refined and used as a decision making tool for the City of Boerne.

Several computer models have been developed to perform water quality assessments. A stream water quality model that the state of Texas has widely used is QUAL-TX[23]. QUAL-TX is a one-dimensional model based on QUAL, which was developed by the Texas Water Development Board in the late 1960s. QUAL-TX primarily assesses impacts to the concentration of oxygen in a water body from the input of organic loads. The state of Texas has extensively used QUAL-TX for its waste-load evaluation procedures. However, through communication in late 2008[24], TCEQ encouraged the use of QUAL2K, which is based in a more user friendly spreadsheet format compared to the FORTRAN DOS-window-operated QUAL-TX and to which TCEQ is moving toward using for permit recommendations. Therefore, QUAL2K was applied for this project.

QUAL2K[25] is a stream water quality model and is intended to be an update of the preceding stream water quality model QUAL2E[26]. QUAL was the precursor to QUAL2E. QUAL2K simulates steady state hydraulics. It is one dimensional and assumes a channel is well mixed vertically and laterally. Water quality and heat budget calculations are on a diel, or daily, time scale. Water quality mass and heat may be input into the model, and point and nonpoint source loads and withdrawals may be simulated. The model is available through the U.S. Environmental Protection Agency (EPA) and is also included as one of the models in the EPA's BASINS (Better Assessment Science Integrating Point and Nonpoint Sources) framework.

[23] Ward, Jr., George H. and Jennifer Benaman, 1999. Models for TMDL Application in Texas Watercourses: Screening and Model Review, Center for Research in Water Resources, Online Report CRWR Rpt 99-7.
[24] Charlie Marshall, Water Quality Assessment Section, TCEQ. Email communication dated October 7, 2008.
[25] Chapra, S.C. and Pelletier, G.J. 2004. QUAL2K: A Modeling Framework for Simulating River and Stream Water Quality: Documentation and Users Manual.
[26] Brown, L.C., and Barnwell, T.O. 1987. The Enhanced Stream Water Quality Models QUAL2E and QUAL2E-UNCAS, EPA/600/3-87-007, U.S. Environmental Protection Agency, Athens, GA, 189 pp.

4.2 Cibolo Creek Nutrient Model

QUAL2K was applied to Cibolo Creek, and the resulting calibrated model simulates concentrations of nutrients in Cibolo Creek with ambient conditions and wastewater treatment loads as inputs by calculating the various mechanisms of nutrient transformations and fluxes.

The model includes 7.6 mi (12.2 km) of Cibolo Creek from the outlet of Boerne Lake to one-half mile downstream of the water quality sampling location 12853. The model is divided into stream modeling segments every one-tenth of a mile. Figure 4-1 shows the stream reach and segments included in the model.

For this project two base applications of QUAL2K to Cibolo Creek were developed. The first model application, which will be called the Summer 2008 model throughout this report, was developed because low-flow and high-temperature conditions are typically used for water quality investigations to assess periods when water bodies may be most impaired and aquatic biota most stressed. The second base model application is the Winter 2008 model. For the summer model, July 22, 2008, was used and for the winter model, November 18, 2008, was used. These dates correspond to sample collection dates.

Data related to stream geometry included in the model were segment elevations, channel roughness and slope, and bottom width. Other factors that affect nutrient transformation and transport and that are incorporated in the model are air temperature, dew point temperature, wind, cloud cover, and shade. Climate data, including air temperature, relative humidity, wind, and cloud cover, were available from the National Weather Service San Antonio and Kerrville stations.

Three shade values were incorporated into the model and derived from aerial photos of the study area. For the most upstream segments 76 through 47, (Figure 4-1) solar radiation that is blocked because of shade from vegetation or topography was set at 25% at noon. For segments 46 through 15 (Figure 4-1), which is based on the city limit of Boerne, shade at noon was increased to 50%. For the segments downstream of the city limits from 14 to 0 (Figure 4-1), shade at noon was set to 10%.

Water quality and discharge from Boerne's wastewater treatment plant based on the effluent sample collection for the July and November dates were also incorporated for the two base models.

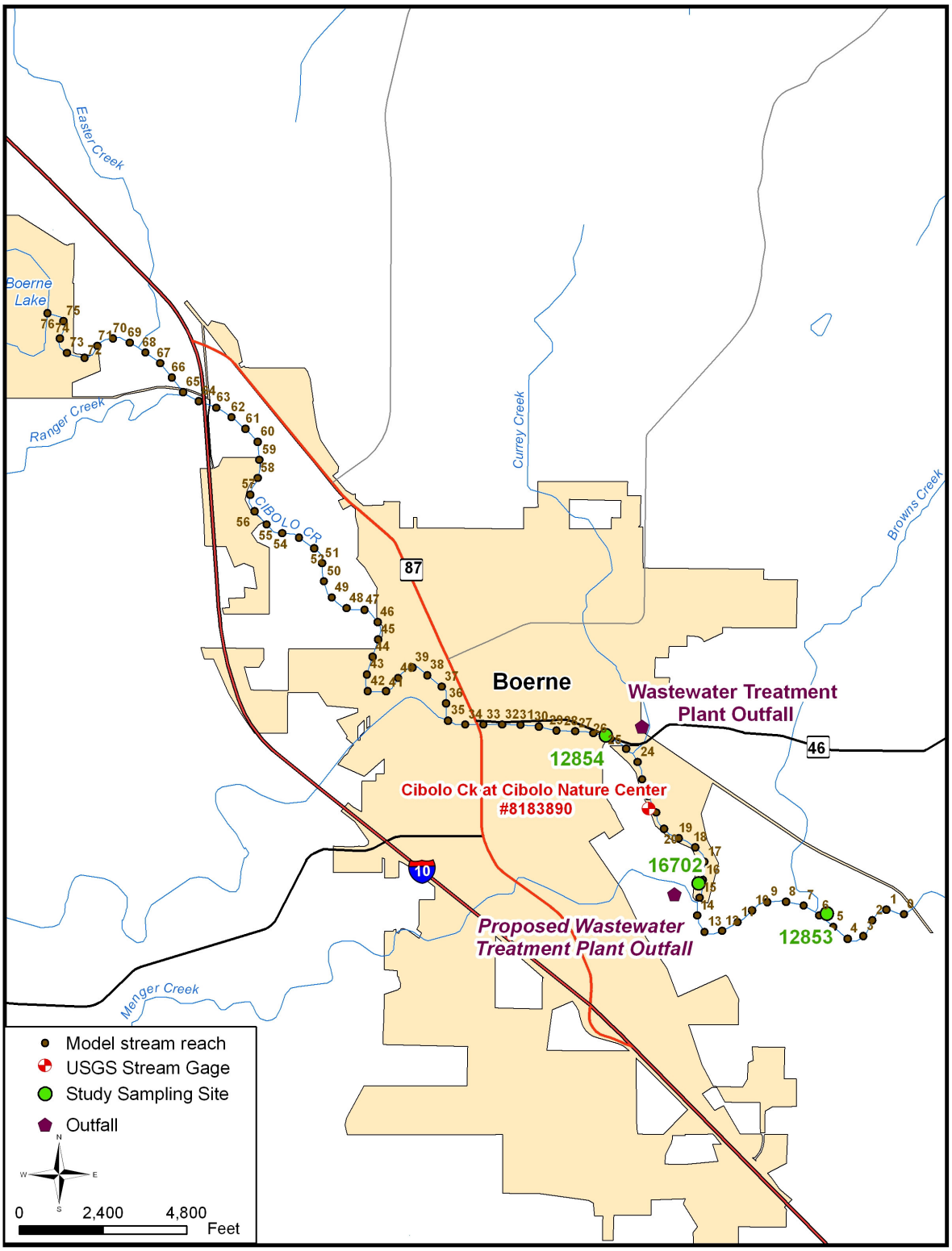


Figure 4-1. The 7.6-mile reach of Cibolo Creek and 0.1-mile segments modeled using QUAL2K

4.2.1 Model Calibration

Flow and nutrient water quality data from July 22, 2008, and November 18, 2008, were used to calibrate the Summer 2008 and Winter 2008 models. The models were developed by iteratively comparing graphical model results to observed water quality data. Stations used for calibration of the models included 16702 and 12853, which are both located downstream of Boerne's WWTP discharge.

For the Summer 2008 model several fluxes within the model were adjusted from the WWTP discharge to downstream end of the model. The sediment oxygen demand (SOD) flux was fixed at 30 g O2/m^2/day, the ammonium (NH4) flux was fixed at 200 mg N/m^2/day, and the inorganic P (orthophosphorus) flux was fixed at 3,500 mg P/m^2/day. For the Winter 2008 model the inorganic P (orthophosphorus) flux was fixed at 3,500 mg P/m^2/day. Often the presence of organic matter deposited prior to the summer steady-state period, the condition can exist that the downward flux of particulate organic matter is insufficient to generate the observed SOD as the QUAL2K theoretical manual states[27].

Figures 4-2 through 4-6 show the calibration results of the Summer 2008 model. Parameters shown include flow, total P, and parameters regulated by Texas surface water quality standards, including DO, temperature and pH. For comparison purposes, scales for figures included in the report have been kept the same where possible between the summer and winter models.

[27] Chapra, S.C. and Pelletier, G.J. 2004. QUAL2K: A Modeling Framework for Simulating River and Stream Water Quality, Version 1.2: Documentation and Users Manual. Civil and Environmental Engineering Dept., Tufts University, Medford, MA.

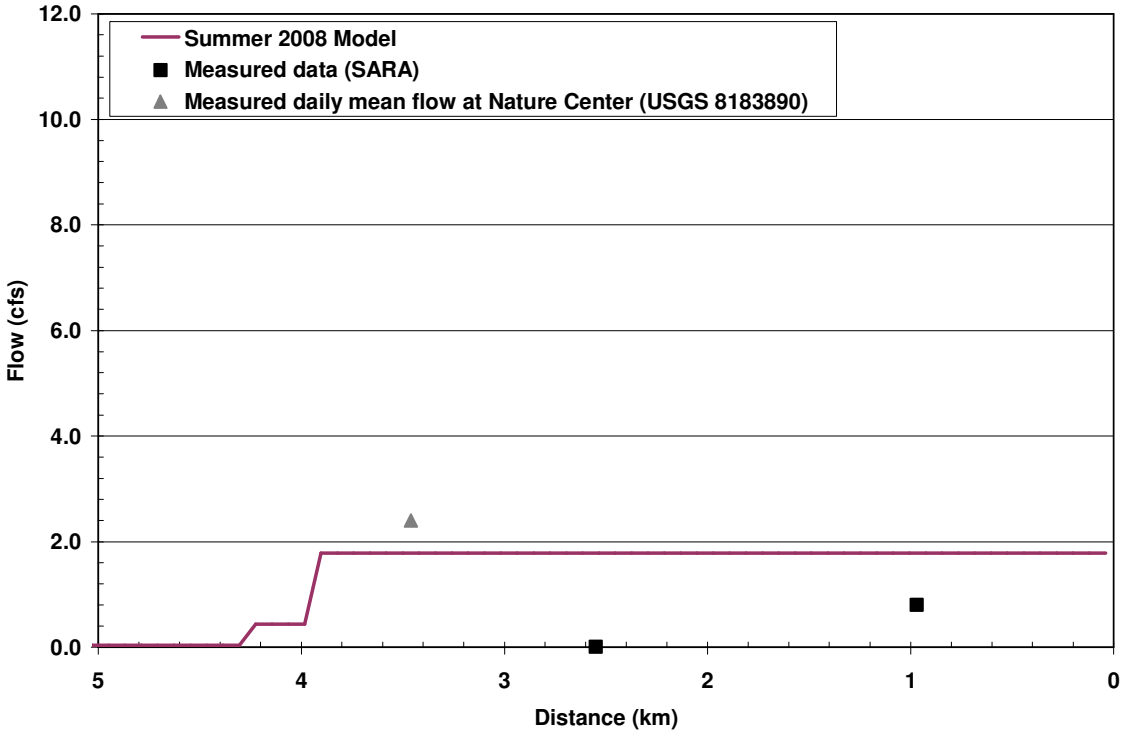


Figure 4-2. Calibrated flow for Summer 2008 model

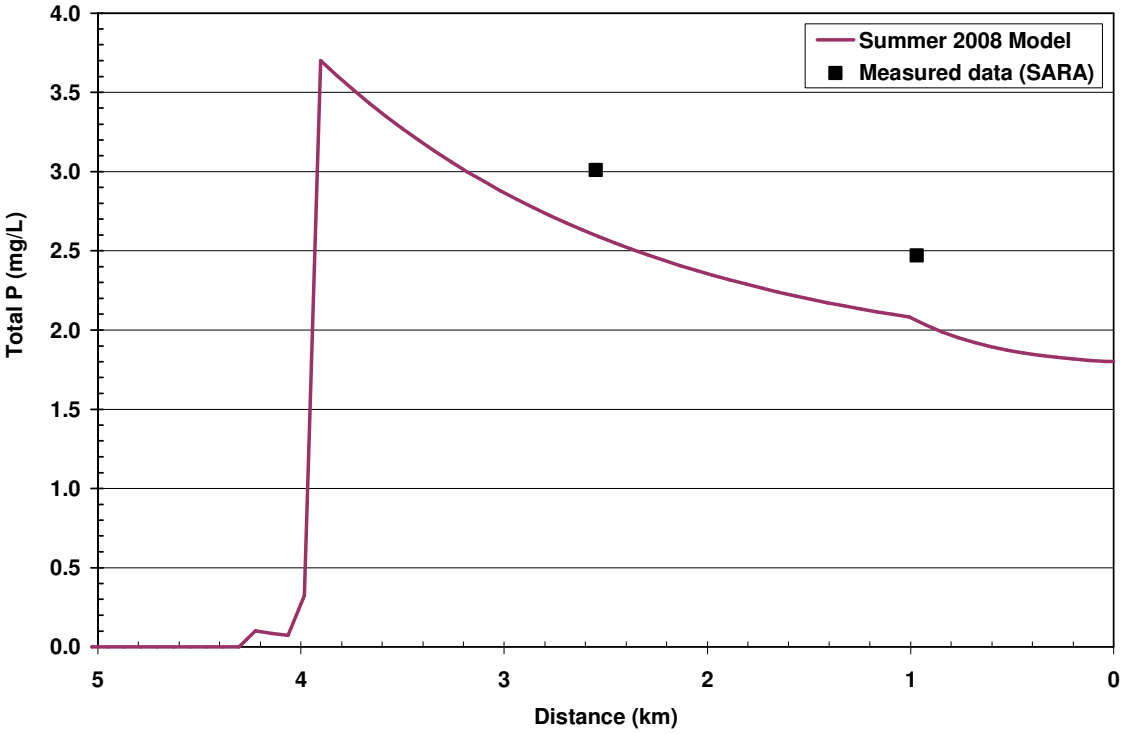


Figure 4-3. Calibrated total P for Summer 2008 model

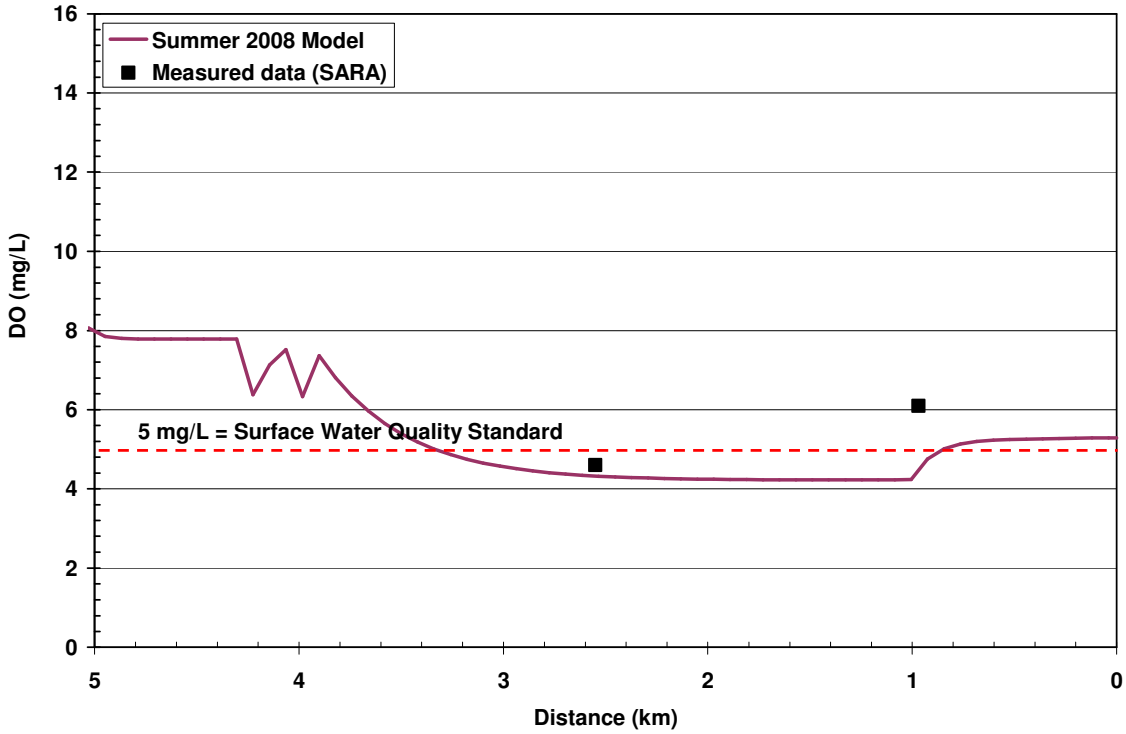


Figure 4-4. Calibrated DO for Summer 2008 model

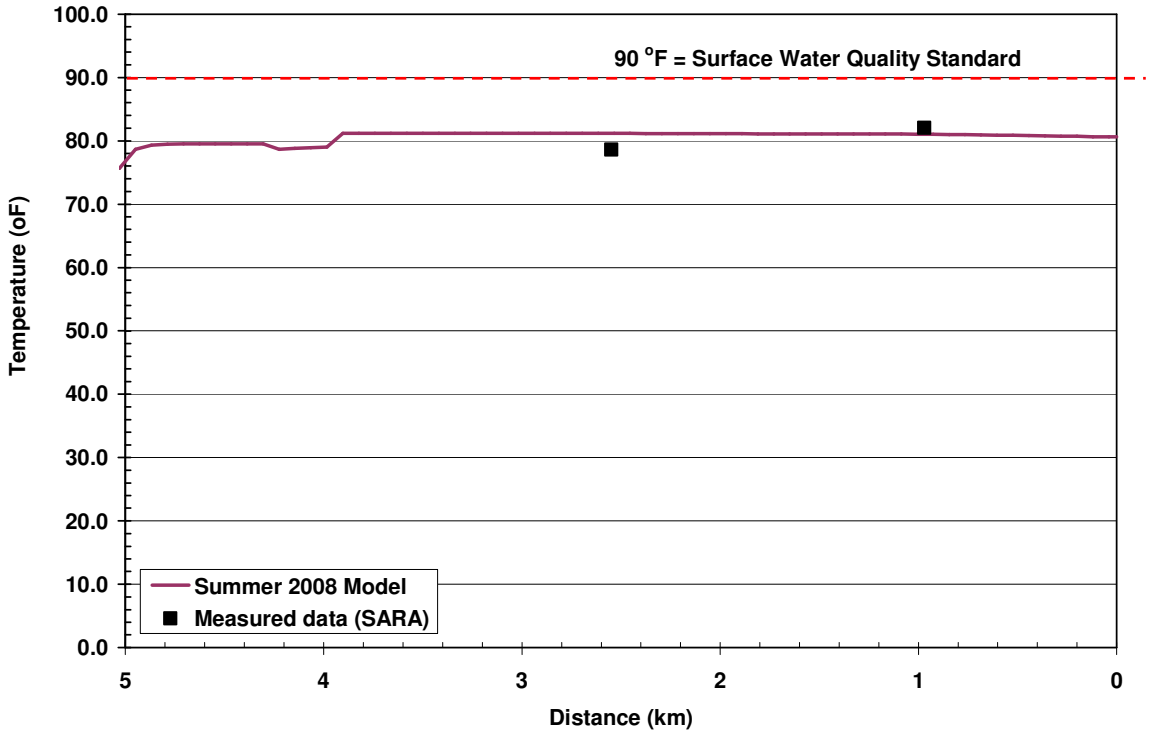


Figure 4-5. Calibrated temperature for Summer 2008 model

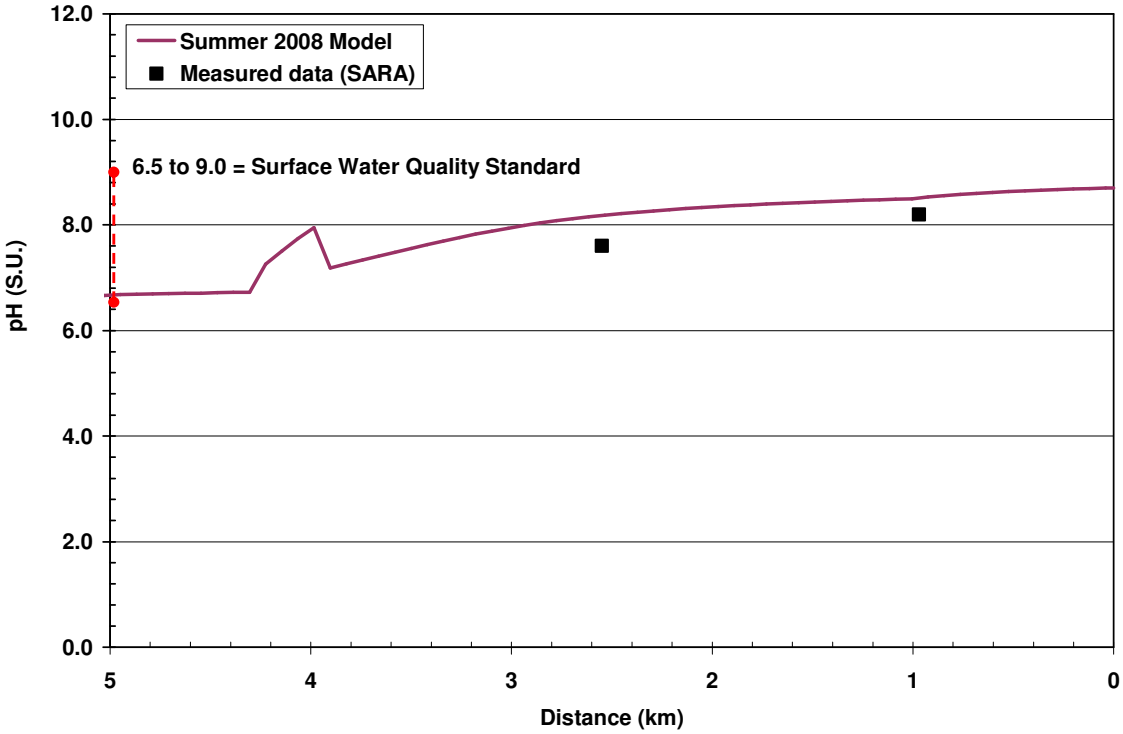


Figure 4-6. Calibrated pH for Summer 2008 model

Figures 4-7 through 4-10 show the calibration results of the Winter 2008 model. Parameters shown include flow, total P, DO, temperature and pH. For the November 2008 sampling on which the Winter 2008 model is based, the field pH post calibration did not meet the necessary criteria. Therefore, the results were not reported. However, to estimate pH values for the two stations, the average pH of the sampling events before and after November were used. For station 16702 the values averaged were 7.8 and 7.9 and for station 12853, the values averaged were 8.1 and 8.4.

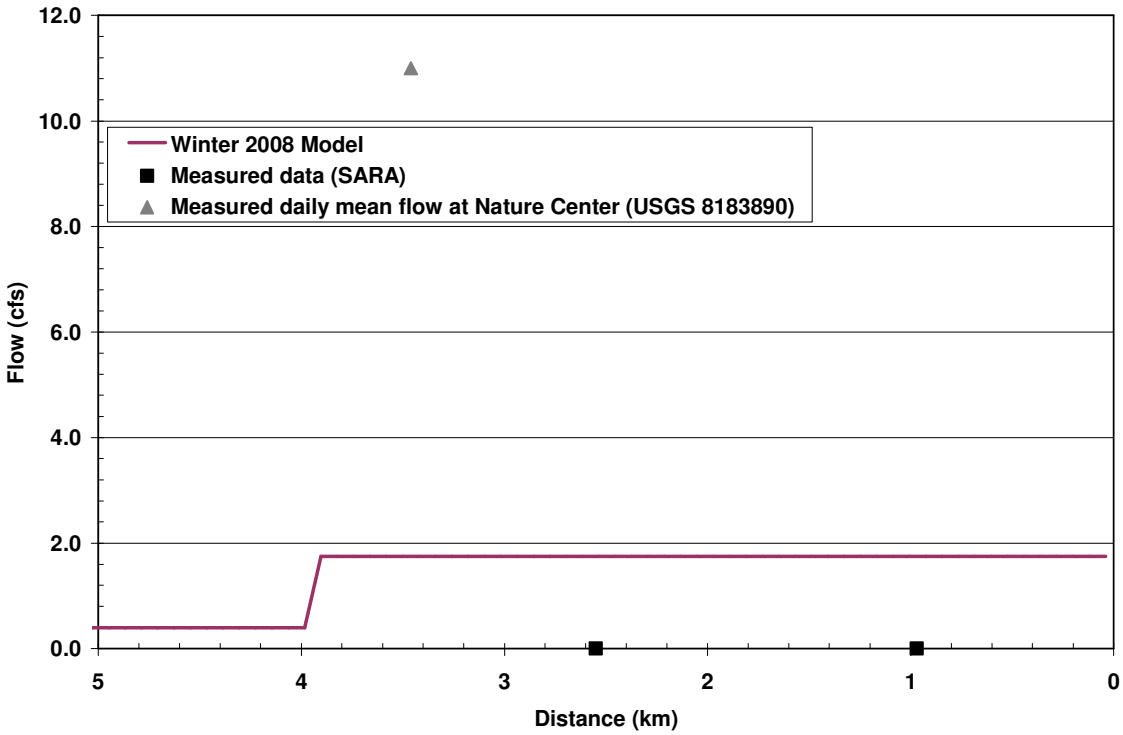


Figure 4-7. Calibrated flow for Winter 2008 model

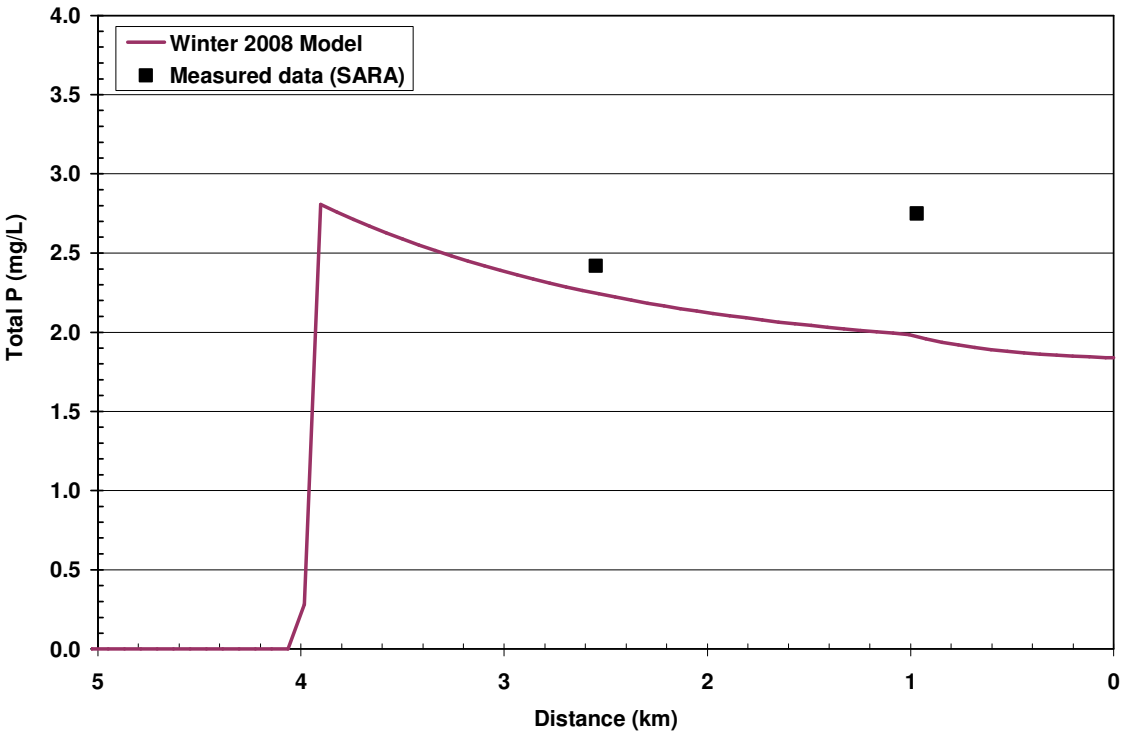


Figure 4-8. Calibrated total P for Winter 2008 model

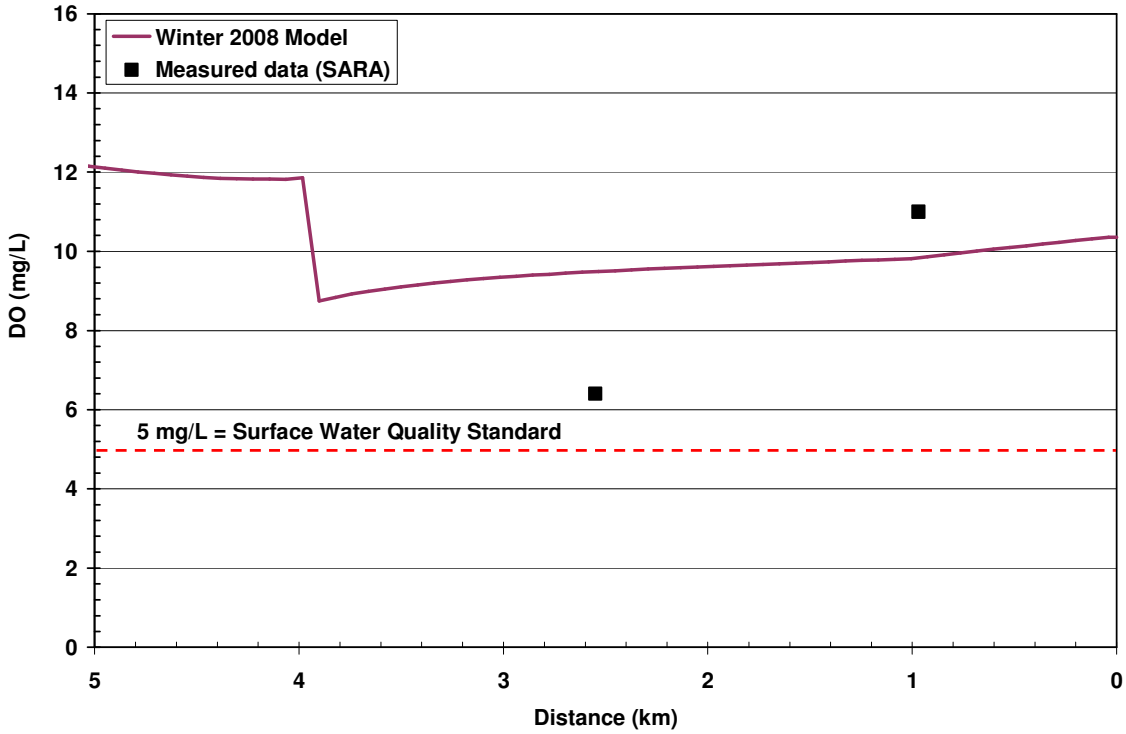


Figure 4-9. Calibrated DO for Winter 2008 model

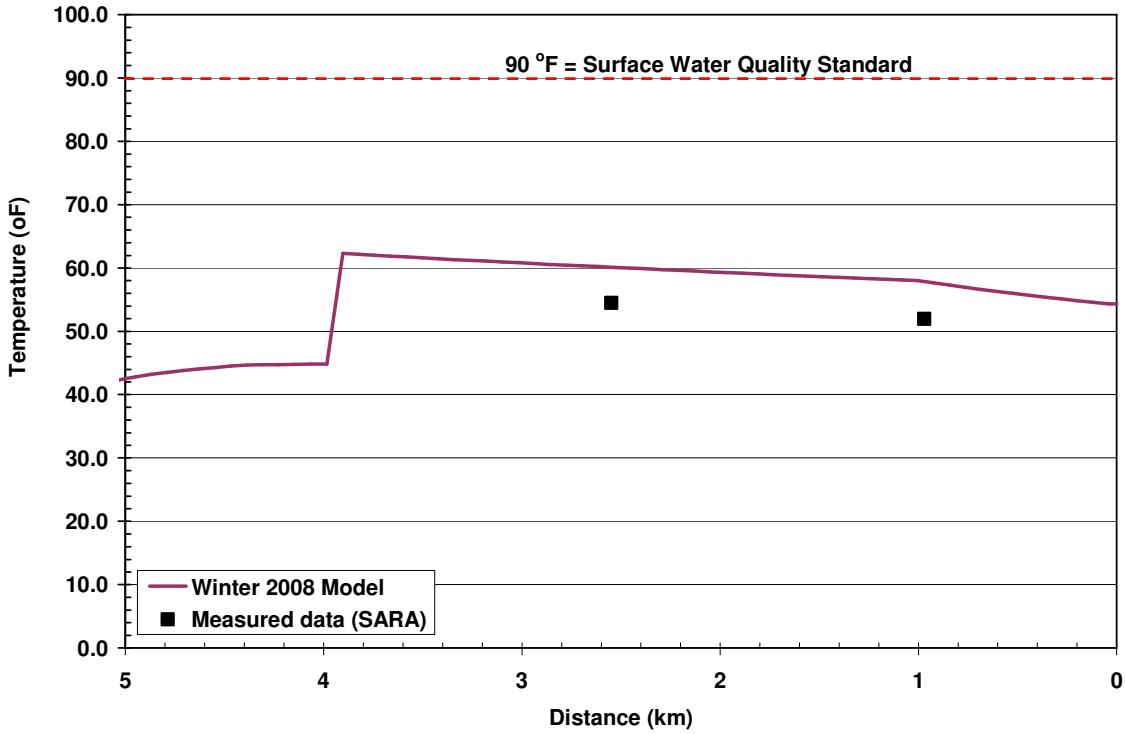


Figure 4-10. Calibrated temperature for Winter 2008 model

4.2.2 Model Scenarios

The calibrated Summer 2008 and Winter 2008 models were used to assess the permit requirement of 3 mg/L ammonia concentration and the new requirement of 2 mg/L P for the existing WWTP. The models were also used to evaluate water quality in Cibolo Creek if a new WWTP were constructed on Menger Creek just upstream of the confluence with Cibolo Creek (Figure 4-1). For the proposed WWTP, water quality criteria of 2 mg/L ammonia and 0.5 mg/L P were examined. Several scenarios that are described below were tested using the models. Table 4-1 summarizes the flow scenarios completed for the project.

- **Existing Conditions** – This scenario represents the Summer 2008 and Winter 2008 models with corresponding 2008 streamflow and water quality. The calibrated model without changes represents this scenario.
- **Existing Conditions with 7Q2 Streamflow** – This scenario represents the Summer 2008 and Winter 2008 models using the 7Q2 streamflow of 1.1 ft^3/s for this reach of Cibolo Creek. The 7Q2 streamflow is the minimum 7-day, 2-year discharge. In Texas, the 7Q2 is often used to evaluate permit applications for water allocation, water-supply planning, in-stream flow requirements, and waste-load allocations for point and nonpoint source discharges.
- **Future Phase A of Existing and New WWTP in Operation** – This scenario represents the Summer 2008 and Winter 2008 models in which the water quality of the WWTP effluent is set to the following criteria. The discharge of the existing WWTP is set to 0.7 MGD, and the discharge of the new WWTP is set to 0.2 MGD.
    - Existing WWTP effluent water quality:
        - 10 mg/L BOD,
        - 3 mg/L NH3-N, and
        - No P criterion (Effluent water quality kept at measured level).
    - New WWTP effluent water quality:
        - 10 mg/L BOD,
        - 2 mg/L NH3-N, and
        - 0.5 mg/L P.

- **Future Phase A of Existing and New WWTP in Operation with 7Q2 Streamflow** – This scenario represents the Summer 2008 and Winter 2008 models in which the water quality of the WWTP effluent is set to the criteria above, and the streamflow in Cibolo Creek is equal to the 7Q2 streamflow of 1.1 ft^3/s.
- **Future Phase B with P Limit at Existing WWTP and Increased Flow at New WWTP** – This scenario represents the Summer 2008 and Winter 2008 models in which the water quality of the WWTP effluent is set to the following criteria. The discharge of the existing WWTP is set to 1.2 MGD, and the discharge of the new WWTP is set to 1.4 MGD.
    - Existing WWTP effluent water quality:
        - 10 mg/L BOD,
        - 3 mg/L NH3-N, and
        - 2 mg/L P.
    - New WWTP effluent water quality:
        - 10 mg/L BOD,
        - 2 mg/L NH3-N, and
        - 0.5 mg/L P.
- **Future Phase B with P Limit at Existing WWTP and Increased Flow at New WWTP with 7Q2 Streamflow** – This scenario represents the Summer 2008 and Winter 2008 models in which the water quality of the WWTP effluent is set to the criteria above, and the streamflow in Cibolo Creek is equal to the 7Q2 streamflow of 1.1 ft^3/s.
- **Future Phase B with P Limit at Existing WWTP and Increased Flow and Varying P limits at New WWTP** – This scenario represents the Summer 2008 model in which the water quality of the existing WWTP effluent is set to the criteria above, and the water quality of the new WWTP is set at 2 mg/L NH3-N and the P concentration of the effluent is varied for the scenarios at 0.5 mg/L, 1.0 mg/L, and the summer 2008 P concentration.
- **Future Phase C with Permitted Capacity at both WWTPs** – This scenario represents the Summer 2008 and Winter 2008 models in which the water quality

of the WWTP effluent is set to the criteria in Future Phase B. In addition the discharge of the existing WWTP is set to 1.2 MGD, and the discharge of the new WWTP is set to 2.7 MGD.

- **Future Phase C with Permitted Capacity at both WWTPs with 7Q2 streamflow** – This scenario represents the Summer 2008 and Winter 2008 models in which the water quality of the WWTP effluent is set to the criteria in Future Phase B, and the streamflow in Cibolo Creek is equal to the 7Q2 streamflow of 1.1 ft^3/s.
- **Future Phase C with Permitted Capacity at both WWTPs and Increased Flow and Varying P limits at New WWTP** – This scenario represents the Summer 2008 model in which the water quality of the existing WWTP effluent is set to the criteria above, and the water quality of the new WWTP is set at 2 mg/L NH3-N and the P concentration of the effluent is varied for the scenarios at 0.5 mg/L, 1.0 mg/L, and the summer 2008 P concentration.

Table 4-1. Scenarios simulated with QUAL2K Cibolo Creek model

Scenario	Wastewater Treatment Plant Flow		Season / Streamflow	Water Quality (mg/L) E = Existing WWTP N = New WWTP
	Existing	Proposed		
1	2008 flow	-	Summer 2008	E: No P limit, 3 NH3, 10 BOD N: 0.5 P, 2 NH3, 10 BOD
2	2008 flow	-	Winter 2008	E: No P limit, 3 NH3, 10 BOD N: 0.5 P, 2 NH3, 10 BOD
3	2008 flow	-	Summer / 7Q2	E: No P limit, 3 NH3, 10 BOD N: 0.5 P, 2 NH3, 10 BOD
4	2008 flow	-	Winter / 7Q2	E: No P limit, 3 NH3, 10 BOD N: 0.5 P, 2 NH3, 10 BOD
5	0.700 MGD	0.200 MGD	Summer 2008	E: No P limit, 3 NH3, 10 BOD N: 0.5 P, 2 NH3, 10 BOD
6	0.700 MGD	0.200 MGD	Winter 2008	E: No P limit, 3 NH3, 10 BOD N: 0.5 P, 2 NH3, 10 BOD
7	0.700 MGD	0.200 MGD	Summer / 7Q2	E: No P limit, 3 NH3, 10 BOD N: 0.5 P, 2 NH3, 10 BOD
8	0.700 MGD	0.200 MGD	Winter / 7Q2	E: No P limit, 3 NH3, 10 BOD N: 0.5 P, 2 NH3, 10 BOD
9	1.2 MGD	1.4 MGD	Summer 2008	E: 2 P, 3 NH3, 10 BOD N: 0.5 P, 2 NH3, 10 BOD
9b	1.2 MGD	1.4 MGD	Summer 2008	E: 2 P, 3 NH3, 10 BOD N: 1 P, 2 NH3, 10 BOD
9c	1.2 MGD	1.4 MGD	Summer 2008	E: 2 P, 3 NH3, 10 BOD N: 2 P, 2 NH3, 10 BOD
9d	1.2 MGD	1.4 MGD	Summer 2008	E: 2 P, 3 NH3, 10 BOD N: No P limit, 2 NH3, 10 BOD
9e	1.2 MGD	1.4 MGD	Summer 2008	E: No P limit, 3 NH3, 10 BOD N: 0.5 P, 2 NH3, 10 BOD
9f	1.2 MGD	1.4 MGD	Summer 2008	E: No P limit, 3 NH3, 10 BOD N: 1 P, 2 NH3, 10 BOD
9g	1.2 MGD	1.4 MGD	Summer 2008	E: No P limit, 3 NH3, 10 BOD N: 2 P, 2 NH3, 10 BOD
9h	1.2 MGD	1.4 MGD	Summer 2008	E: No P limit, 3 NH3, 10 BOD N: No P limit, 2 NH3, 10 BOD
10	1.2 MGD	1.4 MGD	Winter 2008	E: 2 P, 3 NH3, 10 BOD N: 0.5 P, 2 NH3, 10 BOD
11	1.2 MGD	1.4 MGD	Summer / 7Q2	E: 2 P, 3 NH3, 10 BOD N: 0.5 P, 2 NH3, 10 BOD
12	1.2 MGD	1.4 MGD	Winter / 7Q2	E: 2 P, 3 NH3, 10 BOD N: 0.5 P, 2 NH3, 10 BOD

Table 4-1 (continued). Scenarios simulated with QUAL2K Cibolo Creek model

Scenario	Wastewater Treatment Plant Flow		Season / Streamflow	Water Quality (mg/L) E = Existing WWTP N = New WWTP
	Existing	Proposed		
13	1.2 MGD	2.7 MGD	Summer 2008	E: 2 P, 3 NH3, 10 BOD N: 0.5 P, 2 NH3, 10 BOD
13b	1.2 MGD	2.7 MGD	Summer 2008	E: 2 P, 3 NH3, 10 BOD N: 1 P, 2 NH3, 10 BOD
13c	1.2 MGD	2.7 MGD	Summer 2008	E: 2 P, 3 NH3, 10 BOD N: 2 P, 2 NH3, 10 BOD
13d	1.2 MGD	2.7 MGD	Summer 2008	E: 2 P, 3 NH3, 10 BOD N: No P limit, 2 NH3, 10 BOD
13e	1.2 MGD	2.7 MGD	Summer 2008	E: No P limit, 3 NH3, 10 BOD N: 0.5 P, 2 NH3, 10 BOD
13f	1.2 MGD	2.7 MGD	Summer 2008	E: No P limit, 3 NH3, 10 BOD N: 1 P, 2 NH3, 10 BOD
13g	1.2 MGD	2.7 MGD	Summer 2008	E: No P limit, 3 NH3, 10 BOD N: 2 P, 2 NH3, 10 BOD
13h	1.2 MGD	2.7 MGD	Summer 2008	E: No P limit, 3 NH3, 10 BOD N: No P limit, 2 NH3, 10 BOD
14	1.2 MGD	2.7 MGD	Winter 2008	E: 2 P, 3 NH3, 10 BOD N: 0.5 P, 2 NH3, 10 BOD
15	1.2 MGD	2.7 MGD	Summer / 7Q2	E: 2 P, 3 NH3, 10 BOD N: 0.5 P, 2 NH3, 10 BOD
16	1.2 MGD	2.7 MGD	Winter / 7Q2	E: 2 P, 3 NH3, 10 BOD N: 0.5 P, 2 NH3, 10 BOD

4.2.3 Model Results

Using the calibrated QUAL2K Summer 2008 and Winter 2008 models, the sixteen scenarios were simulated. Results are shown for DO, which has been the past reason for Segment 1908, Upper Cibolo Creek being present on the state's 303(d) list, and for two nutrient parameters regulated by the City of Boerne's TPDES effluent discharge permit, NH3 and total P.

Graphical results show values from the most downstream point on Cibolo Creek that was modeled to a point 8 km upstream. During summer 2008 Cibolo Creek did not flow over the small dam located in the City of Boerne near the intersection of Hwy 87 and Hwy 46.

4.2.3.1 Summer 2008 Model Results

Figure 4-11 shows simulated streamflow in Cibolo Creek, which varies based on the WWTP effluent permitted discharge for each of the four scenarios presented.

For NH3 the Summer 2008 model shows the lowest value of NH3. An increase from the measured non-detect value of <0.1 mg/L, typical of every sampling event but one, to 3 mg/L or 2 mg/L for the permitted concentrations at the existing and proposed WWTP, respectively, is shown is Figure 4-12.

For total P, shown in Figure 4-13, values of 2 mg/L and 0.5 mg/L were modeled for Future Phases B and C (Scenarios 9 and 13), while for Future Phase A (Scenario 5), the P value was set equal to the measured value of 4.3 mg/L. For Scenario 13, no change in total P is noted until the confluence with Menger Creek, the proposed location of the new WWTP. Scenario 5 shows a somewhat lower value of total P than the Summer 2008 model at the existing plant because of the slight decrease in flow for the simulation at the existing plant (from 0.8 MGD for the July 2008 measured value to 0.7 MGD for Scenario 5).

Dissolved oxygen values in the summer remain relatively low for each scenario. However, the extremely low flows can represent a challenge to the QUAL2K model as shown in the erratic fluctuations of the summer 2008 model scenarios before the flow from the WWTPs is introduced to Cibolo Creek at the distance of 4 km.

Figures 4-15 through 4-17 show the model simulations completed using the 7Q2 streamflow of 1.1 ft^3/s in Cibolo Creek above the WWTP discharge. Although the 7Q2 streamflow typically is used as an example of low flow, streamflow in 2008 was less than the 7Q2 streamflow. In general, the NH3, total P, and DO results demonstrate similar patterns to the results of simulations made using streamflow from summer 2008.

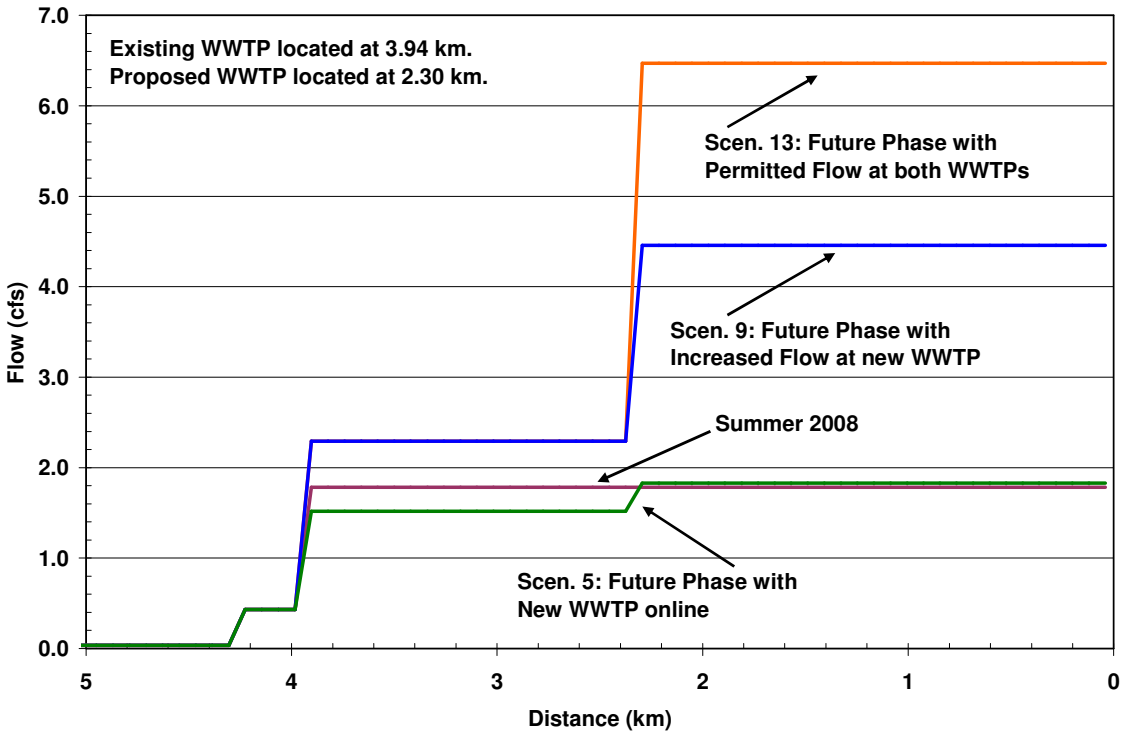


Figure 4-11. Simulated streamflow for summer 2008 model scenarios

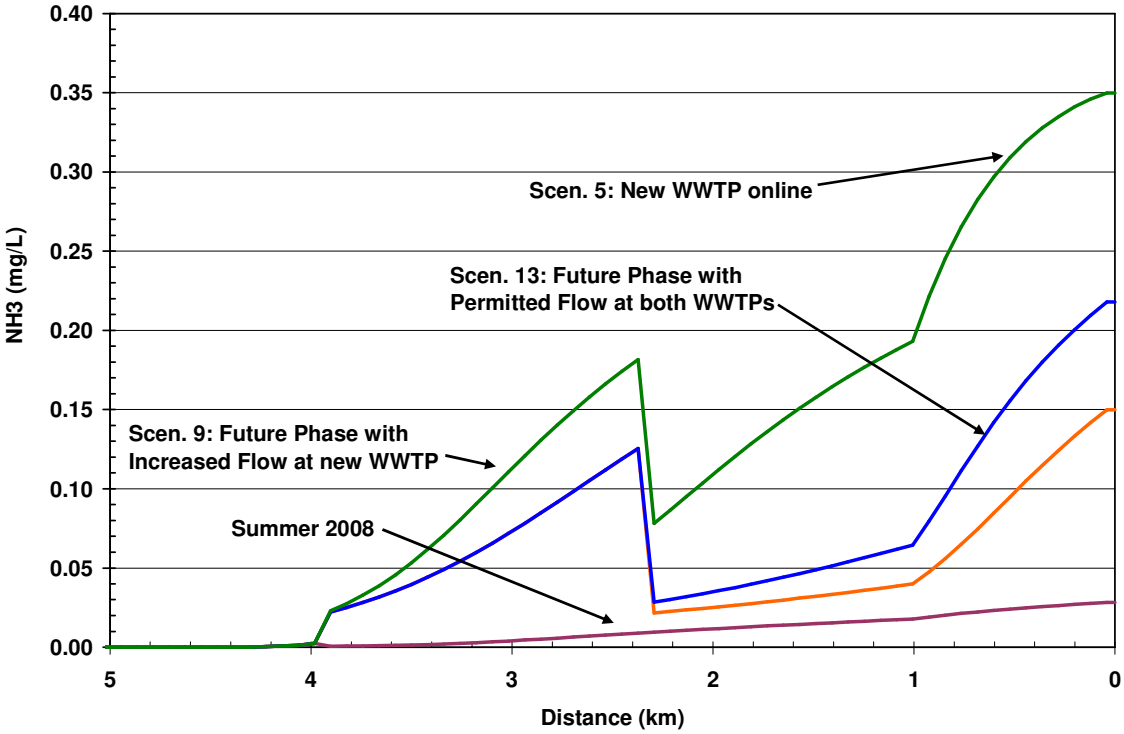


Figure 4-12. Simulated NH3 for summer 2008 model scenarios

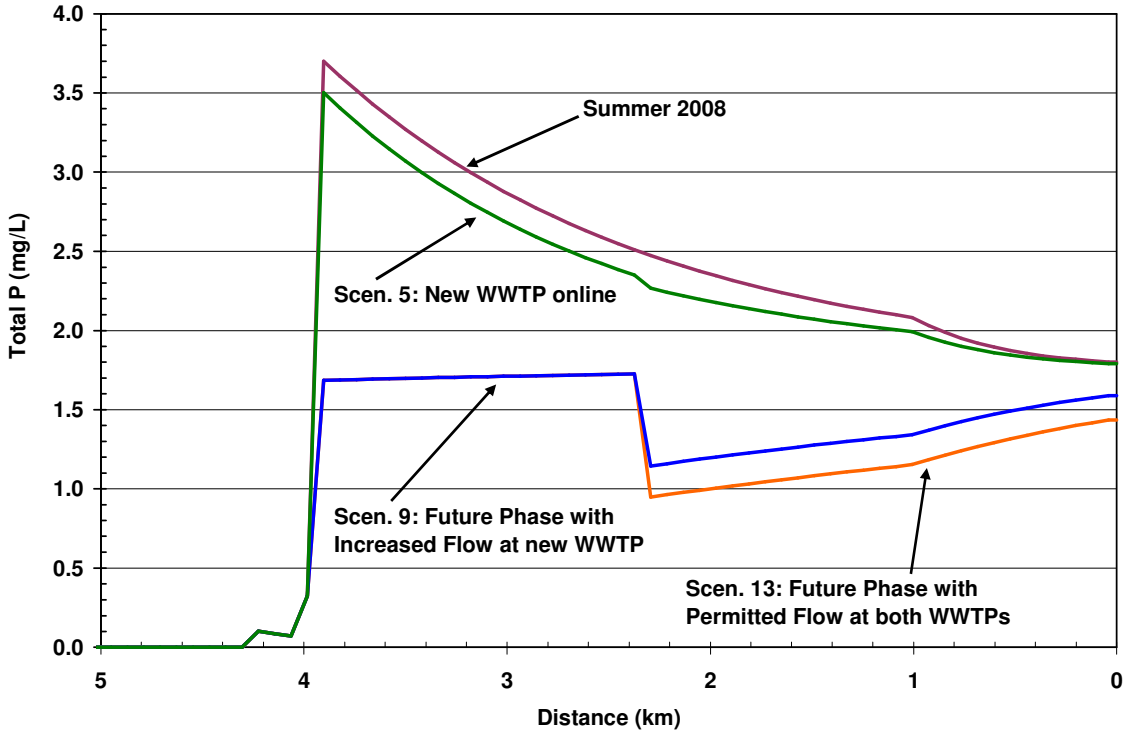


Figure 4-13. Simulated total P for summer 2008 model scenarios

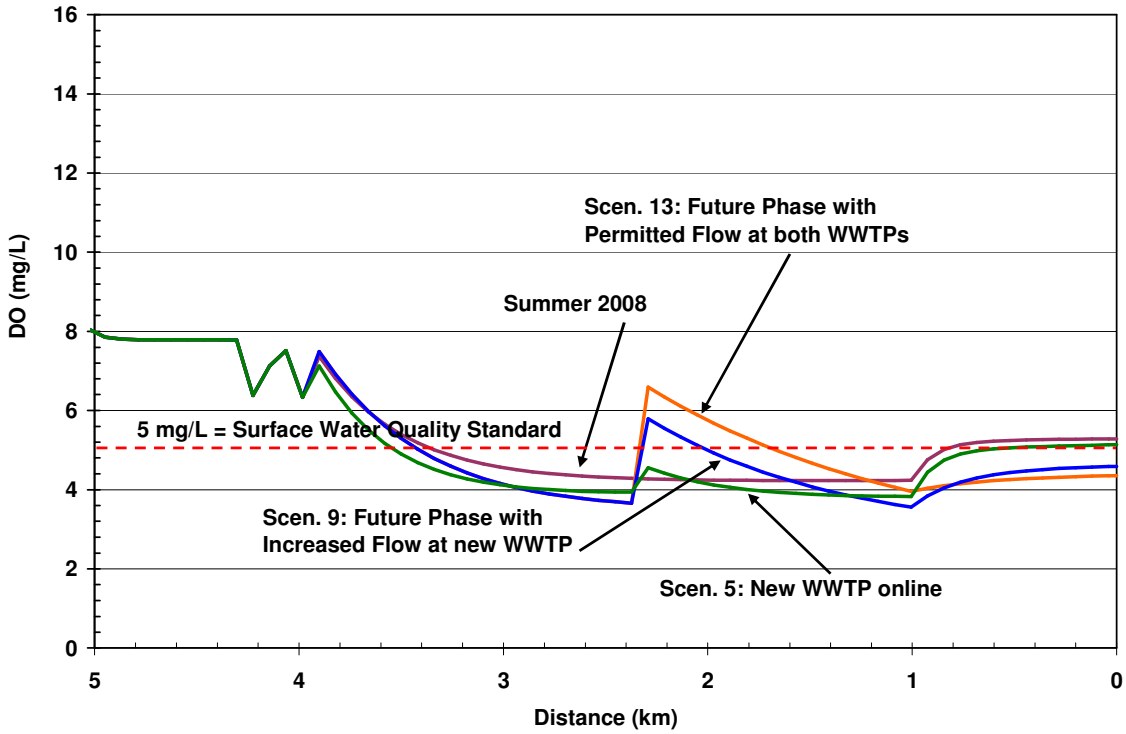


Figure 4-14. Simulated DO for summer 2008 model scenarios

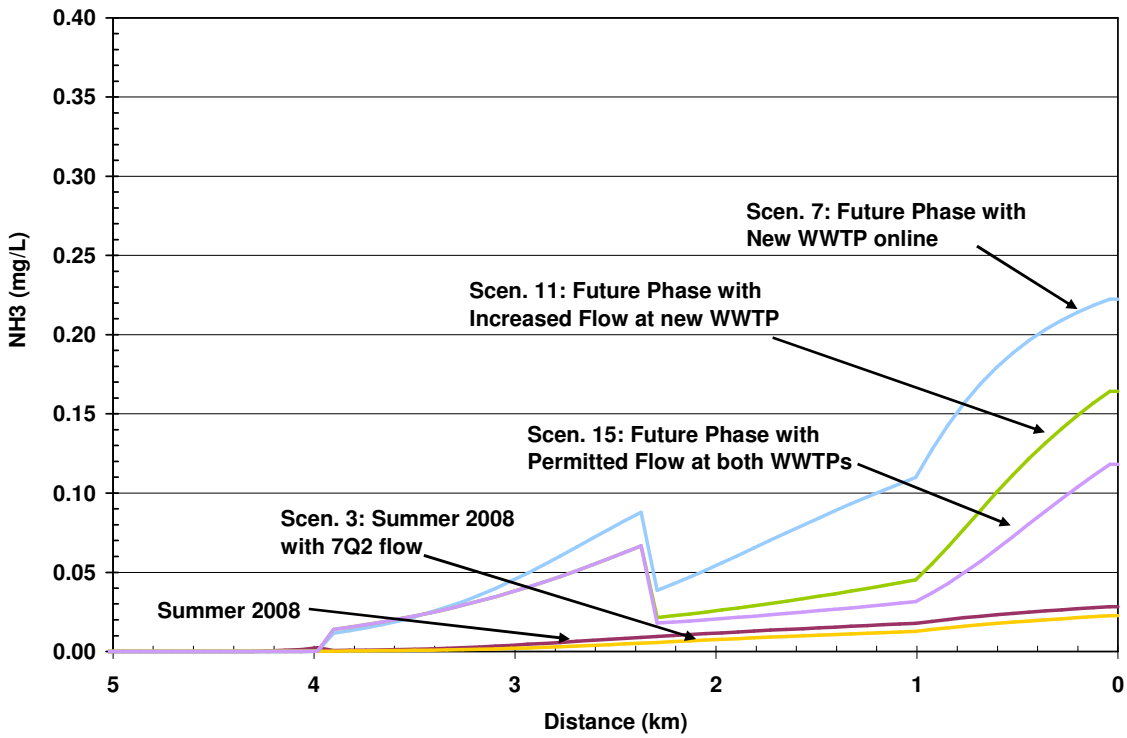


Figure 4-15. Simulated NH3 for summer 2008 model scenarios with 7Q2 streamflow of 1.1 ft^3/s

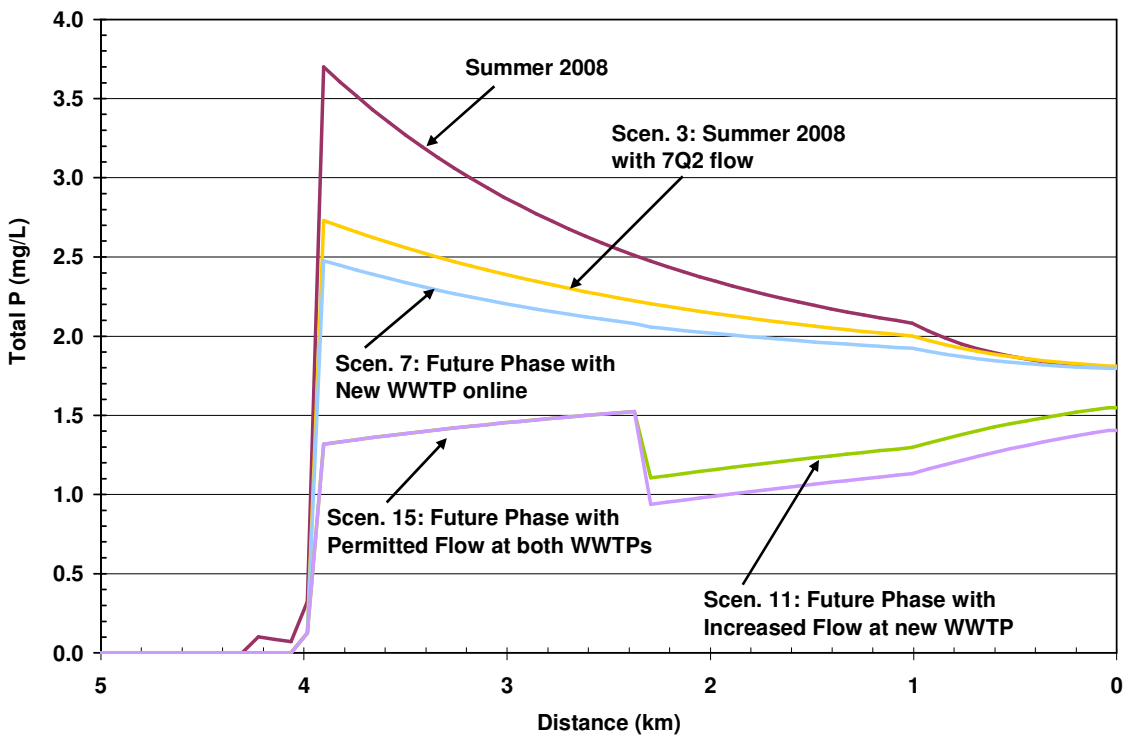


Figure 4-16. Simulated total P for summer 2008 model scenarios with 7Q2 streamflow of 1.1 ft^3/s

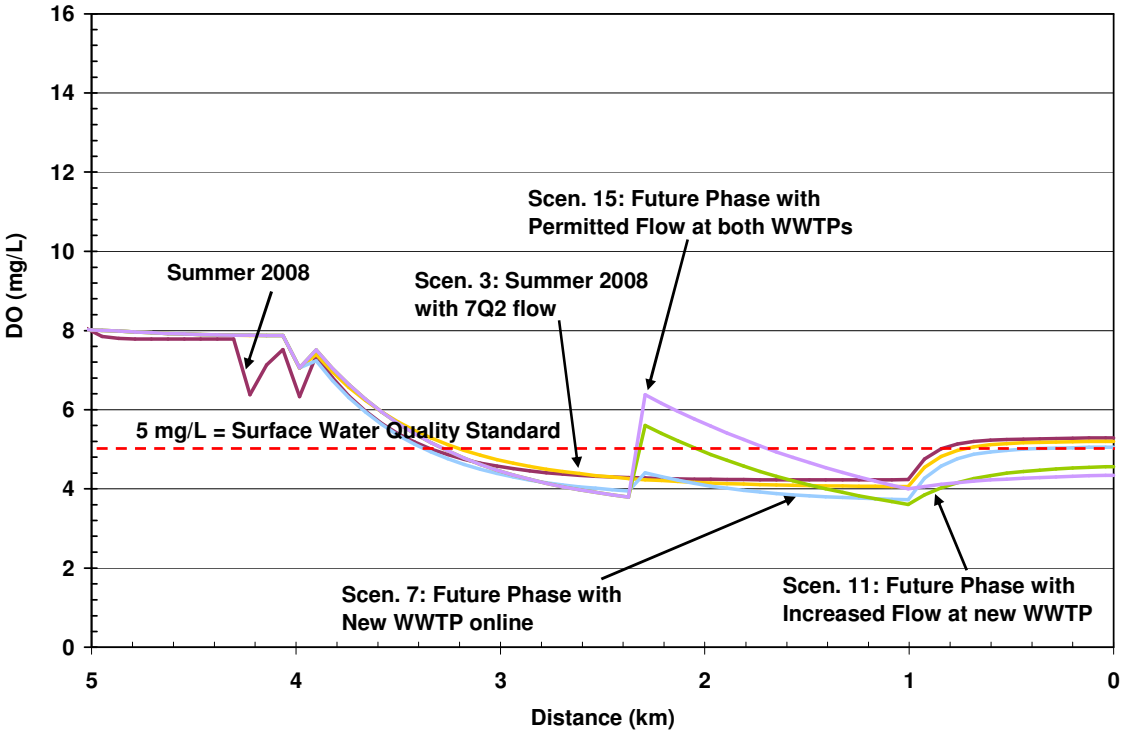


Figure 4-17. Simulated DO for summer 2008 model scenarios with 7Q2 streamflow of 1.1 ft^3/s

4.2.3.2 Winter 2008 Model Results

Figure 4-18 shows simulated streamflow in Cibolo Creek, which varies based on the WWTP effluent permitted discharge for each of the four scenarios presented. The various streamflow simulations are identical to the streamflow scenarios shown for the summer models as the WWTP discharges for the scenarios are equal as is the measured streamflow in Cibolo Creek.

For NH3 the Winter 2008 model shows the lowest value of NH3. As with the summer models, values above the NH3 laboratory analyses value of 0.1 mg/L were not detected in any sample in November. The simulated increase to 3 mg/L or 2 mg/L for the permitted concentrations at the existing and proposed WWTP, respectively, is shown is Figure 4-19. In addition, simulated values of NH3 in the winter are lower than the simulated values of NH3 in the summer models (Figure 4-12).

For total P, shown in Figure 4-20, values of 2 mg/L and 0.5 mg/L were modeled for Future Phases B and C (Scenarios 10 and 14), while for Future Phase A (Scenario 6), the P value

was set equal to the measured value of 3.62 mg/L. For Scenario 13, no change in total P is noted until the confluence with Menger Creek, the proposed location of the new WWTP. Scenario 5 shows a somewhat lower value of total P than the Summer 2008 model at the existing plant because of the slight decrease in flow for the simulation at the existing plant (from 0.8 MGD for the July 2008 measured value to 0.7 MGD for Scenario 5).

Simulated dissolved oxygen values in the winter shown in Figure 4-21 are higher than those simulated in the summer (Figure 4-14) and remain above the surface water quality standard of 5 mg/L. The scenario with the highest DO is the Winter 2008 model calibration.

Figures 4-22 through 4-24 show the model simulations completed using the 7Q2 flow of 1.1 ft^3/s in Cibolo Creek above the WWTP discharge. Although the 7Q2 streamflow typically is used as an example of low flow, streamflow in 2008 was less than the 7Q2 streamflow. In general, the NH3, total P, and DO results demonstrate similar patterns to the results of simulations made using streamflow from winter 2008.

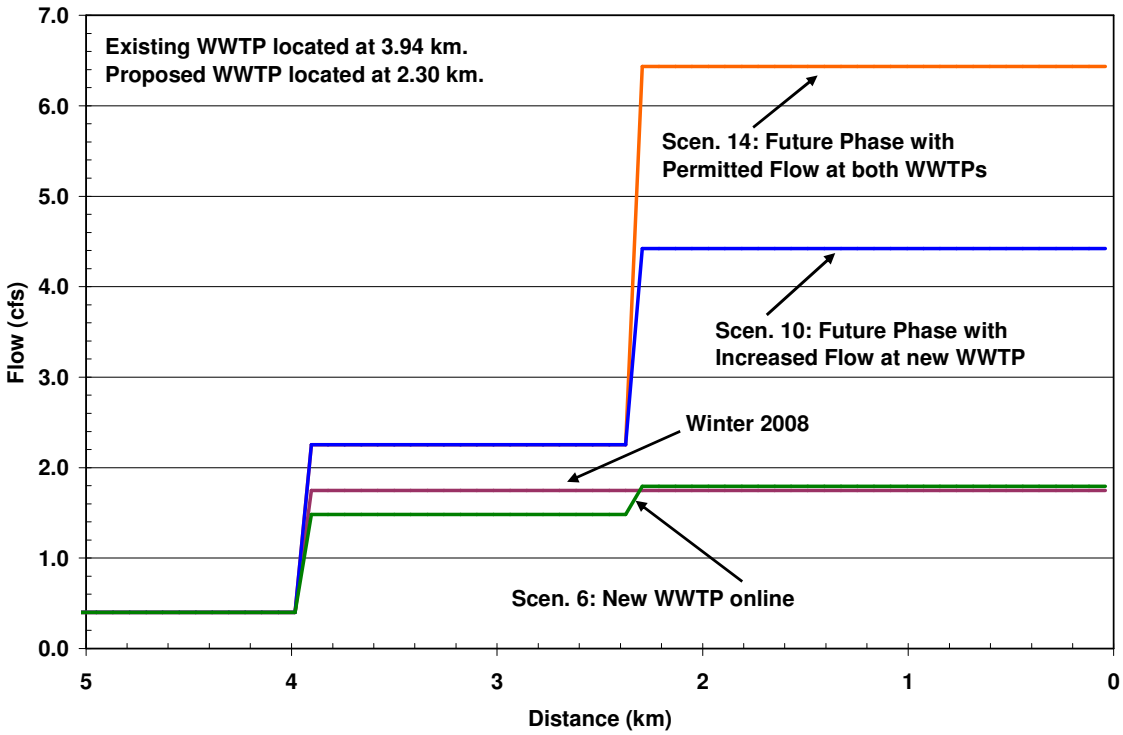


Figure 4-18. Simulated streamflow for winter 2008 models scenarios

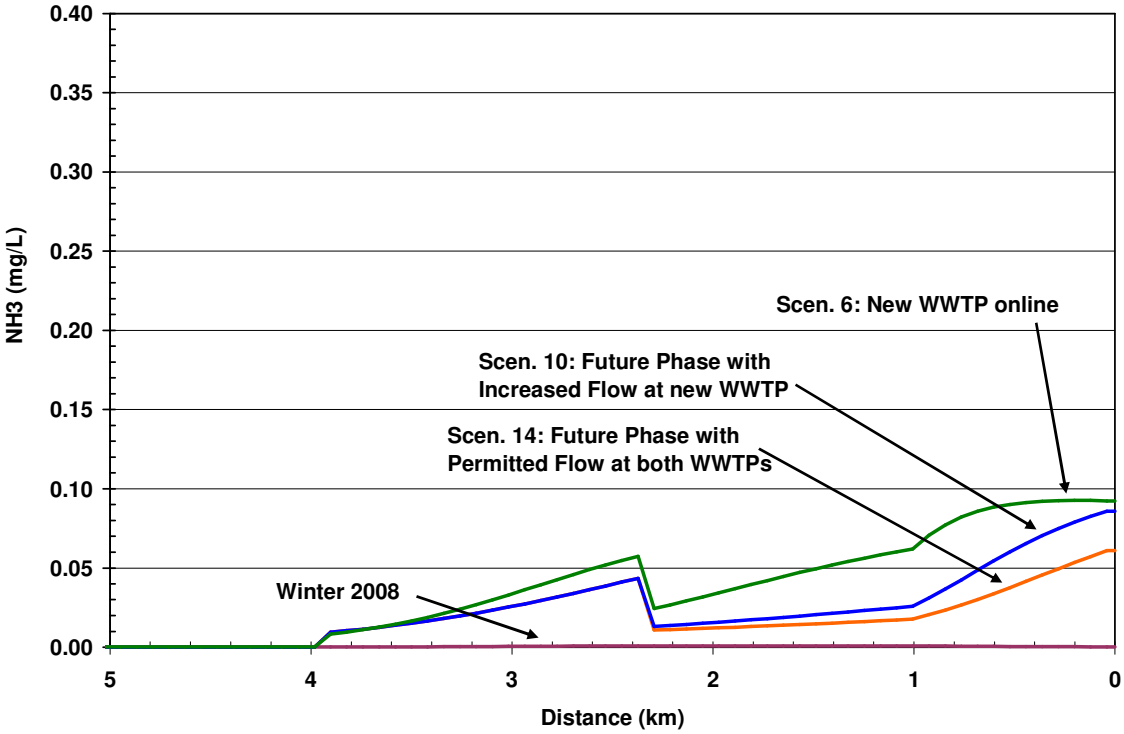


Figure 4-19. Simulated NH3 for winter 2008 models scenarios

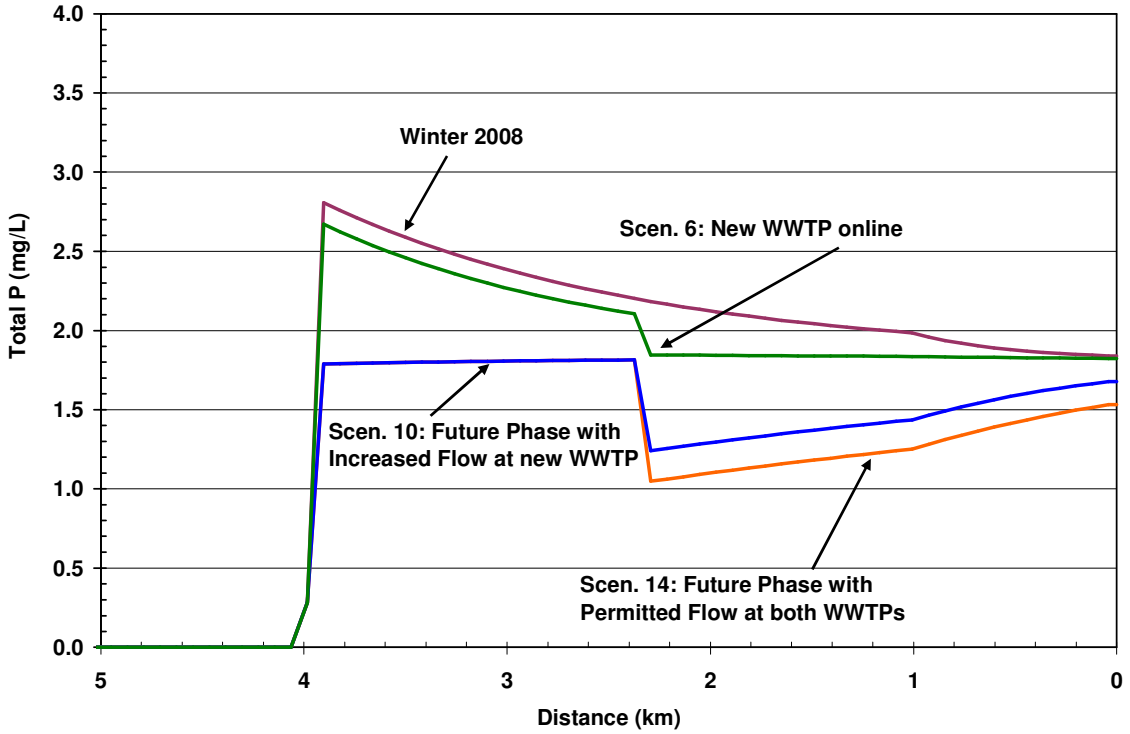


Figure 4-20. Simulated total P for winter 2008 models scenarios

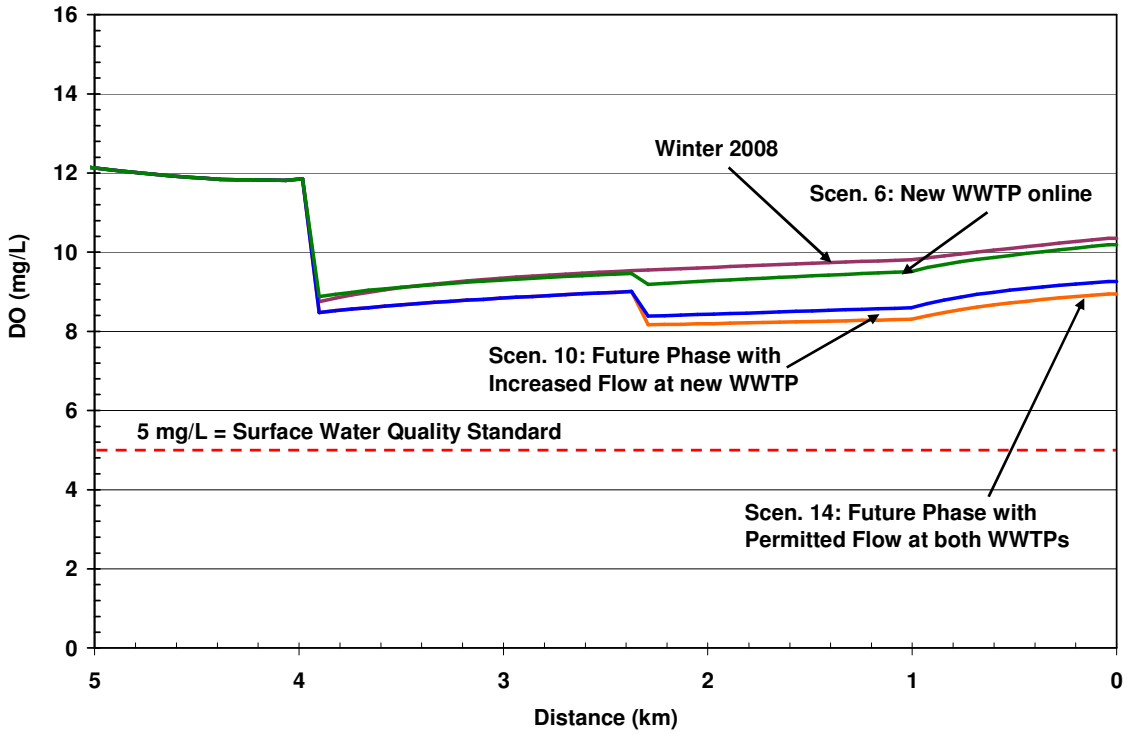


Figure 4-21. Simulated DO for winter 2008 models scenarios

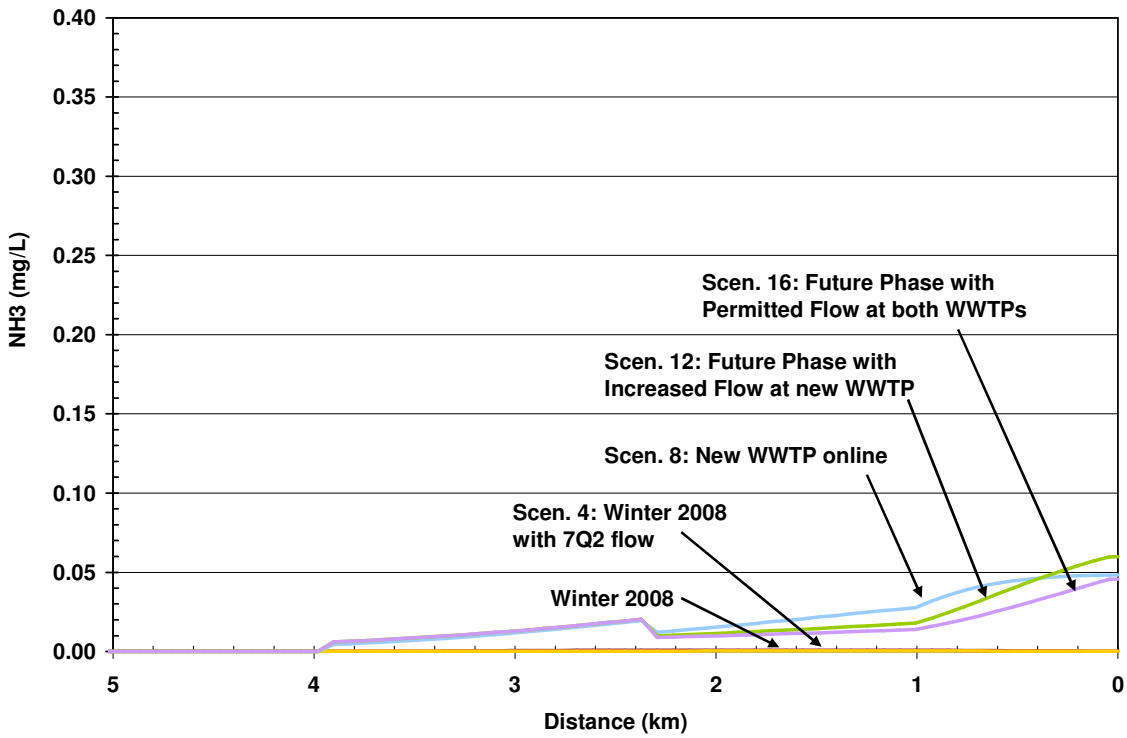


Figure 4-22. Simulated NH3 for winter 2008 model scenarios with 7Q2 streamflow of 1.1 ft^3/s

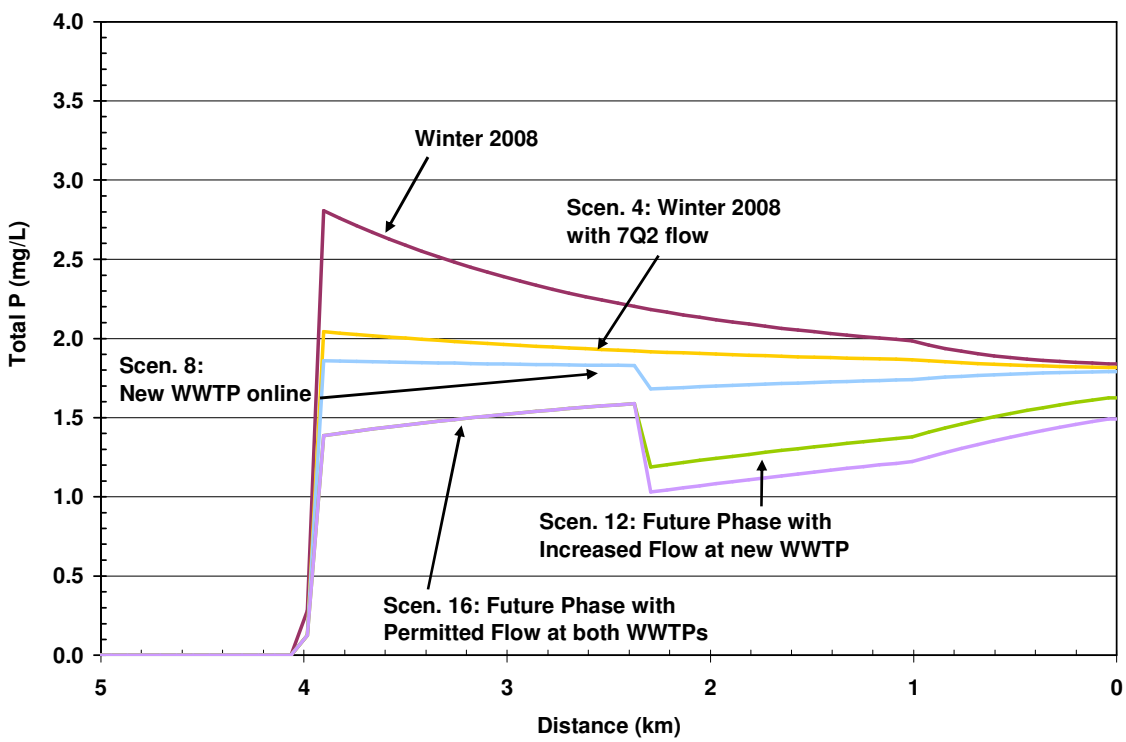


Figure 4-23. Simulated total P for winter 2008 model scenarios with 7Q2 streamflow of 1.1 ft^3/s

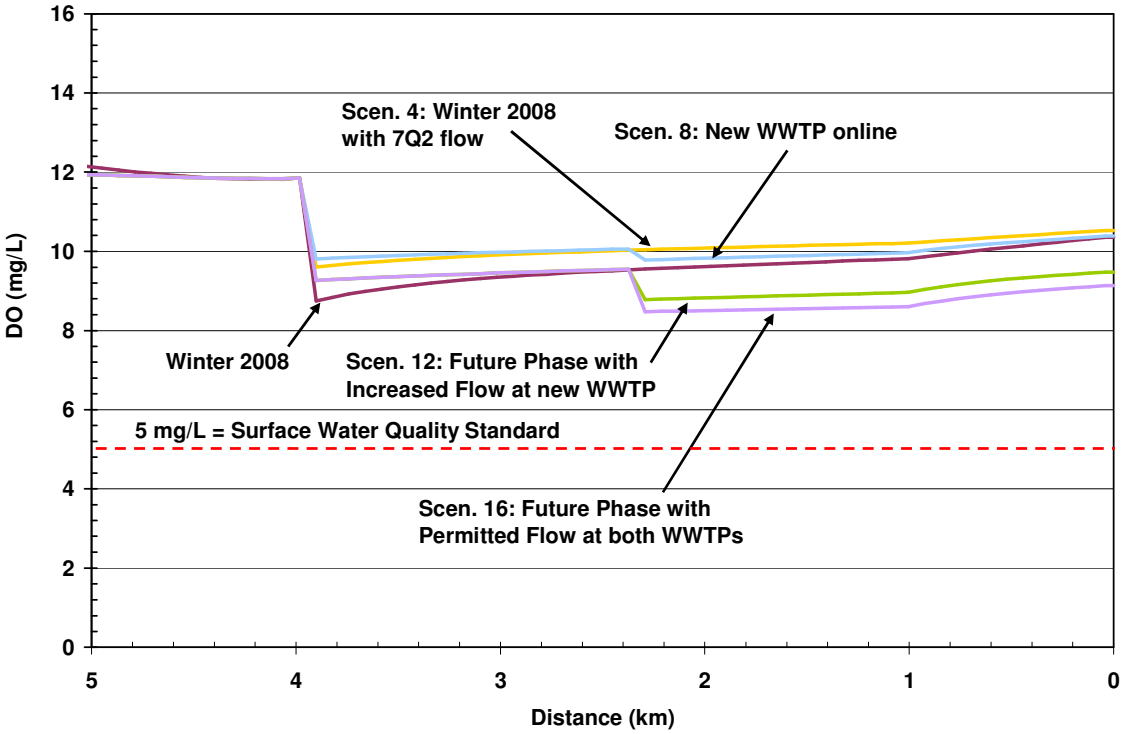


Figure 4-24. Simulated DO for winter 2008 model scenarios with 7Q2 streamflow of 1.1 ft^3/s

4.2.3.3 Varying P Concentrations at New WWTP

For two of the modeling scenarios, simulations were completed to examine the effects of varying the P concentration of the WWTP effluent on Cibolo Creek. These variations were completed for scenarios 9 and 13. For scenario 9, the discharge of the existing WWTP was simulated as 1.2 MGD and the discharge of the new WWTP was simulated as 1.4 MGD. While maintaining an effluent P concentration of 2 mg/L at the existing WWTP, the effluent P concentration at the new WWTP was varied. The simulations completed included P concentrations of 0.5 mg/L, 1 mg/L, 2 mg/L, and no P limit using the summer 2008 effluent P concentration. Figure 4-25 shows the results of these scenarios. In addition, using scenario 9 discharge volumes, the existing WWTP effluent P concentration was not limited and used summer 2008 effluent discharge concentration while the new WWTP effluent P concentration was varied as shown Figure 4-26.

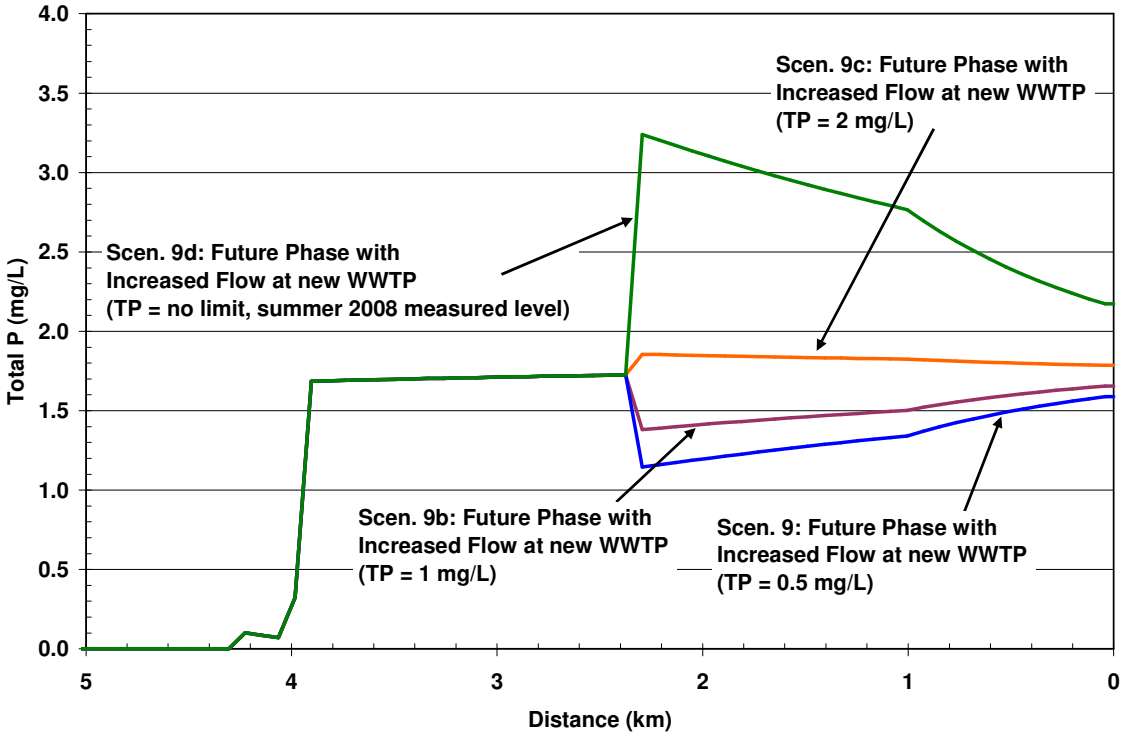


Figure 4-25. Simulated total P (Scenario 9) with the existing WWTP effluent P concentration at 2 mg/L and varying the new WWTP effluent P concentration

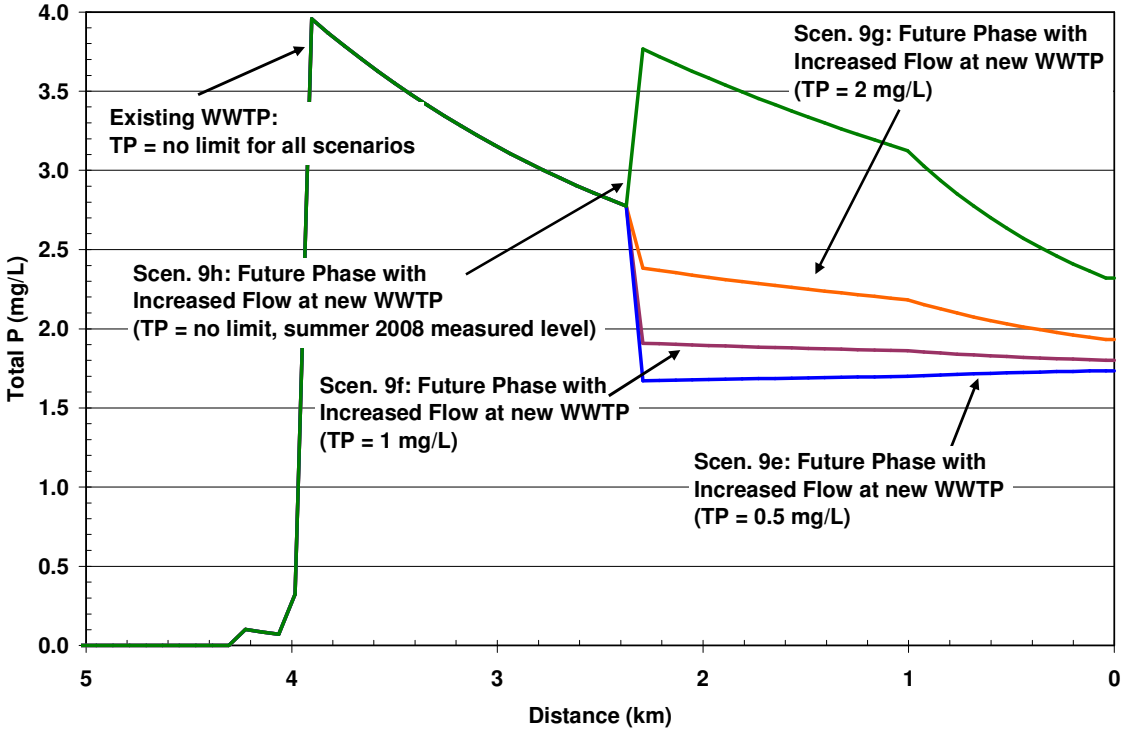


Figure 4-26. Simulated total P (Scenario 9) with existing WWTP effluent P concentration at the summer 2008 level and varying the new WWTP effluent P concentration

The constant-flow and varied effluent P concentration simulations for scenario 9 show that, as expected, all simulations are similar until the effluent from the new WWTP is discharged into Cibolo Creek. The scenarios of effluent P concentrations of 0.5 mg/L, 1 mg/L, and 2 mg/L show that total P concentrations in Cibolo Creek downstream of the WWTP asymptotically converge to within 0.5 mg/L of each other.

For scenario 13, the discharge of the existing WWTP was simulated as 1.2 MGD and the discharge of the new WWTP was simulated as 2.7 MGD. While maintaining an effluent P concentration of 2 mg/L at the existing WWTP, the effluent P concentration at the new WWTP was varied. The simulations completed included P concentrations of 0.5 mg/L, 1 mg/L, 2 mg/L, and no P limit using the summer 2008 effluent P concentration. Figure 4-27 shows the results of these scenarios. In addition, using scenario 9 discharge volumes, the existing WWTP effluent P concentration was not limited and used summer 2008 effluent discharge concentration while the new WWTP effluent P concentration was varied as shown Figure 4-28. Like the scenario 9 simulations, the simulations with effluent P concentrations of 0.5 mg/L, 1 mg/L, and 2 mg/L show that total P concentrations in Cibolo Creek downstream of the WWTP converge to within 0.5 mg/L of each other at approximately 2.4 km downstream of the new WWTP.

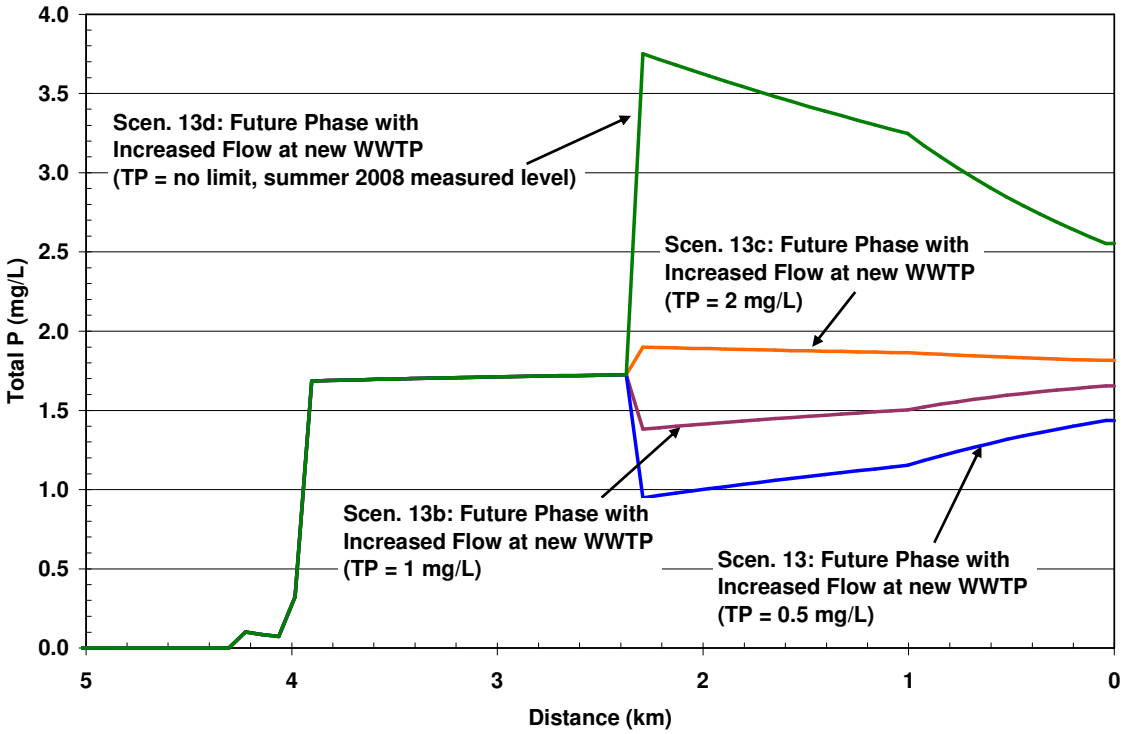


Figure 4-27. Simulated total P (Scenario 13) with the existing WWTP effluent P concentration at 2 mg/L and varying the new WWTP effluent P concentration

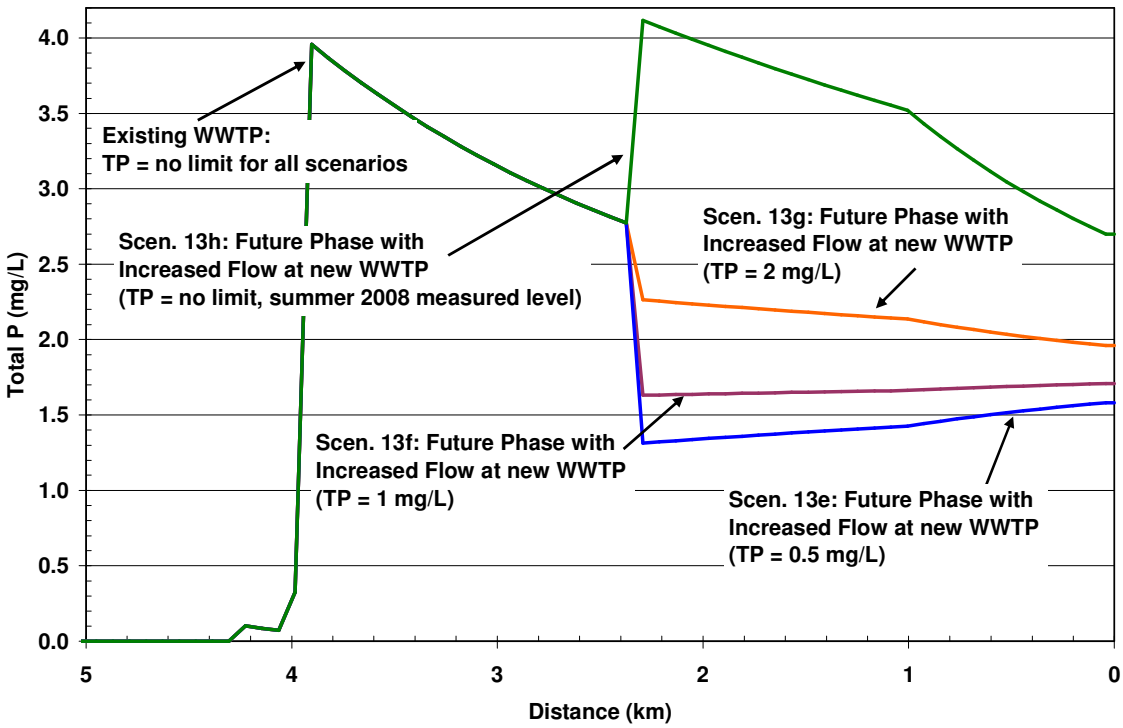


Figure 4-28. Simulated total P (Scenario 13) with existing WWTP effluent P concentration at the summer 2008 level and varying the new WWTP effluent P concentration

Section 5
Summary, Conclusions, and Recommendations

5.1 Summary

For this project two major tasks were completed: 1) twelve months of stream monitoring for flow and water quality in Cibolo Creek and the existing WWTP effluent and 2) nutrient modeling of Cibolo Creek.

5.1.1 Stream Monitoring

Based on a TCEQ-approved amendment to SARA's QAPP, stream monitoring results met the criteria to be reported to TCEQ and included in the STORET database. The data were analyzed in a laboratory accredited as complying with standards established by the National Environmental Laboratory Accreditation Conference (NELAC), and SARA staff and laboratory facilities were utilized for sample collection and analyses.

Water samples were collected 15 times between December 2007 and November 2008. Samples were collected from Cibolo Creek at one location upstream of Currey Creek, which receives the WWTP permitted discharge from the City of Boerne, and at two locations downstream of the permitted discharge. One downstream location corresponds to TCEQ Station 16702, Cibolo Creek 1.6 km downstream of SH 46. The other sampling location is located southeast of Boerne at the site of the former USGS streamflow gaging station 8183900, Cibolo Creek 2.5 mi SE of Boerne. The TCEQ station number for this location is 12853.

For each sampling event, field measurements of temperature, dissolved oxygen, conductivity, and pH were made with calibrated electronic instruments during sample collection at each monitoring location, as described in the QAPP and according to SARA laboratory reports. In addition, a nitrogen suite of ammonia, nitrate, and total Kjeldahl nitrogen and biochemical oxygen demand (BOD), orthophosphorus, chlorophyll a, and pheophytin also were laboratory analyzed.

A monthly 24-hour composite sample set was collected from the wastewater treatment plant effluent by City staff and then picked up by SARA staff on the day of stream monitoring. In addition, a duplicate discrete sample set, or field split, was collected from one of the stream stations each month for quality control purposes and assessment of variability, resulting in a total

monthly collection of five sample sets (three stream samples, a WWTP effluent sample, and a field split).

5.1.2 Nutrient Water Quality Modeling

Goals of the modeling included analysis of receiving water quality and developing a functional model that could be refined and used as a planning tool for the City of Boerne. Model selection for the project required consideration of present and future needs of the City of Boerne. QUAL2K was applied to Cibolo Creek, and the resulting calibrated models using the stream monitoring data simulate concentrations of nutrients in Cibolo Creek with ambient conditions and wastewater treatment loads as inputs by calculating the various mechanisms of nutrient transformations and fluxes.

The model includes 7.6 mi (12.2 km) of Cibolo Creek from the outlet of Boerne Lake to one-half mile downstream of the water quality sampling location 12853 southeast of Boerne. The model is divided into stream modeling segments every one-tenth of a mile.

Two base applications of QUAL2K to Cibolo Creek were developed. The first model application, the Summer 2008 model, was developed because low-flow and high-temperature conditions are typically used for water quality investigations to assess periods when water bodies may be most impaired and aquatic biota most stressed. The second base model application is the Winter 2008 model. For the summer model, July 22, 2008, was used and for the winter model, November 18, 2008, was used. These dates correspond to stream sample collection dates.

The calibrated Summer 2008 and Winter 2008 models were used to assess the permit requirement of 3 mg/L NH3 concentration and the new requirement of 2 mg/L P for the existing WWTP. The models were also used to evaluate water quality in Cibolo Creek if a new WWTP were constructed on Menger Creek just upstream of the confluence with Cibolo Creek. For the proposed WWTP, water quality criteria of 2 mg/L NH3 and 0.5 mg/L P were examined. Sixteen flow scenarios were tested using the Summer 2008 and Winter 2008 models, including:

- Existing Conditions,
- Existing Conditions with 7Q2 Streamflow,
- Future Phase A of Existing and New WWTP in Operation,
- Future Phase A of Existing and New WWTP in Operation with 7Q2 Streamflow,

- Future Phase B with P Limit at Existing WWTP and Increased Flow at New WWTP,
- Future Phase B with P Limit at Existing WWTP and Increased Flow at New WWTP with 7Q2 Streamflow,
- Future Phase C with Permitted Capacity at both WWTPs, and
- Future Phase C with Permitted Capacity at both WWTPs with 7Q2 streamflow.

In addition to these scenarios, additional simulations were completed to examine the effects of different effluent P concentration from the new WWTP on Cibolo Creek. These scenarios include:

- Future Phase B with 2 mg/L P Limit and with no P limit at Existing WWTP and Increased Flow at New WWTP
  - Effluent P concentrations at the new WWTP of 0.5 mg/L, 1 mg/L, 2 mg/L and summer 2008 P concentrations.
- Future Phase C with Permitted Capacity at both WWTPs and with 2 mg/L P Limit and with no P limit at Existing WWTP.
  - Effluent P concentrations at the new WWTP of 0.5 mg/L, 1 mg/L, 2 mg/L and summer 2008 P concentrations.

The stream monitoring data and model results show the extremely low flow, drought conditions present during 2008. For most modeling scenarios, Texas surface water quality standards are met. Simulated stream temperatures remain below the 90°F criterion, and simulated pH values are within the criterion of 6.5 to 9.0. However, DO concentrations for the summer 2008 scenarios sometimes drop below the 5 mg/L DO criterion. This is not to be unexpected as flows in 2008 were extremely low and several DO concentration values in the stream monitoring data were below 5 mg/L.

Because of the extremely low streamflow conditions of 2008, the current models could not be expected to assess the impacts of nonpoint sources on Cibolo Creek. Typically runoff from precipitation events may exhibit an increase in P runoff associated with sediment movement. However, in 2008 no significant rain events occurred.

Simulated total P and NH3 concentrations reflect the limits that may be required in a permit for a new WWTP and permit renewal for the existing WWTP. Although Cibolo Creek

has no P or NH3 criteria based on the Texas surface water quality standards, TCEQ screening levels for nutrients exist. If these screening levels are surpassed, segments of Cibolo Creek can be listed in TCEQ's "Water Bodies with Concerns for Use Attainment and Screening Levels" document. As discussed in Section 2, the upper segment of Cibolo Creek was listed for orthophosphorus and ammonia in 2008.

The modeling results show that within the planned discharge limits, nutrients remain within acceptable levels to maintain health in Cibolo Creek. In particular, when varying the effluent P concentration at the new WWTP, with or without a 2 mg/L effluent P concentration limit at the existing WWTP, the simulations of 0.5 mg/L, 1 mg/L, and 2 mg/L show that total P concentrations in Cibolo Creek downstream of the WWTP are not considerably different. This is especially important in Cibolo Creek, which for most of 2008 was effluent dominated. As is noted in the Summer 2008 issue of the TCEQ Water Quality Monitoring and Assessment Section's newsletter, *The Water Monitor*[28], which is included in this report as Appendix D, Cibolo Creek's aquatic life is abundant even though the stream is effluent dominated and in drought.

5.2 Conclusions

Specific conclusions based on this project include the following.

- The water quality modeling represents the most conservative case possible. The third driest year ever on record was 2008 based on rainfall records in San Antonio from 1871 to 2008. In San Antonio, the recorded rainfall was 13.76 inches.
- The calibrated model represents the 2008 conditions in Cibolo Creek.
- For most modeling scenarios, Texas surface water quality standards are met. Simulated stream temperatures remain below the 90°F criterion, and simulated pH values are within the criterion of 6.5 to 9.0. However, DO concentrations for the summer 2008 scenarios sometimes drop below the 5 mg/L DO criterion. This is not to be unexpected as flows in 2008 were extremely low and several DO concentration values in the stream monitoring data were below 5 mg/L.

[28] Blair, Michele, 2008. Cibolo Creek – A Success Story, The Water Monitor, TCEQ Water Quality Monitoring and Assessment Section newsletter, Vol. 1, Issue 2, Summer 2008.

- The modeling results show that within the planned discharge limits, nutrients remain within acceptable levels to maintain health in Cibolo Creek. In particular, when varying the effluent P concentration at the new WWTP, with or without a 2 mg/L effluent P concentration limit at the existing WWTP, the simulations of 0.5 mg/L, 1 mg/L, and 2 mg/L show that total P concentrations in Cibolo Creek downstream of the WWTP are not considerably different.

5.3 Recommendations

Specific recommendations based on this project include the following.

- The City of Boerne should resume stream monitoring of Cibolo Creek to capture a better representation of water quality in a non-drought situation if the permitting schedule allows when normal streamflow returns. Drought conditions still exist within the Cibolo Creek watershed. Precipitation as reported by the National Weather Service for San Antonio for the month of January 2009 was 0.27 in. This value is 16% of the normal January precipitation of 1.66 in.
- The City of Boerne should consider necessary additional scenarios with different water quality criteria and flow regimes as plans for and design of a new WWTP solidify.
- The City of Boerne should share the existing modeling results with TCEQ permitting and surface water quality staff. Coordinating with TCEQ staff on completion of the new WWTP permit and permit renewal for the existing WWTP is recommended.
- The City of Boerne should complete additional scenarios with the calibrated Summer 2008 and Winter 2008 models, depending on TCEQ-recommended permit requirements. A stream water quality model does not show how a WWTP should be designed, but it can show how various criteria can be met.
- The City of Boerne should develop a calibrated water quality model that better reflects non-drought conditions or at least 7Q2 streamflow conditions if non-drought streamflow and water quality data are available within WWTP permitting and design deadlines. With a calibrated non-drought condition water quality

model, it would be more feasible to determine the impacts of nonpoint sources of P on Cibolo Creek.

Appendix A
Analytical Laboratory Results and Graphical Analysis

A.1 Analytical Laboratory Results

Table A-1 shows data analyzed by the San Antonio River Authority (SARA) for this study.

During several of the sampling events and related analysis, atypical situations occurred and are described here. For the first five WWTP samples, the biochemical oxygen demand (BOD) WWTP values reported were <2 mg/L, but the values should have been reported as <50 mg/L. The samples were analyzed as influent instead of as effluent samples, and as a result higher sample dilutions were utilized. On Day 5, each sample dilution yielded dissolved oxygen depletions of < 2 mg/L and the result was reported as such. However, the result did not reflect a dilution factor of 25 which yields the correct value of <50 mg/L. SARA implemented corrective actions to their quality system to prevent recurrence per email communication with Chuck Lorea[29].

On August 14, 2008, the WWTP effluent sample corresponding to the stream data collection was not available. The SARA field staff sampled again on August 26th and was able to collect all necessary samples. On November 18, 2008, the field pH post calibration did not meet the necessary criteria; therefore, the results were not reported.

Flows for the December 2007, January 2008, and February 2008 sample events seem to exhibit abnormally high streamflow at the 12853 sampling location. However, the SARA field staff believes that these flows are accurate and were possibly caused by spring flow between the Menger Creek confluence with Cibolo Creek and the 12853 location after the unusually high precipitation experienced in 2007. The increased flow may also be caused by flow from Menger Creek and Brown Creek, which enter Cibolo Creek downstream of site 16702 but upstream of site 12853.

Table A-2 shows the analytical laboratory results, as well as the nutrient constituents organic P, biomass, and the chlorophyll to pheophytin ratio calculated based on reported nutrient concentrations. The results are shown in units of concentration and in units of stream load based

[29] Email dated August 24, 2008. Chuck Lorea, Laboratory Operations Supervisor, San Antonio River Authority.

on the reported streamflow. The field split is not shown in Table A-2, as it represents results from all three stream sampling locations.

A.2 Graphical Analysis of Laboratory Results

This section presents figures of the analytical laboratory results in units of concentration and where applicable in units of calculated load. In addition to the laboratory data, the figures show City of Boerne Discharge Monitoring Report data to serve as a comparison to the water quality sampling results from this study. Table A-3 summarizes the discharge monitoring report data from March 2005 through December 2008. Figures A-1 through A-26 show time series figures of the concentrations and loads of the study constituents.

Table A-1. Analytical Lab Results

Site ID	Site Name	Location	Sub-basin	Site Type	Date	Flow	Flow	Water Temp	DO	pH	Sp Cond	Secchi	Secchi	BOD_5	Chloride	Ammonia	Nitrate	TKN	Total P	Ortho-P	Chlorophyll	Pheophytin
						cfs	GPD	oC	mg/L		uS/cm	qualifier	m	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	ug/L	ug/L
N/A	WWTP	Boerne	1908	fixed	12/18/2007		890,700	18.1	8.5	7.7	907	-	-	<50	109	<0.1	0.61	0.58	2.45	3.17	<1	<1
N/A	WWTP	Boerne	1908	fixed	1/15/2008		869,400	17.2	8.1	7.8	992	N/A	N/A	<50	128	<0.1	0.569	0.779	3.89	3.04	<1	<1
N/A	WWTP	Boerne	1908	fixed	2/12/2008		866,500	19.4	7.7	7.8	922	N/A	N/A	<50	123	<0.1	<0.05	0.859	4.43	3.1	2	<1
N/A	WWTP	Boerne	1908	fixed	3/25/2008		877,000	18.9	8.2	7.7	960	N/A	N/A	<50	136	0.105	0.445	0.935	4.09	3.62	<1	<1
N/A	WWTP	Boerne	1908	fixed	4/15/2008		862,900	20.5	7.2	7.3	901	N/A	N/A	<50	126	<0.1	<0.05	0.751	2.8	2.97	1	<1
N/A	WWTP	Boerne	1908	fixed	05/13/08		994,500	23.6	7.4	7.8	942	N/A	N/A	<2	120	<0.1	<0.05	0.806	3.45	3.27	1	<1
N/A	WWTP	Boerne	1908	fixed	06/10/08		935,600	26.7	7.1	7.6	582	N/A	N/A	<2	130	<0.1	0.277	0.704	4.03	3.86	1	27
N/A	WWTP	Boerne	1908	fixed	06/24/08		858,000	26.6	7.5	7.7	997	N/A	N/A	<2	129	<0.1	1.64	1.01	3.11	3.13	1	<1
N/A	WWTP	Boerne	1908	fixed	07/08/08		914,800	26.8	6.7	7.8	940	N/A	N/A	<2	137	<0.1	4.52	1	4.59	4.63	2	<1
N/A	WWTP	Boerne	1908	fixed	07/22/08		873,100	27.7	8.6	7.6	928	N/A	N/A	<2	131	<0.1	2.1	0.877	4.3	4.92	1	<1
N/A	WWTP	Boerne	1908	fixed	08/14/08		861,600	28.2	6.9	7.7	896	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
N/A	WWTP	Boerne	1908	fixed	08/26/08		944,100	27.8	7.1	7.5	665	N/A	N/A	<2	120	<0.1	<0.05	0.823	2.47	2.46	<1	<1
N/A	WWTP	Boerne	1909	fixed	09/16/08		924,600	25.1	7	7.7	910	N/A	N/A	<2	127	<0.1	<0.05	0.897	1.77	1.73	<1	<1
N/A	WWTP	Boerne	1908	fixed	10/07/08		888,800	25.8	7.3	7.6	891	N/A	N/A	<2	135	<0.1	1.97	1.15	3.68	3.55	<1	<1
N/A	WWTP	Boerne	1908	fixed	11/18/08		868,400	19.8	7.7	N/A	968	N/A	N/A	<2	136	<0.1	8.51	0.99	3.62	3.51	<1	<1
N/A	Field Split	Boerne	1908	fixed	12/18/2007	-	-	-	-	-	-	-	-	<2	16.8	<0.1	0.526	<0.2	<0.06	<0.03	<1	<1
N/A	Field Split	Boerne	1908	fixed	1/15/2008	-	-	-	-	-	-	-	-	<2	36.4	<0.1	0.174	0.318	0.697	0.4	4	3
N/A	Field Split	Boerne	1908	fixed	2/12/2008	-	-	-	-	-	-	-	-	<2	19.9	<0.1	0.545	<.2	0.06	<0.03	1	<1
N/A	Field Split	Boerne	1908	fixed	3/25/2008	-	-	-	-	-	-	-	-	<2	54.8	<0.1	0.324	0.509	0.52	0.986	8	5
N/A	Field Split	Boerne	1908	fixed	4/15/2008	-	-	-	-	-	-	-	-	<50	63.5	<0.1	<0.05	0.477	0.948	1.2	4	7
N/A	Field Split	Boerne	1908	fixed	05/13/08	-	-	-	-	-	-	-	-	<2	23.2	<0.1	0.318	0.303	<0.02	<0.02	4	3
N/A	Field Split	Boerne	1908	fixed	06/10/08	-	-	-	-	-	-	-	-	<2	78.6	<0.1	0.366	0.722	2.02	1.95	3	3
N/A	Field Split	Boerne	1908	fixed	06/24/08	-	-	-	-	-	-	-	-	2	91.1	<0.1	<0.05	0.866	1.59	1.78	4	6
N/A	Field Split	Boerne	1908	fixed	07/08/08	-	-	-	-	-	-	-	-	<2	22.9	0.102	0.145	0.49	0.029	<.02	5	2
N/A	Field Split	Boerne	1908	fixed	07/22/08	-	-	-	-	-	-	-	-	<2	101	<0.1	1.15	0.68	3	2.25	3	1
N/A	Field Split	Boerne	1908	fixed	08/14/08	-	-	-	-	-	-	-	-	3	96.5	<0.1	<0.05	1.25	2.43	2.53	33	21
N/A	Field Split	Boerne	1908	fixed	08/26/08	-	-	-	-	-	-	-	-	<2	48.2	0.119	0.104	1.04	1.08	0.971	7	11
N/A	Field Split	Boerne	1909	fixed	09/16/08	-	-	-	-	-	-	-	-	<2	19.6	<0.1	0.252	0.433	<0.02	<0.02	3	1
N/A	Field Split	Boerne	1908	fixed	10/07/08	-	-	-	-	-	-	-	-	<2	104	<0.1	1.67	0.92	2.25	2.27	<1	<1
N/A	Field Split	Boerne	1908	fixed	11/18/08	-	-	-	-	-	-	-	-	<2	111	<0.1	0.122	0.683	2.75	2.71	5	2
12854	Cibolo Creek	Herff Road	1908	fixed	12/18/2007	7.3	-	13.5	9.4	7.6	526	>	1.2	<2	16.7	<0.1	0.524	<0.2	<0.06	<0.03	<1	<1
12854	Cibolo Creek	Herff Road	1908	fixed	1/15/2008	5.2	-	12.8	8.9	7.6	544	>	1.2	<2	19	<0.1	0.502	0.208	0.133	<0.03	<1	<1
12854	Cibolo Creek	Herff Road	1908	fixed	2/12/2008	2.7	-	16.6	7.9	7.6	552	>	1.2	<2	19.9	<0.1	0.545	<0.2	<0.06	<0.03	1	2
12854	Cibolo Creek	Herff Road	1908	fixed	3/25/2008	2.6	-	17.5	9.3	7.6	550	>	1.2	<2	20	<0.1	0.34	0.3	0.049	<0.02	4	<1
12854	Cibolo Creek	Herff Road	1908	fixed	4/15/2008	1.2	-	18	9.5	7.2	592	>	1.2	2	22.7	<0.1	0.344	0.373	0.052	0.088	3	<1
12854	Cibolo Creek	Herff Road	1908	fixed	05/13/08	1.4	-	21.8	5.4	7.3	633	>	1.2	<2	23.2	<0.1	0.318	0.276	0.026	<0.02	4	3
12854	Cibolo Creek	Herff Road	1908	fixed	06/10/08	0.6	-	24.6	5.1	7.2	661	>	1.2	<2	22.8	<0.1	0.214	0.285	0.021	<0.02	3	2
12854	Cibolo Creek	Herff Road	1908	fixed	06/24/08	0.6	-	24.9	4.3	7.4	671		0.95	<2	23.1	0.2	0.168	0.58	0.032	<0.02	4	3
12854	Cibolo Creek	Herff Road	1908	fixed	07/08/08	0.8	-	24.3	3.2	7.6	674		0.85	<2	22.9	0.105	0.144	0.504	0.026	<0.02	5	2
12854	Cibolo Creek	Herff Road	1908	fixed	07/22/08	0.4	-	25.8	4.7	7.4	675	>	1.2	<2	23.1	<0.1	0.209	0.32	0.033	0.131	7	3
12854	Cibolo Creek	Herff Road	1908	fixed	08/14/08	0.5	-	25.8	5.4	7.4	634		0.75	<2	21.2	<0.1	0.218	0.537	0.021	<0.02	6	2
12854	Cibolo Creek	Herff Road	1908	fixed	08/26/08	1.5	-	24.2	2.4	7.3	471		0.72	3	13.1	<0.1	0.173	0.531	0.055	<0.02	13	3
12855	Cibolo Creek	Herff Road	1909	fixed	09/16/08	0.9	-	21.9	5.3	7.3	674	>	1.2	<2	19.6	<0.1	0.251	0.427	<0.02	<0.02	3	1
12854	Cibolo Creek	Herff Road	1908	fixed	10/07/08	0.159	-	21.5	4.9	7.6	670		1	<2	19.2	<0.1	0.228	0.54	<0.02	<0.02	2	1
12854	Cibolo Creek	Herff Road	1908	fixed	11/18/08	0.4	-	12.2	2.5	N/A	710	>	1.2	<2	19.6	<0.1	0.053	0.33	<0.02	<0.02	2	<1
16702	Cibolo Creek	1.6 KM d/s of SH 46	1908	fixed	12/18/2007	10	-	13.1	8.9	7.8	598	>	1.2	<2	32.1	<0.1	0.665	<0.2	0.571	0.499	2.5	1.6
16702	Cibolo Creek	1.6 KM d/s of SH 46	1908	fixed	1/15/2008	2	-	12.5	7.7	7.8	654	>	1.2	<0.1	40.8	<0.1	0.639	0.268	0.82	0.603	2	<1
16702	Cibolo Creek	1.6 KM d/s of SH 46	1908	fixed	2/12/2008	4.1	-	16.9	6.2	7.7	661	>	1.2	<2	46.9	<0.1	0.357	0.401	1.15	0.7	2	3
16702	Cibolo Creek	1.6 KM d/s of SH 46	1908	fixed	3/25/2008	4.1	-	17.1	6.6	7.8	679	>	1.2	<2	54.7	<0.1	0.323	0.426	0.526	0.992	6	6
16702	Cibolo Creek	1.6 KM d/s of SH 46	1908	fixed	4/15/2008	2.1	-	17	5.6	7.6	738	>	1.2	2	64.6	<0.1	0.261	0.576	1.05	1.32	5	12
16702	Cibolo Creek	1.6 KM d/s of SH 46	1908	fixed	05/13/08	2.2	-	21.4	4.8	7.6	788	>	1.2	<2	67.8	<0.1	0.221	0.416	1.65	1.98	4	4
16702	Cibolo Creek	1.6 KM d/s of SH 46	1908	fixed	06/10/08	<0.01	-	25.7	4	7.5	833		0.64	<2	77.6	<0.1	0.365	0.616	1.81	1.84	3	2
16702	Cibolo Creek	1.6 KM d/s of SH 46	1908	fixed	06/24/08	0.2	-	25.2	4.9	7.7	877		1.06	<2	94.4	0.111	0.334	0.465	1.58	1.87	2	2
16702	Cibolo Creek	1.6 KM d/s of SH 46	1908	fixed	07/08/08	1.2	-	24.2	4.4	7.8	886		0.97	<2	99	<0.1	3.46	0.678	2.68	2.66	5	1
16702	Cibolo Creek	1.6 KM d/s of SH 46	1908	fixed	07/22/08	<0.01	-	25.9	4.6	7.6	865	>	1.2	<2	101	<0.1	1.15	0.684	3.01	2.24	3	1
16702	Cibolo Creek	1.6 KM d/s of SH 46	1908	fixed	08/14/08	0.8	-	25.5	4.3	7.5	741		1.10	2	77.1	<0.1	0.27	0.661	2.13	2.09	3	3
16702	Cibolo Creek	1.6 KM d/s of SH 46	1908	fixed	08/26/08	0.1	-	25.4	4.4	7.7	681	>	1.2	<2	67.7	<0.1	0.205	0.591	1.26	1.2	1	1
16703	Cibolo Creek	1.6 KM d/s of SH 46	1909	fixed	09/16/08	<0.01	-	21.3	5.5	7.7	815	>	1.2	<2	83.3	<0.1	0.081	0.654	1.39	1.36	6	8
16702	Cibolo Creek	1.6 KM d/s of SH 46	1908	fixed	10/07/08	-0.2682	-	22.1	4.9	7.9	871		0.17	<2	103	<0.1	1.67	0.754	2.31	2.23	<1	<1
16702	Cibolo Creek	1.6 KM d/s of SH 46	1908	fixed	11/18/08	<0.01	-	12.5	6.4	N/A	921	>	1.2	<2	111	<0.1	2.74	0.573	2.42	2.38	5	3
12853	Cibolo Creek	SE of Boerne	1908	fixed	12/18/2007	54	-	12.4	10.8	8.1	590	>	1.2	<2	30.5	<0.1	0.324	<0.2	0.475	0.418	<1	<1
12853	Cibolo Creek	SE of Boerne	1908	fixed	1/15/2008	79	-	11.1	10.9	8.2	628	>	1.2	<2	36.3	<0.1	0.174	0.394	0.666	0.4	4	3
12853	Cibolo Creek	SE of Boerne	1908	fixed	2/12/2008	40	-	16.8	9.2	8.1	652	>	1.2	<2	45	<0.1	0.211	0.344	0.794	0.468	<1	1
12853	Cibolo Creek	SE of Boerne	1908	fixed	3/25/2008	3.6	-	16.3	5.3	7.9	646		0.98	2	48.1	<0.1	<0.05	0.851	0.459	0.861	4	4
12853	Cibolo Creek	SE of Boerne	1908	fixed	4/15/2008	3.1	-	17.3	9.9	8.3	703		0.32	<2	63	<0.1	<0.05	0.513	0.919	1.21	4	7
12853	Cibolo Creek	SE of Boerne	1908	fixed	05/13/08	1.2	-	22	5.3	7.9	787		0.57	<2	70.6	<0.1	<0.05	0.67	1.78	1.8	1	2
12853	Cibolo Creek	SE of Boerne	1908	fixed	06/10/08	1.1	-	27.1	6.1	7.9	834		0.17	3	82	0.171	<0.05	1.32	1.78	1.73	22	4
12853	Cibolo Creek	SE of Boerne	1908	fixed	06/24/08	0.4	-	26.2	6.3	8.1	850		0.12	2	94	<0.1	<0.05	0.769	1.59	1.78	4	5
12853	Cibolo Creek	SE of Boerne	1908	fixed	07/08/08	0.01	-	25.5	4.7	8.1	854		0.13	<2	98.9	<0.1	0.108	0.849	2.21	2.08	19	15
12853	Cibolo Creek	SE of Boerne	1908	fixed	07/22/08	0.8	-	27.8	6.1	8.2	854		0.46	3	102	<0.1	<0.05	1.08	2.47	2.36	42	41
12853	Cibolo Creek	SE of Boerne	1908	fixed	08/14/08	0.9	-	27.1	5.1	7.5	817		0.18	5	95.7	<0.1	<0.05	1.12	2.59	2.55	32	22
12853	Cibolo Creek	SE of Boerne	1908	fixed	08/26/08	2.8	-	26.3	5.9	7.9	545		0.41	<2	48.1	0.119	0.104	0.961	0.982	0.961	6	10
12854	Cibolo Creek	SE of Boerne	1909	fixed	09/16/08	1	-	22	8.6	8.3	817		0.3	<2	85.2	<0.1	<0.05	0.754	1.56	1.54	5	3
12853	Cibolo Creek	SE of Boerne	1908	fixed	10/07/08	1.1232	-	22.9	9.5	8.4	866		0.32	<2	103	<0.1	0.428	0.885	1.99	1.93	8	<1
12853	Cibolo Creek	SE of Boerne	1908	fixed	11/18/08	<0.01	-	11.1	11	N/A	920		0.87	<2	109	<0.1	0.119	0.728	2.75	2.68	6	2

A-2 Constituent Stream Load

Site ID	Site Name	Location	Sub-basin	Site Type	Date	Flow	Flow	Chloride	Chloride	TKN	TKN	Ammonia	Ammonia	Nitrate	Nitrate	Total P	Total P	Ortho-P	Ortho-P	Organic P	Organic P	Chlorophyll	Biomass	Pheophytin	C/P ratio
						cfs	GPD	mg/L	lbs/day	mg/L	lbs/day	mg/L	lbs/day	mg/L	lbs/day	mg/L	lbs/day	mg/L	lbs/day	mg/L	lbs/day	ug/L	mg/l	ug/L	
N/A	WWTP	Boerne	1908	fixed	12/18/2007	-	890,700	109	810.22	0.58	4.31	0.1	0.74	0.61	4.53	2.45	18.21	3.17	23.56	0	0.00	<1	0.067	<1	1.0
N/A	WWTP	Boerne	1908	fixed	1/15/2008	-	869,400	128	928.70	0.779	5.65	0.1	0.73	0.569	4.13	3.89	28.22	3.04	22.06	0.85	6.17	<1	0.067	<1	1.0
N/A	WWTP	Boerne	1908	fixed	2/12/2008	-	866,500	123	889.45	0.859	6.21	0.1	0.72	0.05	0.36	4.43	32.03	3.1	22.42	1.33	9.62	2	0.134	<1	4.0
N/A	WWTP	Boerne	1908	fixed	3/25/2008	-	877,000	136	995.37	0.935	6.84	0.105	0.77	0.445	3.26	4.09	29.93	3.62	26.49	0.47	3.44	<1	0.067	<1	1.0
N/A	WWTP	Boerne	1908	fixed	4/15/2008	-	862,900	126	907.36	0.751	5.41	0.1	0.72	0.05	0.36	2.8	20.16	2.97	21.39	0	0.00	1	0.067	<1	2.0
N/A	WWTP	Boerne	1908	fixed	05/13/08	-	994,500	120	995.94	0.806	6.69	0.1	0.83	0.05	0.41	3.45	28.63	3.27	27.14	0.18	1.49	1	0.067	<1	2.0
N/A	WWTP	Boerne	1908	fixed	06/10/08	-	935,600	130	1015.03	0.704	5.50	0.1	0.78	0.277	2.16	4.03	31.47	3.86	30.14	0.17	1.33	1	0.067	27	0.0
N/A	WWTP	Boerne	1908	fixed	06/24/08	-	858,000	129	923.69	1.01	7.23	0.1	0.72	1.64	11.74	3.11	22.27	3.13	22.41	0	0.00	1	0.067	<1	2.0
N/A	WWTP	Boerne	1908	fixed	07/08/08	-	914,800	137	1045.91	1	7.63	0.1	0.76	4.52	34.51	4.59	35.04	4.63	35.35	0	0.00	2	0.134	<1	4.0
N/A	WWTP	Boerne	1908	fixed	07/22/08	-	873,100	131	954.51	0.877	6.39	0.1	0.73	2.1	15.30	4.3	31.33	4.92	35.85	0	0.00	1	0.067	<1	2.0
N/A	WWTP	Boerne	1908	fixed	08/14/08	-	861,600	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
N/A	WWTP	Boerne	1908	fixed	08/26/08	-	944,100	120	945.47	0.823	6.48	0.1	0.79	0.05	0.39	2.47	19.46	2.46	19.38	0.01	0.08	<1	0.067	<1	1.0
N/A	WWTP	Boerne	1909	fixed	09/16/08	-	924,600	127	979.95	0.897	6.92	0.1	0.77	0.05	0.39	1.77	13.66	1.73	13.35	0.04	0.31	<1	0.067	<1	1.0
N/A	WWTP	Boerne	1908	fixed	10/07/08	-	888,800	135	1001.35	1.15	8.53	0.1	0.74	1.97	14.61	3.68	27.30	3.55	26.33	0.13	0.96	<1	0.067	<1	1.0
N/A	WWTP	Boerne	1908	fixed	11/18/08	-	868,400	136	985.61	0.99	7.17	0.1	0.72	8.51	61.67	3.62	26.23	3.51	25.44	0.11	0.80	<1	0.067	<1	1.0
																				0					
12854	Cibolo Creek	Herff Road	1908	fixed	12/18/2007	7.3	-	16.7	657.55	0.2	7.87	0.1	3.94	0.524	20.63	0.06	2.36	0.03	1.18	0.03	1.18	<1	0.067	<1	1.0
12854	Cibolo Creek	Herff Road	1908	fixed	1/15/2008	5.2	-	19	532.90	0.208	5.83	0.1	2.80	0.502	14.08	0.133	3.73	0.03	0.84	0.103	2.89	<1	0.067	<1	1.0
12854	Cibolo Creek	Herff Road	1908	fixed	2/12/2008	2.7	-	19.9	289.81	0.2	2.91	0.1	1.46	0.545	7.94	0.06	0.87	0.03	0.44	0.03	0.44	1	0.067	2	0.5
12854	Cibolo Creek	Herff Road	1908	fixed	3/25/2008	2.6	-	20	280.48	0.3	4.21	0.1	1.40	0.34	4.77	0.049	0.69	0.02	0.28	0.029	0.41	4	0.268	<1	8.0
12854	Cibolo Creek	Herff Road	1908	fixed	4/15/2008	1.2	-	22.7	146.93	0.373	2.41	0.1	0.65	0.344	2.23	0.052	0.34	0.088	0.57	0	0.00	3	0.201	<1	6.0
12854	Cibolo Creek	Herff Road	1908	fixed	05/13/08	1.4	-	23.2	175.19	0.276	2.08	0.1	0.76	0.318	2.40	0.026	0.20	0.02	0.15	0.006	0.05	4	0.268	3	1.3
12854	Cibolo Creek	Herff Road	1908	fixed	06/10/08	0.6	-	22.8	73.79	0.285	0.92	0.1	0.32	0.214	0.69	0.021	0.07	0.02	0.06	0.001	0.00	3	0.201	2	1.5
12854	Cibolo Creek	Herff Road	1908	fixed	06/24/08	0.6	-	23.1	74.76	0.58	1.88	0.2	0.65	0.168	0.54	0.032	0.10	0.02	0.06	0.012	0.04	4	0.268	3	1.3
12854	Cibolo Creek	Herff Road	1908	fixed	07/08/08	0.8	-	22.9	98.81	0.504	2.17	0.105	0.45	0.144	0.62	0.026	0.11	0.02	0.09	0.006	0.03	5	0.335	2	2.5
12854	Cibolo Creek	Herff Road	1908	fixed	07/22/08	0.4	-	23.1	49.84	0.32	0.69	0.1	0.22	0.209	0.45	0.033	0.07	0.131	0.28	0	0.00	7	0.469	3	2.3
12854	Cibolo Creek	Herff Road	1908	fixed	08/14/08	0.5	-	21.2	57.17	0.537	1.45	0.1	0.27	0.218	0.59	0.021	0.06	0.02	0.05	0.001	0.00	6	0.402	2	3.0
12854	Cibolo Creek	Herff Road	1908	fixed	08/26/08	1.5	-	13.1	105.99	0.531	4.30	0.1	0.81	0.173	1.40	0.055	0.44	0.02	0.16	0.035	0.28	13	0.871	3	4.3
12855	Cibolo Creek	Herff Road	1909	fixed	09/16/08	0.9	-	19.6	95.15	0.427	2.07	0.1	0.49	0.251	1.22	0.02	0.10	0.02	0.10	0	0.00	3	0.201	1	3.0
12854	Cibolo Creek	Herff Road	1908	fixed	10/07/08	0.159	-	19.2	16.47	0.54	0.46	0.1	0.09	0.228	0.20	0.02	0.02	0.02	0.02	0	0.00	2	0.134	1	2.0
12854	Cibolo Creek	Herff Road	1908	fixed	11/18/08	0.4	-	19.6	42.29	0.33	0.71	0.1	0.22	0.053	0.11	0.02	0.04	0.02	0.04	0	0.00	2	0.134	<1	4.0
16702	Cibolo Creek	1.6 KM d/s of SH 46	1908	fixed	12/18/2007	10	-	32.1	1731.40	0.2	10.79	0.1	5.39	0.665	35.87	0.571	30.80	0.499	26.91	0.072	3.88	2.5	0.1675	1.6	1.6
16702	Cibolo Creek	1.6 KM d/s of SH 46	1908	fixed	1/15/2008	2	-	40.8	440.13	0.268	2.89	0.1	1.08	0.639	6.89	0.82	8.85	0.603	6.50	0.217	2.34	2	0.134	<1	4.0
16702	Cibolo Creek	1.6 KM d/s of SH 46	1908	fixed	2/12/2008	4.1	-	46.9	1037.17	0.401	8.87	0.1	2.21	0.357	7.89	1.15	25.43	0.7	15.48	0.45	9.95	2	0.134	3	0.7
16702	Cibolo Creek	1.6 KM d/s of SH 46	1908	fixed	3/25/2008	4.1	-	54.7	1209.66	0.426	9.42	0.1	2.21	0.323	7.14	0.526	11.63	0.992	21.94	0	0.00	6	0.402	6	1.0
16702	Cibolo Creek	1.6 KM d/s of SH 46	1908	fixed	4/15/2008	2.1	-	64.6	731.72	0.576	6.52	0.1	1.13	0.261	2.96	1.05	11.89	1.32	14.95	0	0.00	5	0.335	12	0.4
16702	Cibolo Creek	1.6 KM d/s of SH 46	1908	fixed	05/13/08	2.2	-	67.8	804.53	0.416	4.94	0.1	1.19	0.221	2.62	1.65	19.58	1.98	23.50	0	0.00	4	0.268	4	1.0
16702	Cibolo Creek	1.6 KM d/s of SH 46	1908	fixed	06/10/08	0.01	-	77.6	4.19	0.616	0.03	0.1	0.01	0.365	0.02	1.81	0.10	1.84	0.10	0	0.00	3	0.201	2	1.5
16702	Cibolo Creek	1.6 KM d/s of SH 46	1908	fixed	06/24/08	0.2	-	94.4	101.83	0.465	0.50	0.111	0.12	0.334	0.36	1.58	1.70	1.87	2.02	0	0.00	2	0.134	2	1.0
16702	Cibolo Creek	1.6 KM d/s of SH 46	1908	fixed	07/08/08	1.2	-	99	640.78	0.678	4.39	0.1	0.65	3.46	22.39	2.68	17.35	2.66	17.22	0.02	0.13	5	0.335	1	5.0
16702	Cibolo Creek	1.6 KM d/s of SH 46	1908	fixed	07/22/08	0.01	-	101	5.45	0.684	0.04	0.1	0.01	1.15	0.06	3.01	0.16	2.24	0.12	0.77	0.04	3	0.201	1	3.0
16702	Cibolo Creek	1.6 KM d/s of SH 46	1908	fixed	08/14/08	0.8	-	77.1	332.69	0.661	2.85	0.1	0.43	0.27	1.17	2.13	9.19	2.09	9.02	0.04	0.17	3	0.201	3	1.0
16702	Cibolo Creek	1.6 KM d/s of SH 46	1908	fixed	08/26/08	0.1	-	67.7	36.52	0.591	0.32	0.1	0.05	0.205	0.11	1.26	0.68	1.2	0.65	0.06	0.03	1	0.067	1	1.0
16703	Cibolo Creek	1.6 KM d/s of SH 46	1909	fixed	09/16/08	0.01	-	83.3	4.49	0.654	0.04	0.1	0.01	0.081	0.00	1.39	0.07	1.36	0.07	0.03	0.00	6	0.402	8	0.8
16702	Cibolo Creek	1.6 KM d/s of SH 46	1908	fixed	10/07/08	0	-	103	0.00	0.754	0.00	0.1	0.00	1.67	0.00	2.31	0.00	2.23	0.00	0.08	0.00	<1	0.067	<1	1.0
16702	Cibolo Creek	1.6 KM d/s of SH 46	1908	fixed	11/18/08	0.01	-	111	5.99	0.573	0.03	0.1	0.01	2.74	0.15	2.42	0.13	2.38	0.13	0.04	0.00	5	0.335	3	1.7
12853	Cibolo Creek	SE of Boerne	1908	fixed	12/18/2007	54	-	30.5	8883.53	0.2	58.25	0.1	29.13	0.324	94.37	0.475	138.35	0.418	121.75	0.057	16.60	<1	0.067	<1	1.0
12853	Cibolo Creek	SE of Boerne	1908	fixed	1/15/2008	79	-	36.3	15467.71	0.394	167.89	0.1	42.61	0.174	74.14	0.666	283.79	0.4	170.44	0.266	113.34	4	0.268	3	1.3
12853	Cibolo Creek	SE of Boerne	1908	fixed	2/12/2008	40	-	45	9708.78	0.344	74.22	0.1	21.58	0.211	45.52	0.794	171.31	0.468	100.97	0.326	70.33	<1	0.067	1	0.5
12853	Cibolo Creek	SE of Boerne	1908	fixed	3/25/2008	3.6	-	48.1	933.98	0.851	16.52	0.1	1.94	0.05	0.97	0.459	8.91	0.861	16.72	0	0.00	4	0.268	4	1.0
12853	Cibolo Creek	SE of Boerne	1908	fixed	4/15/2008	3.1	-	63	1053.40	0.513	8.58	0.1	1.67	0.05	0.84	0.919	15.37	1.21	20.23	0	0.00	4	0.268	7	0.6
12853	Cibolo Creek	SE of Boerne	1908	fixed	05/13/08	1.2	-	70.6	456.96	0.67	4.34	0.1	0.65	0.05	0.32	1.78	11.52	1.8	11.65	0	0.00	1	0.067	2.00	0.5
12853	Cibolo Creek	SE of Boerne	1908	fixed	06/10/08	1.1	-	82	486.52	1.32	7.83	0.171	1.01	0.05	0.30	1.78	10.56	1.73	10.26	0.05	0.30	22	1.474	4	5.5
12853	Cibolo Creek	SE of Boerne	1908	fixed	06/24/08	0.4	-	94	202.81	0.769	1.66	0.1	0.22	0.05	0.11	1.59	3.43	1.78	3.84	0	0.00	4	0.268	5	0.8
12853	Cibolo Creek	SE of Boerne	1908	fixed	07/08/08	0.01	-	98.9	5.33	0.849	0.05	0.1	0.01	0.108	0.01	2.21	0.12	2.08	0.11	0.13	0.01	19	1.273	15	1.3
12853	Cibolo Creek	SE of Boerne	1908	fixed	07/22/08	0.8	-	102	440.13	1.08	4.66	0.1	0.43	0.05	0.22	2.47	10.66	2.36	10.18	0.11	0.47	42	2.814	41	1.0
12853	Cibolo Creek	SE of Boerne	1908	fixed	08/14/08	0.9	-	95.7	464.57	1.12	5.44	0.1	0.49	0.05	0.24	2.59	12.57	2.55	12.38	0.04	0.19	32	2.144	22	1.5
12853	Cibolo Creek	SE of Boerne	1908	fixed	08/26/08	2.8	-	48.1	726.43	0.961	14.51	0.119	1.80	0.104	1.57	0.982	14.83	0.961	14.51	0.021	0.32	6	0.402	10	0.6
12854	Cibolo Creek	SE of Boerne	1909	fixed	09/16/08	1	-	85.2	459.55	0.754	4.07	0.1	0.54	0.05	0.27	1.56	8.41	1.54	8.31	0.02	0.11	5	0.335	3	1.7
12853	Cibolo Creek	SE of Boerne	1908	fixed	10/07/08	1.1232	-	103	624.00	0.885	5.36	0.1	0.61	0.428	2.59	1.99	12.06	1.93	11.69	0.06	0.36	8	0.536	<1	16.0
12853	Cibolo Creek	SE of Boerne	1908	fixed	11/18/08	0.01	-	109	5.88	0.728	0.04	0.1	0.01	0.119	0.01	2.75	0.15	2.68	0.14	0.07	0.00	6	0.402	2	3.0

Table A-3. Discharge monitoring report data for City of Boerne WWTP effluent

MONITORING PERIOD END DATE	DISSOLVED OXYGEN, (DO)	pH CONC MAXIMUM	pH CONC MINIMUM	TSS QTY AVERAGE	TSS CONC MAXIMUM	TSS CONC AVERAGE	NO3 QTY AVERAGE[1]	NITROGEN, AMMONIA TOTAL (AS N) AS N CONC MAXIMUM	NITROGEN, AMMONIA TOTAL (AS N) AS N CONC AVERAGE	Flow QTY MAXIMUM	Flow QTY AVERAGE	Flow QTY MAXIMUM	Flow QTY AVERAGE - annual	Fecal Col CONC MAXIMUM	Fecal Col CONC AVERAGE	BOD QTY AVERAGE	BOD CONC MAXIMUM	BOD CONC AVERAGE
	mg/L	S.U.	S.U.	lbs/day	mg/L	mg/L	mg/L	mg/L	mg/L	MGD	MGD	GPM	MGD	COLONY FORMING UNITS PER 100ML	COLONY FORMING UNITS PER 100ML	lbs/day	mg/L	mg/L
31-Mar-05	5.8	7.9	7.7	18.3	3	1.4	1.75	0.2	0.13	2.2979	1.5878	2104	1.2388	5.1	3.3	14.3	2	1.1
30-Apr-05	6.3	8	7.8	17.3	3	2	< 0.96	0.2	< 0.10	1.2511	1.0636	1415	1.2313	6.2	4.3	14.8	3	1.7
31-May-05	6.4	7.9	7.7	12.3	3	1.6	< 0.76	0.1	< 0.10	1.3945	0.9436	2260	1.2054	7	4.7	9.4	3	1.3
30-Jun-05	6	7.9	7.8	16.3	3	2.3	0.85	0.2	0.12	1.0039	0.8376	1144	1.1877	12.8	7.1	8.6	2	1.2
31-Jul-05	5.7	8	7.8	12.8	5	2	0.65	0.1	0.1	0.9561	0.7836	1345	1.1608	20.7	15.2	6.5	1	< 1.0
31-Aug-05	5.7	8	7.8	12.8	4	2	0.72	0.2	0.11	1.226	0.7985	2120	1.1513	30.5	11.3	7.8	2	1.2
30-Sep-05	5.7	8	7.8	16.9	5	2.7	2.78	0.9	0.43	0.8532	0.7899	1031	1.1383	82.9	10.8	7.1	2	1.1
31-Oct-05	6.1	8	7.8	17.9	5	2.8	2.61	1.4	0.39	0.9213	0.7728	1039	1.1167	14.7	5.9	10.3	3	1.6
30-Nov-05	6.3	8	7.8	12.2	3	1.9	1.58	0.5	0.24	0.8774	0.7944	1150	1.0151	10.6	5.5	7.1	2	1.1
31-Dec-05	7.5	7.9	7.7	14	3	2.1	0.82	0.2	0.12	0.8704	0.7972	1016	0.9657	7.3	5.2	10.3	2	1.6
31-Jan-06	7.3	7.9	7.7	15	4	2.3	6.95	5	1.08	0.8548	0.78	960	0.9421	2.9	2.5	7.9	2	1.2
28-Feb-06	7.2	8	7.7	16.9	4	2.7	8.23	2.5	1.34	0.8155	0.7665	9.64	0.895	11.6	3	7	2	1.1
31-Mar-06	6.4	7.9	7.7	12.8	5	2	3.05	2.5	0.47	0.9805	0.7969	1098	0.8278	12.4	7.9	6.4	1	1
30-Apr-06	6.6	7.9	7.7	20.6	4	3.1	2.21	0.6	0.34	0.9413	0.8015	1024	0.8063	26.6	16.9	7.4	2	1.1
31-May-06	6.5	8	7.8	23.3	6	3.4	1.64	0.4	0.24	0.9911	0.8315	1113	0.7968	11.8	7	9	2	1.3
30-Jun-06	6.3	8	7.8	18	4	2.8	1.72	0.4	0.27	1.0048	0.7875	1125	0.7926	28.8	17.5	8.5	2	1.3
31-Jul-06	6.1	7.9	7.7	17.2	4	2.6	1.49	0.3	0.23	0.9341	0.8103	1334	0.7949	18	10.1	8.2	2	1.3
31-Aug-06	5.7	8.1	7.8	14.7	3	2.2	1.02	0.2	0.16	0.8908	0.8016	1786	0.7952	11.6	8.8	11	4	1.7
30-Sep-06	6.1	7.9	7.7	11.8	2	1.8	0.66	0.1	0.1	0.9625	0.8185	1125	0.7975	77.6	20.8	7.4	2	1.1
31-Oct-06	6.4	7.9	7.7	16.1	4	2.3	0.77	0.2	0.11	0.9629	0.8256	1133	0.802	13.9	8.7	7.8	2	1.1
30-Nov-06	6.9	7.9	7.7	23.9	5	3.5	0.78	0.2	0.11	1.141	0.8317	2022	0.8051	6.5	3.6	7.8	2	1.1
31-Dec-06	7.2	7.9	7.6	24.4	5	3.4	0.87	0.2	0.12	0.9246	0.8595	1053	0.8104	6	4.1	8.7	2	1.2
31-Jan-07	7.3	7.8	7.6	11.1	2	1.3	2.1	0.8	0.24	1.4176	1.0165	1639	0.8297	6	4.4	12.1	2	2
28-Feb-07	7.4	7.9	7.7	11.9	3	1.6	2.61	1.3	0.35	1.019	0.8889	1145	0.8391	13.6	7.7	14.6	2	2
31-Mar-07	6	7.9	7.7	20.7	2	1.7	38.78	12.4	2.91	2.5939	1.4347	4060	0.8932	7.7	4.2	24.5	2	2
30-Apr-07	6	7.9	7.8	13.9	2	1.1	13.7	4.7	1.25	2.176	1.5179	1954	0.9521	8.6	2.7	25.4	2	2
31-May-07	5.7	7.9	7.7	24.2	4	1.8	2.14	0.3	0.19	4.0282	1.5217	3618	1.0108	23.9	7.4	23.8	2	2
30-Jun-07	5.4	7.9	7.5	34.6	6	2.6	2.92	0.9	0.2	3.1572	1.5456	4301	1.0731	13.2	6.6	27.4	3	2.1
31-Jul-07	5.3	7.9	7.5	30.1	3	1.7	2.55	0.3	0.13	4.1283	2.27	4500	1.197	12.6	5.9	36.6	2	2
31-Aug-07	5.3	7.9	7.7	22.5	2	1.3	1.91	0.2	0.11	5.0233	2.0772	4500	1.3054	5.9	4.7	34.8	2	2
30-Sep-07	5.8	7.9	7.7	17.2	3	1.4	1.83	0.3	0.14	2.0481	1.5224	1771	1.3632	14.3	7.6	27.3	3	2.1
31-Oct-07	6.3	7.9	7.7	20.6	5	2.3	0.96	0.2	0.11	1.2201	1.0362	1443	1.3811	15.4	9.1	17.2	2	2
30-Nov-07	6.2	7.9	7.7	11.7	2	1.6	0.75	0.1	0.1	0.9769	0.9057	1170	1.3872	8.3	6.5	17.6	4	2.3
31-Dec-07	6.8	7.9	7.7	12.8	3	1.8	1.01	0.2	0.14	0.9688	0.88	1119	1.3889	6.3	4.6	14.7	2	2
31-Jan-08	7.4	8	7.7	14.3	3	2	1.11	0.4	0.16	0.9579	0.8733	1173	1.3768	8.3	4.5	19	4	2.7
29-Feb-08	6.7	8.1	7.7	17.3	4	2.4	1.02	0.3	0.14	0.9381	0.8668	1089	1.3775	9.3	5.4	14.2	2	2
31-Mar-08	6.9	7.9	7.7	15.3	3	2.1	0.9	0.2	0.13	1.0881	0.871	1213	1.3296	31.6	11.2	16.2	3	2.3
30-Apr-08	6.6	7.9	7.7	14.5	3	2	0.81	0.2	0.11	0.9233	0.878	1106	1.277	8.9	7.6	16.9	5	2.3
31-May-08	6.1	7.9	7.7	18	4	2.4	0.82	0.2	0.11	1.038	0.8939	1265	1.2237	24	5.6	15.6	3	2
30-Jun-08	5.9	8.1	7.9	16.9	3	2.3	0.94	0.2	0.13	0.9545	0.8925	1300	1.17	16.3	10	17.8	3	2.4
31-Jul-08	6.1	8	7.8	19.3	4	2.7	0.73	0.1	0.1	1.1044	0.8804	1274	1.052	38	17.5	14.5	2	2
31-Aug-08	6	8	7.7	16.5	5	2.1	0.87	0.2	0.11	1.263	0.9237	1631	0.954	47.1	28.3	15.5	2	2
30-Sep-08	5.9	7.9	7.8	15.2	4	2	0.84	0.2	0.11	0.9841	0.9117	1173	0.9038	25.4	12.7	16	3	2.1
31-Oct-08	6.2	7.9	7.7	24.4	6	3.3	0.72	0.1	0.1	1.0124	0.8908	1373	0.8915	17.3	11.6	16.9	3	2.3
30-Nov-08	6.2	7.9	7.6	13.5	3	1.9	0.9	0.2	0.13	0.9149	0.8638	1176	0.888	43	27.4	17.1	4	2.4
31-Dec-08	6.6	7.9	7.6	19.3	4	2.7	-	0.3	0.14	0.9125	0.8465	1081	0.8852	22.7	19.5	14.3	2	2

[1] Not reported by City of Boerne. Estimated by governing agency (TCEQ or EPA).

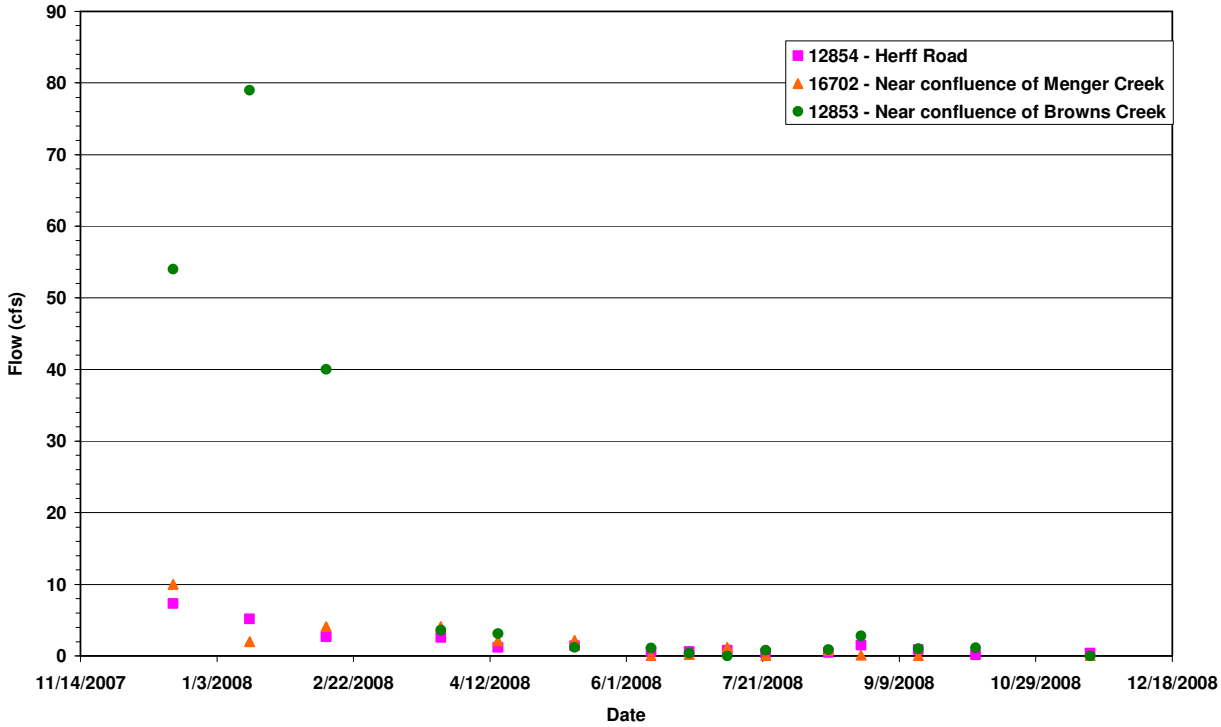


Figure A-1. Field measurement of streamflow

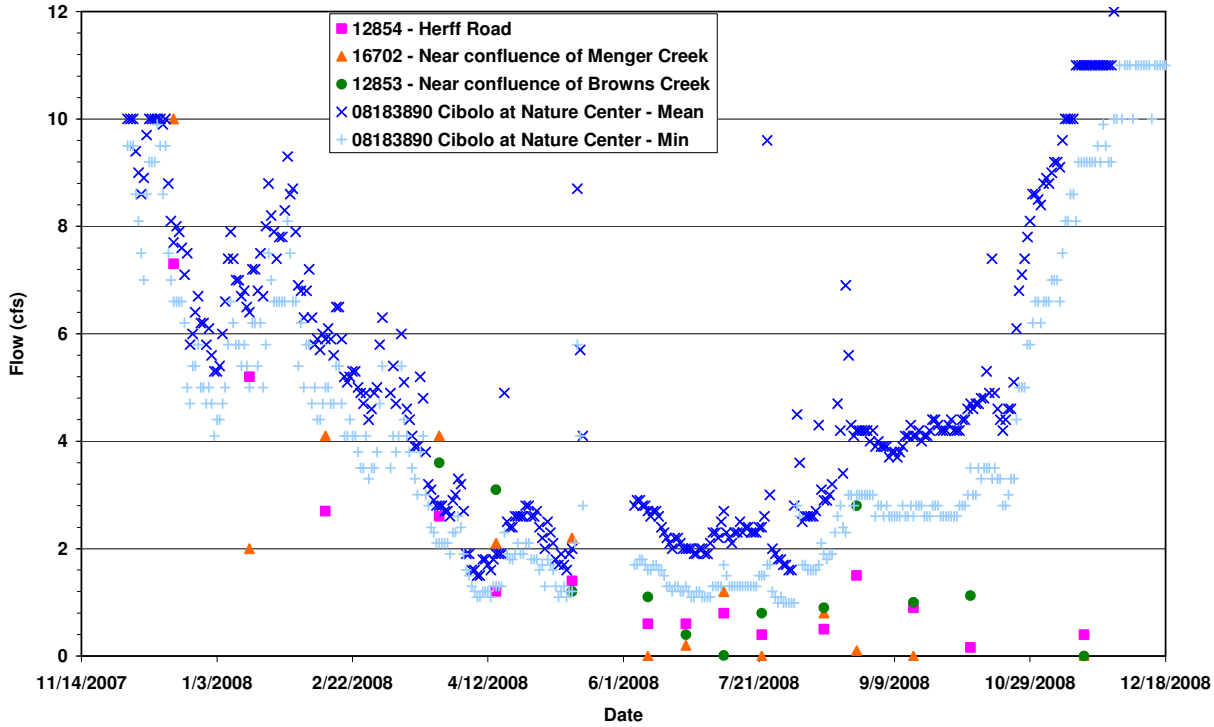


Figure A-2. Field measurement of streamflow (zoomed to a maximum of 12 cfs)

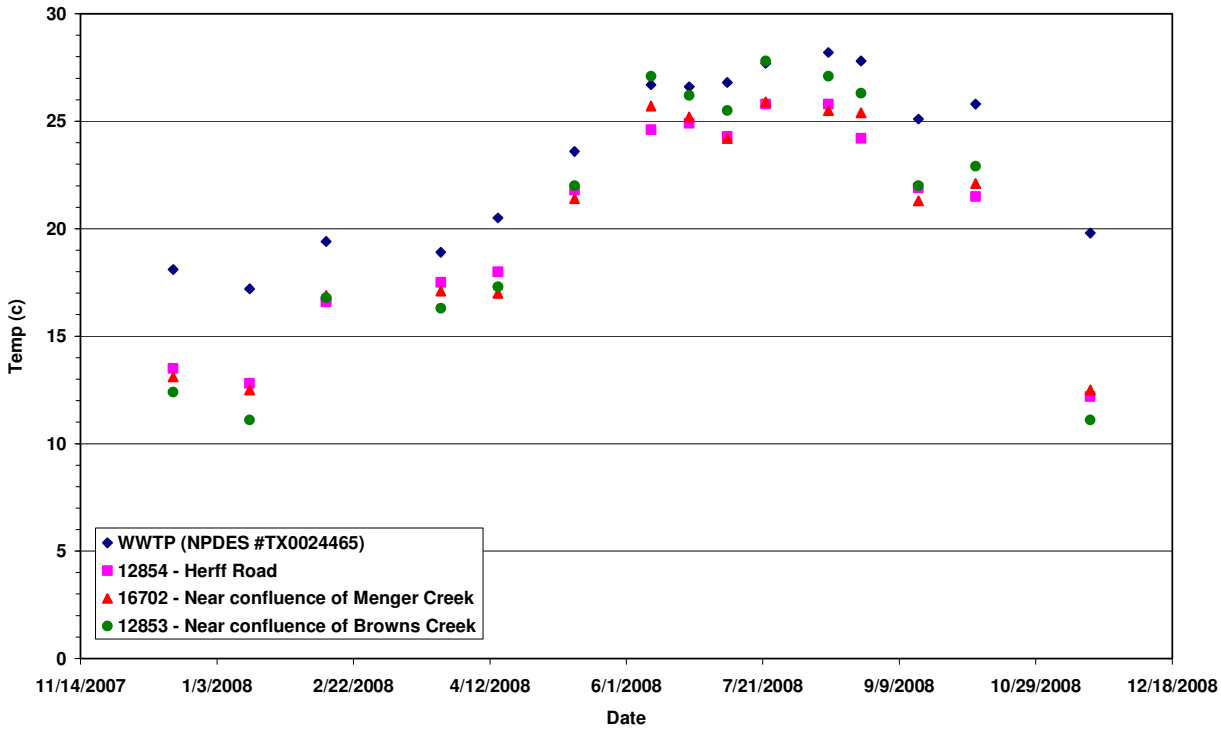


Figure A-3. Field measurement of water temperature

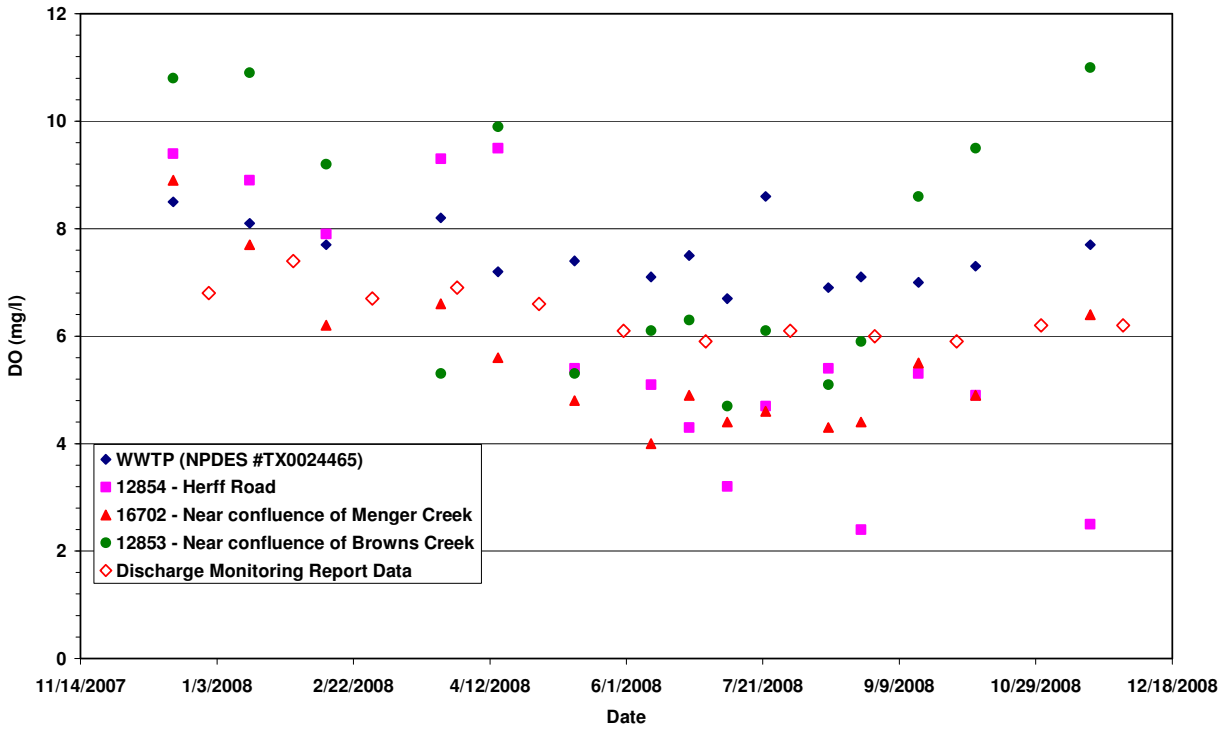


Figure A-4. Field measurement of dissolved oxygen

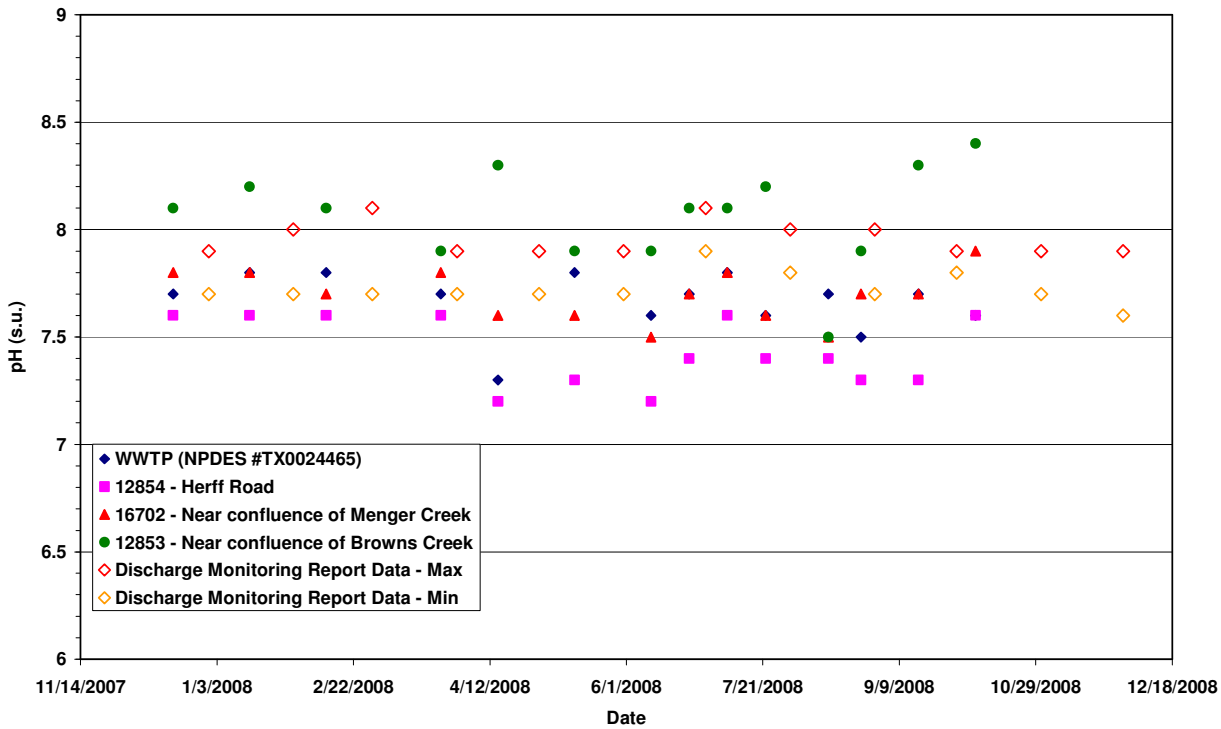


Figure A-5. Field measurement of pH

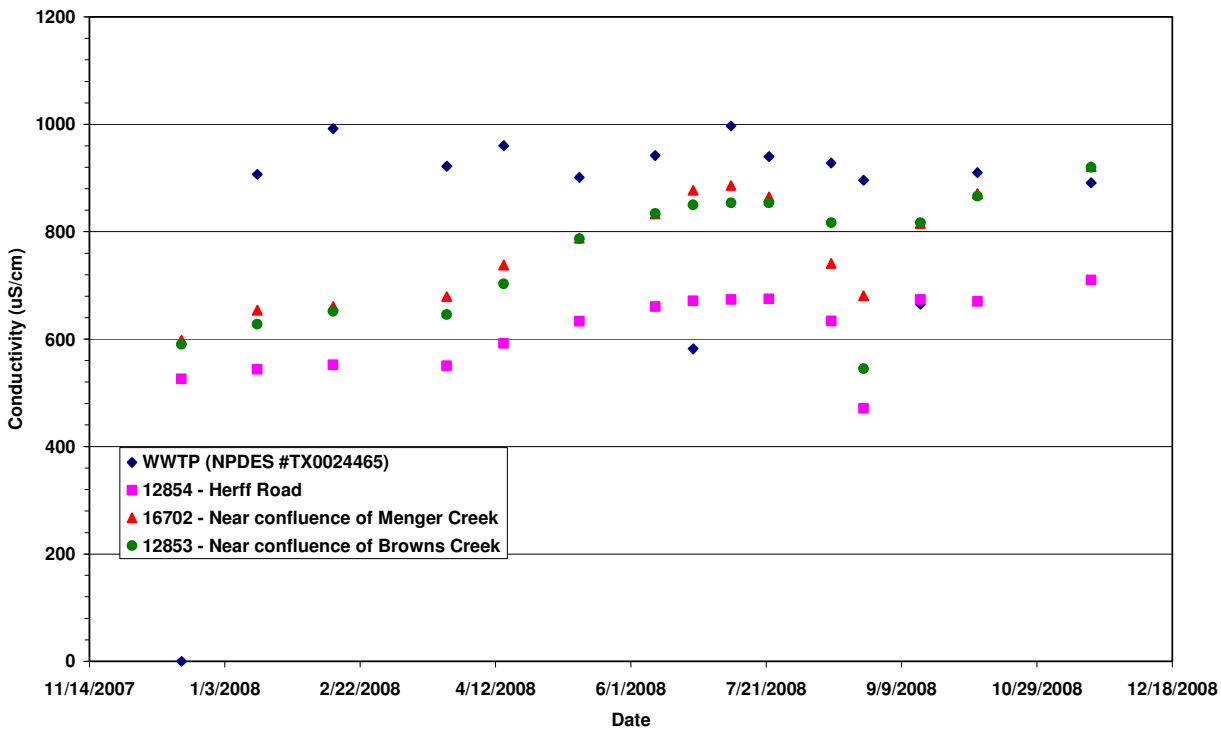


Figure A-6. Field measurement of specific conductivity

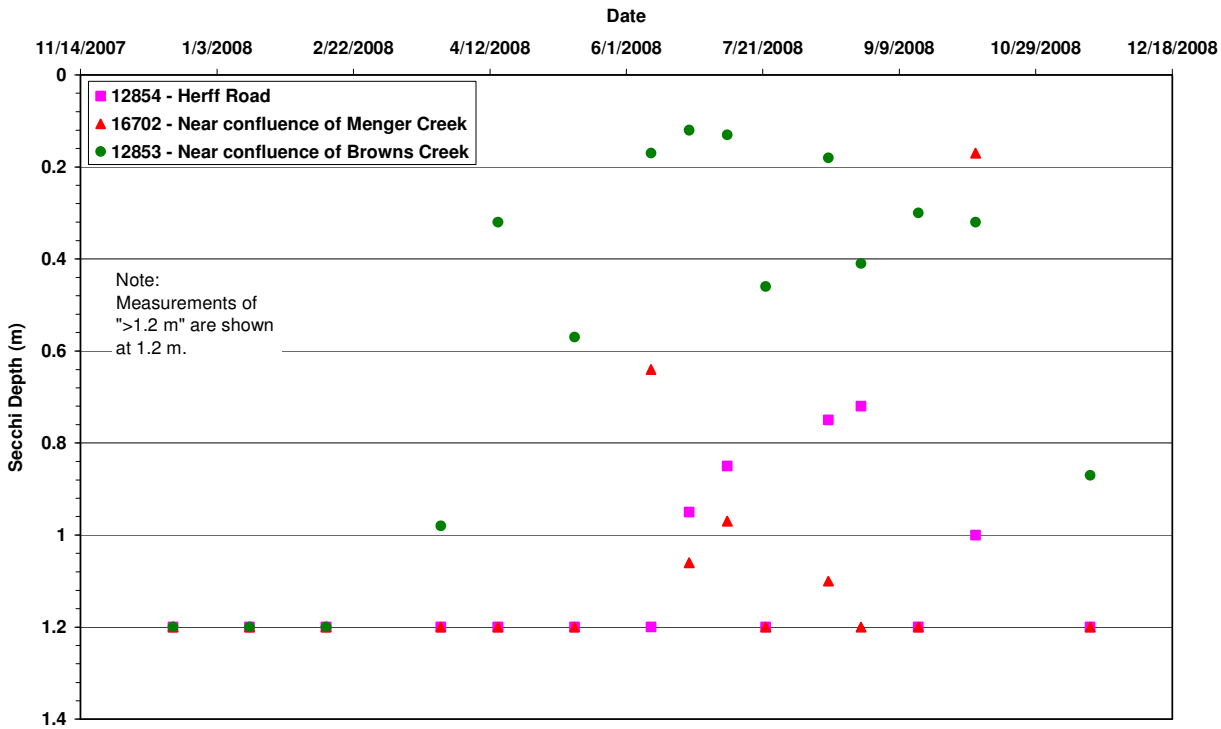


Figure A-7. Field measurement of Secchi Disk Depth

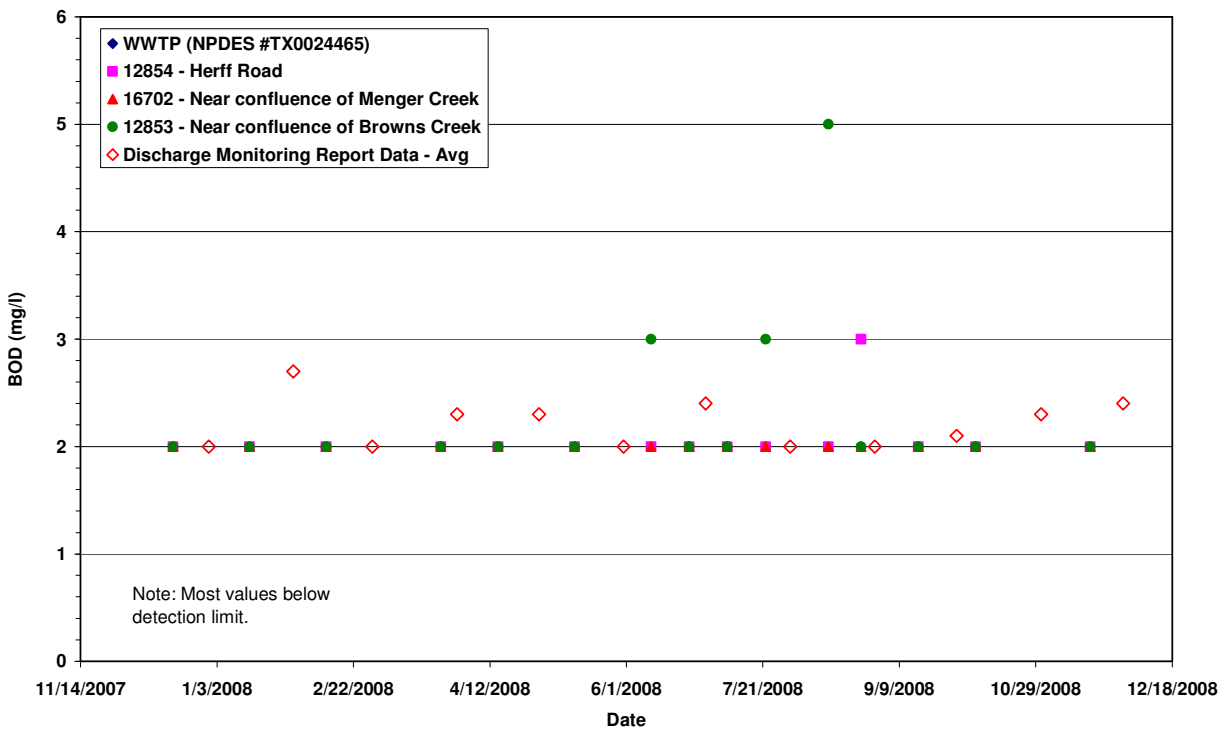


Figure A-8. Analytical laboratory results for biochemical oxygen demand

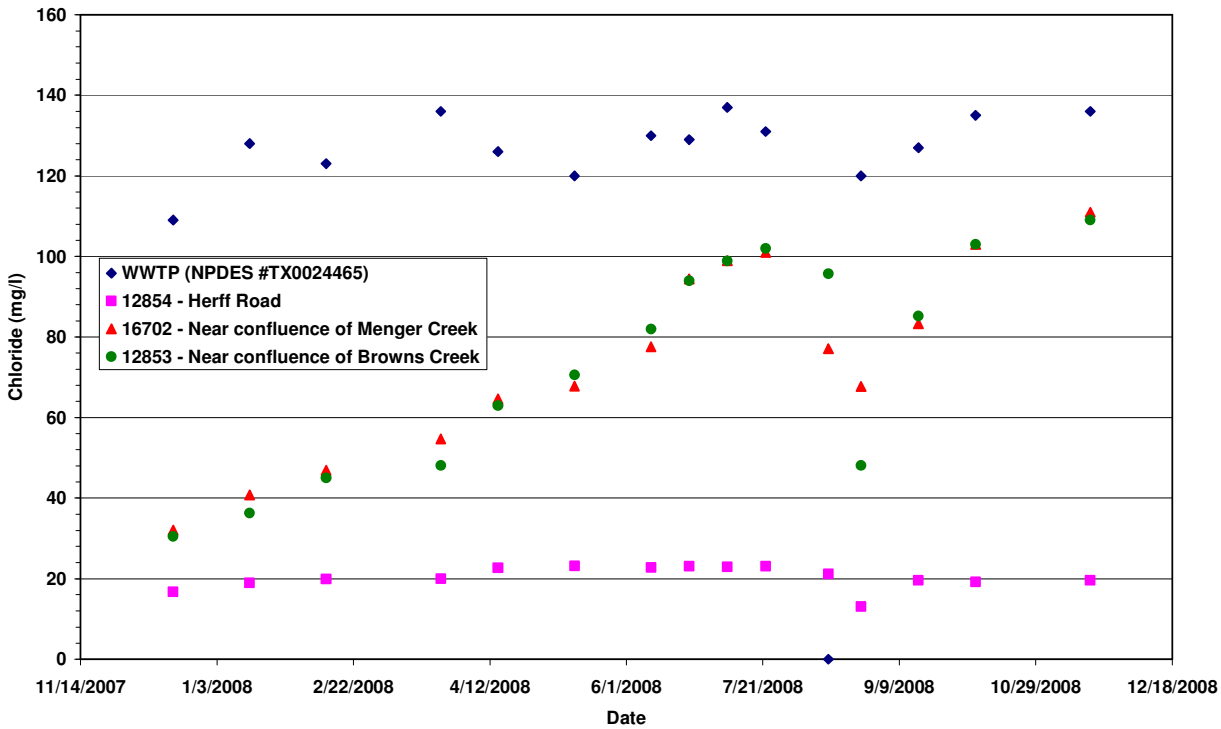


Figure A-9. Analytical laboratory results for chloride

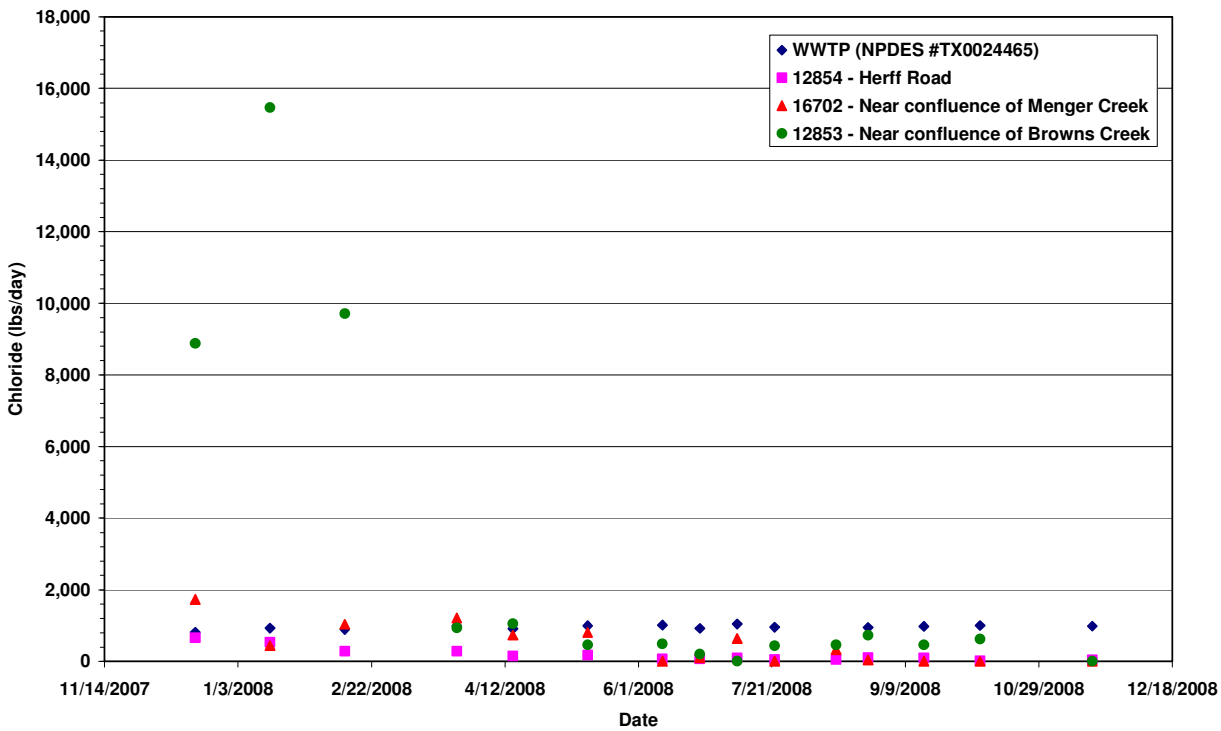


Figure A-10. Calculated loading for chloride

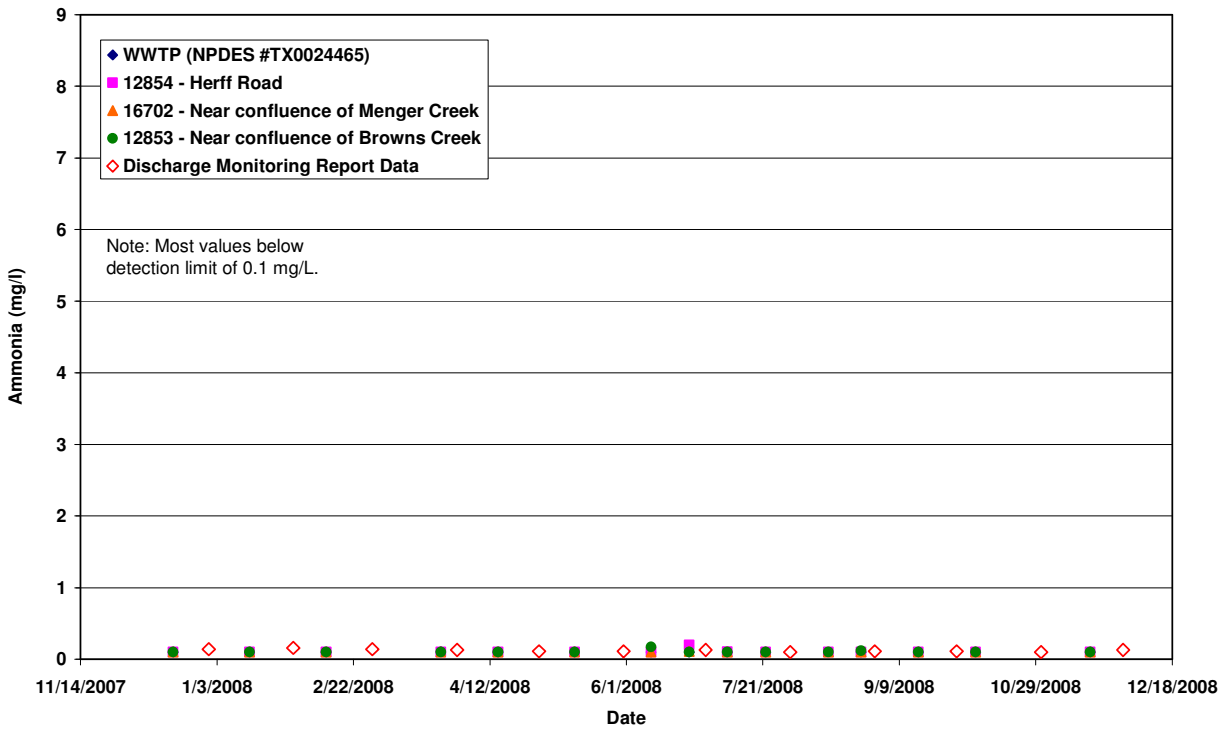


Figure A-11. Analytical laboratory results for ammonia

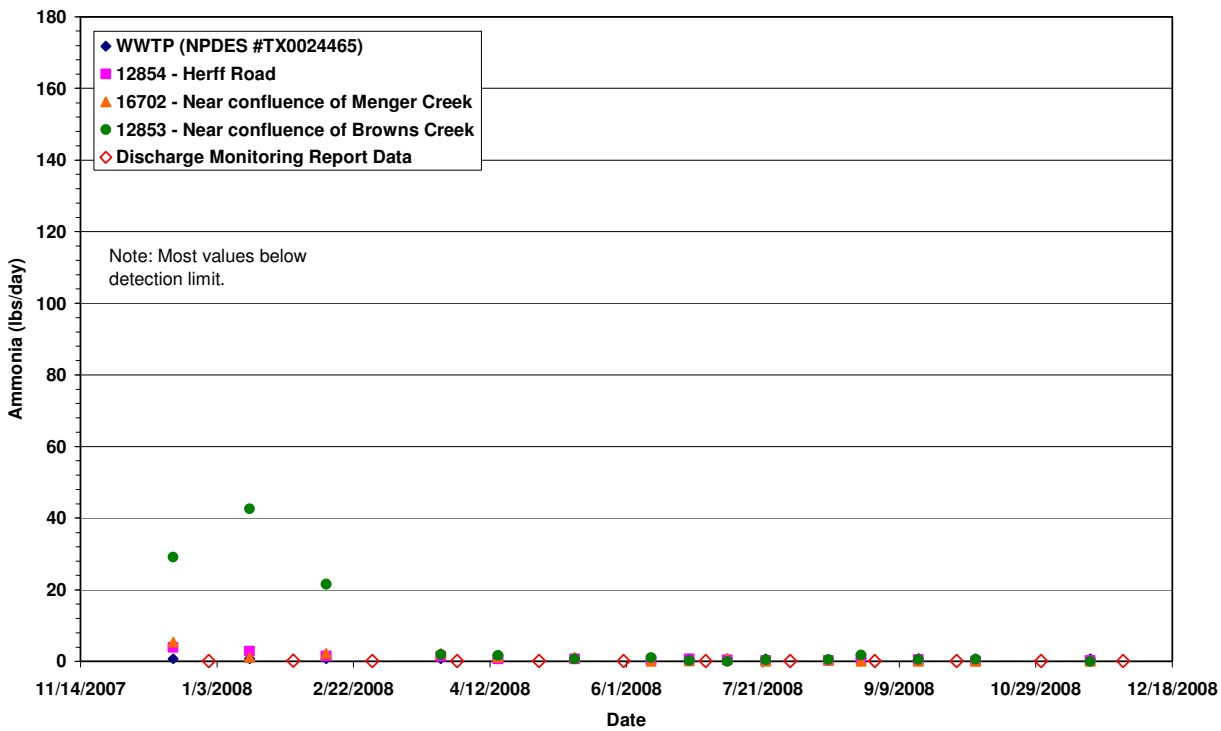


Figure A-12. Calculated loading for ammonia

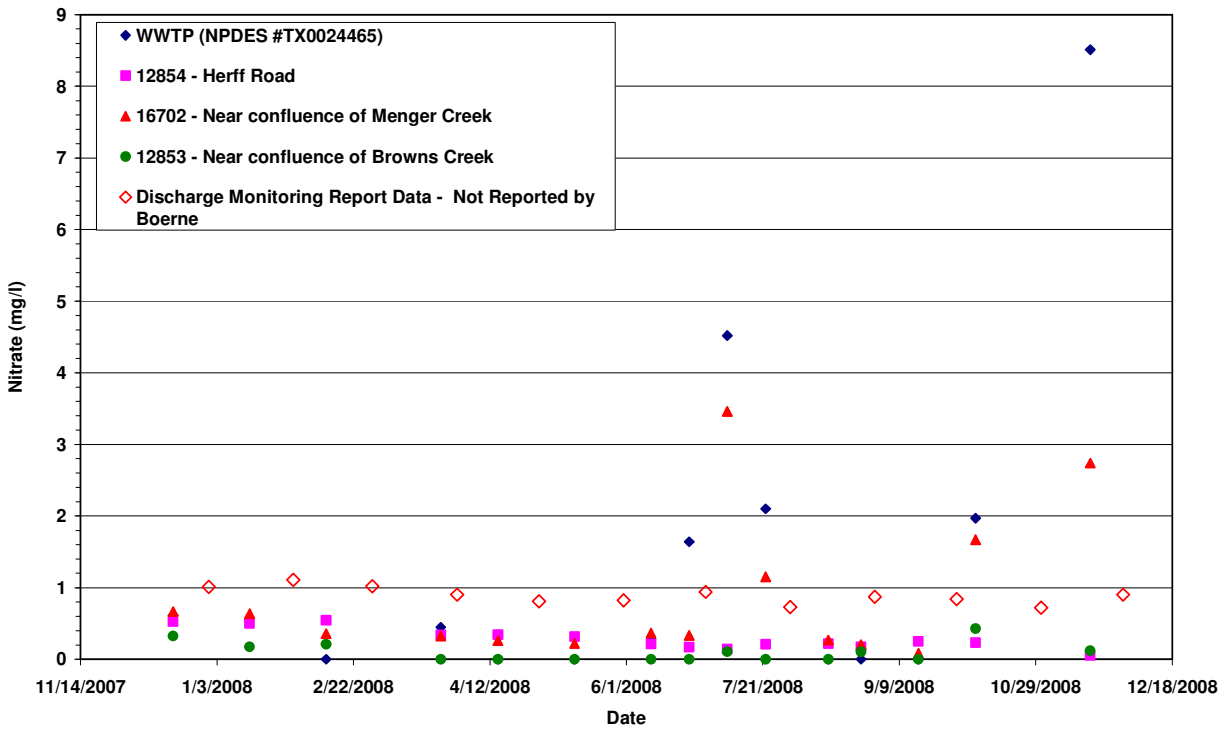


Figure A-13. Analytical laboratory results for nitrate

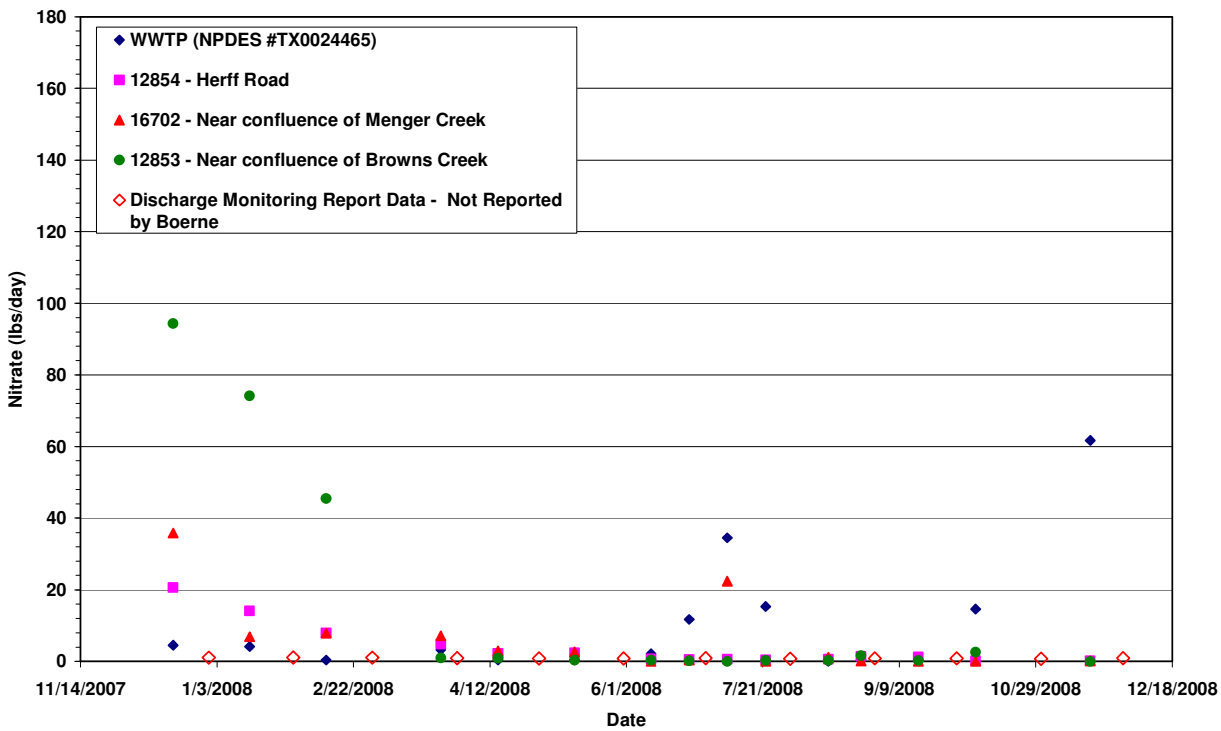


Figure A-14. Calculated loading for nitrate

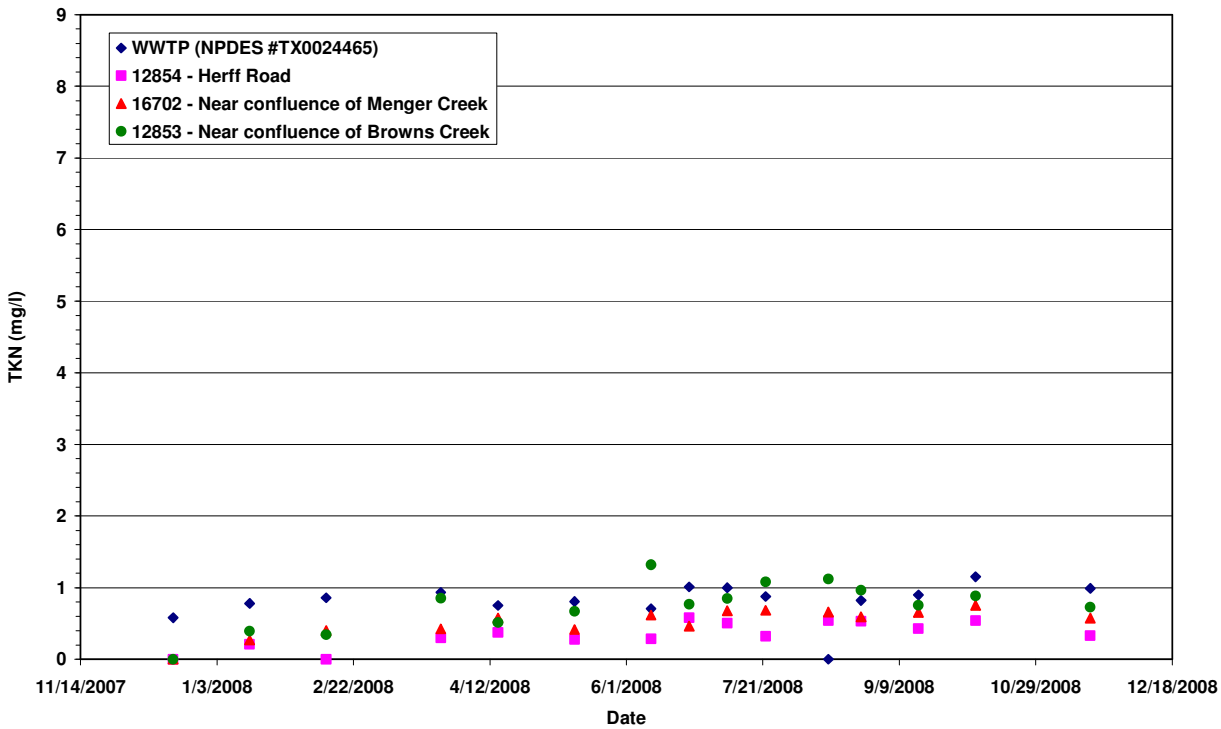


Figure A-15. Analytical laboratory results for total Kjeldahl nitrogen

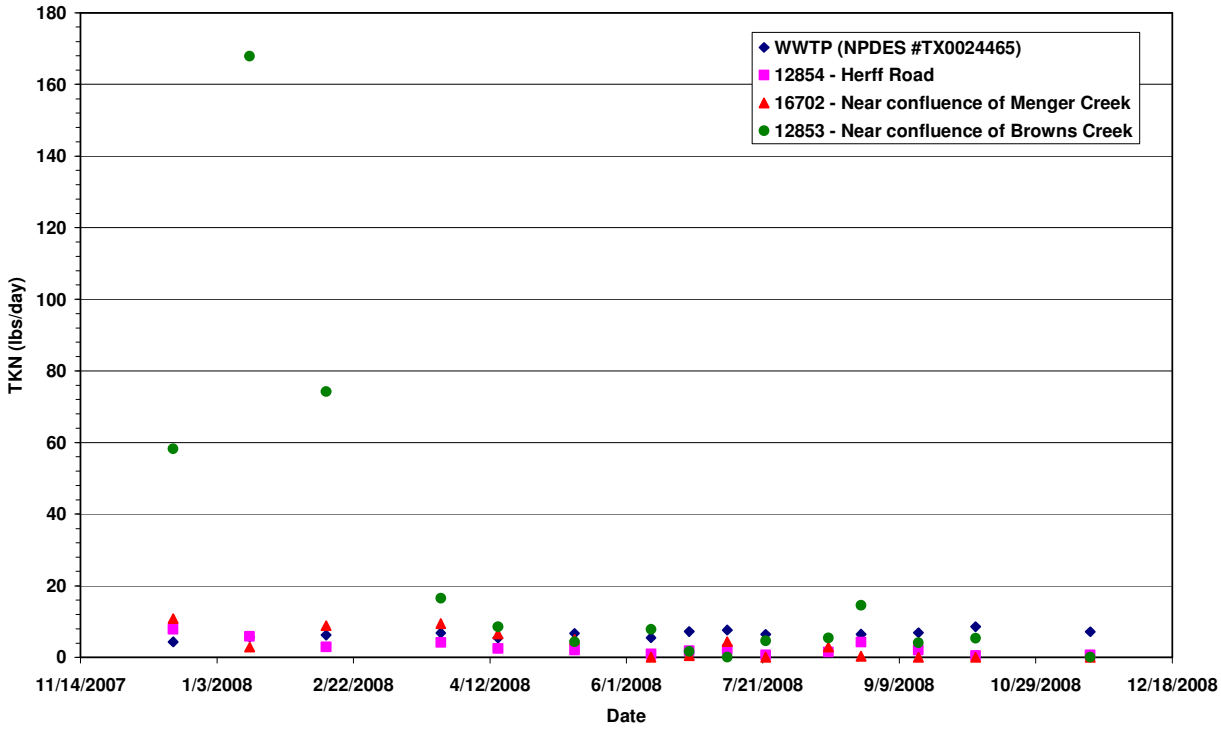


Figure A-16. Calculated loading for total Kjeldahl nitrogen

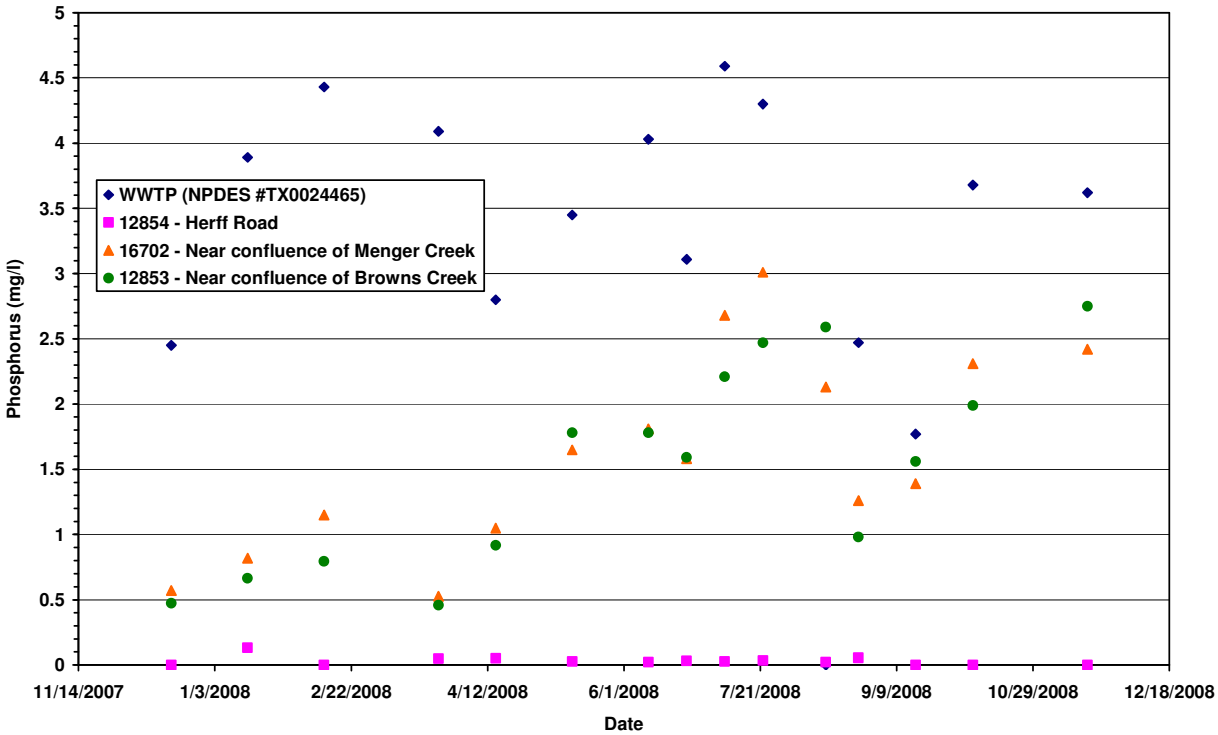


Figure A-17. Analytical laboratory results for total phosphorus

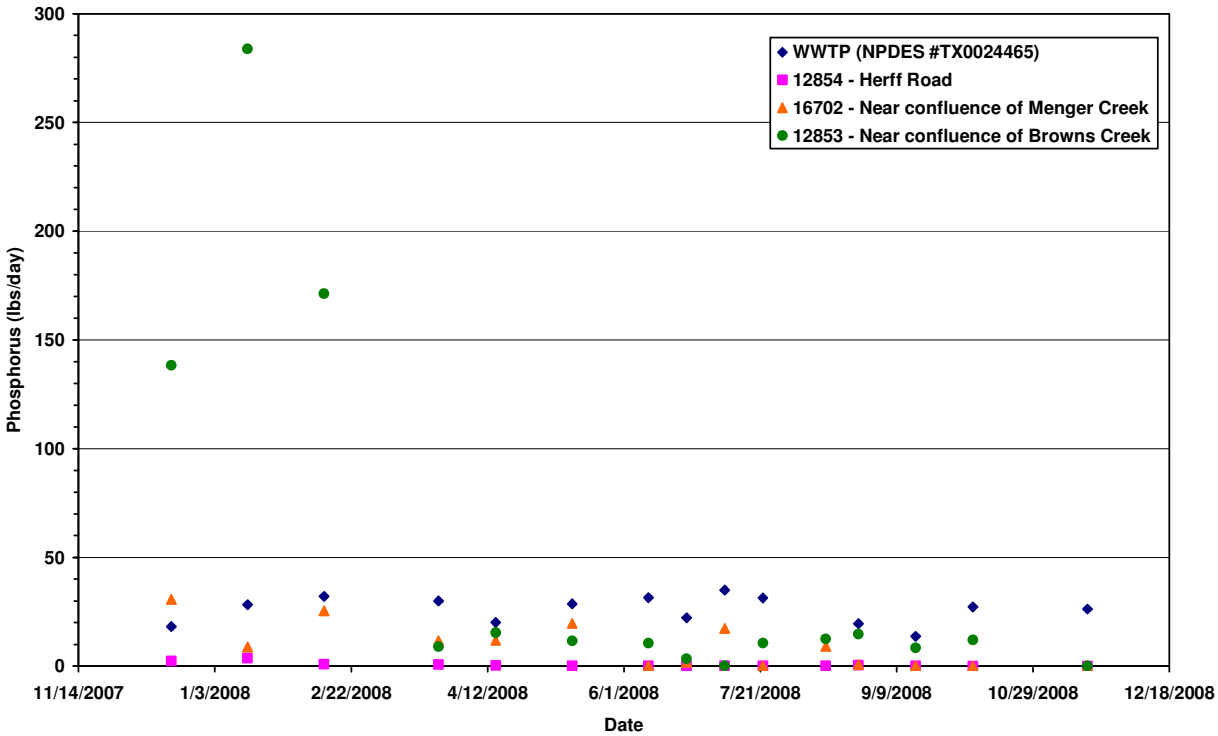


Figure A-18. Calculated loading for phosphorus

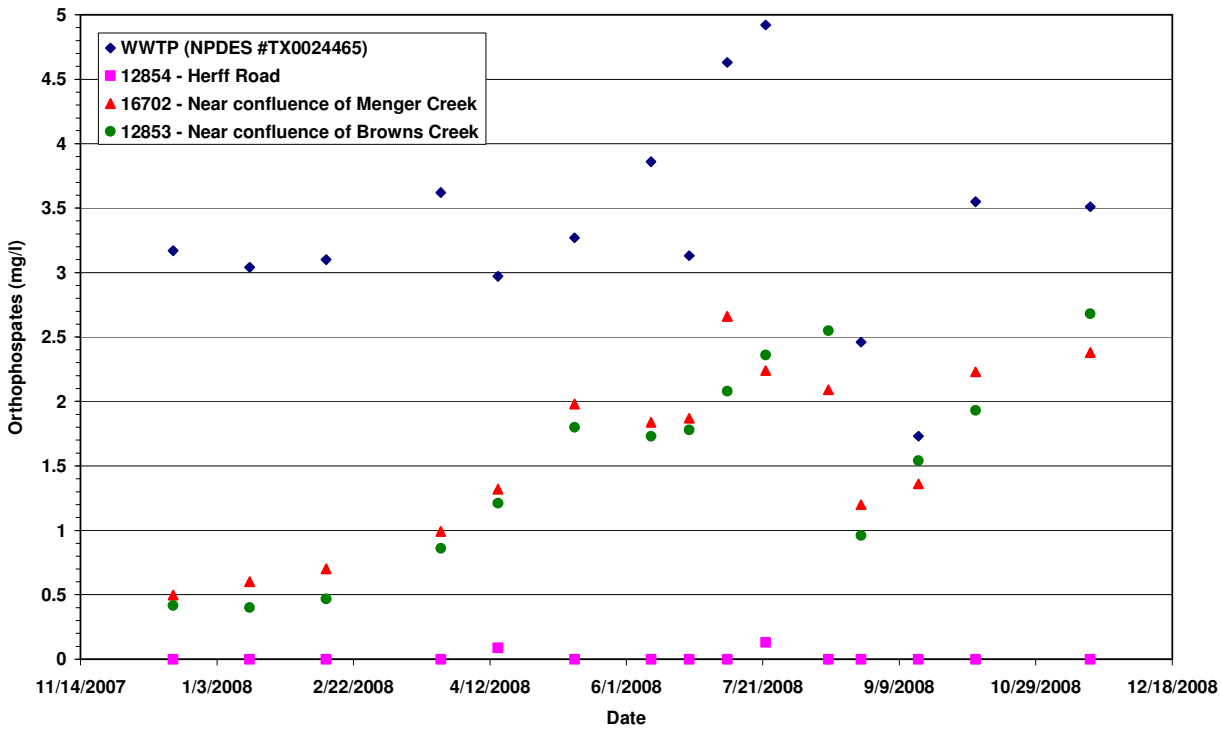


Figure A-19. Analytical laboratory results for orthophosphorus

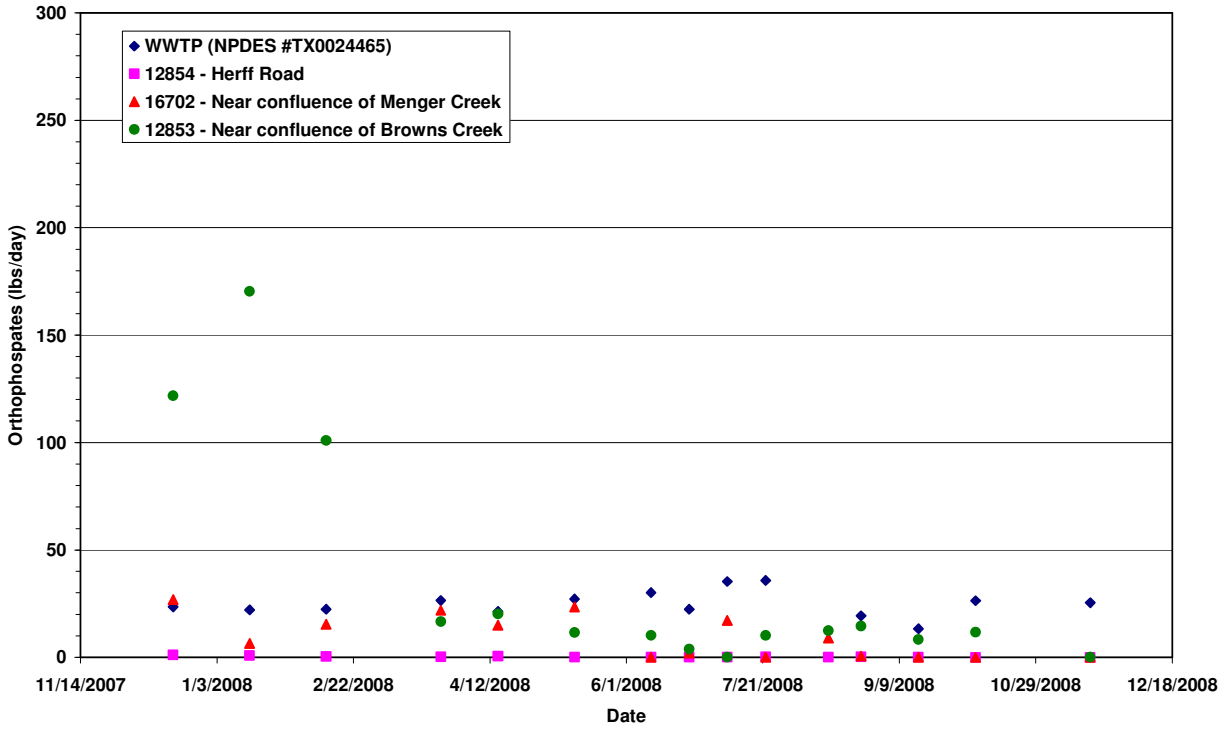


Figure A-20. Calculated loading for orthophosphorus

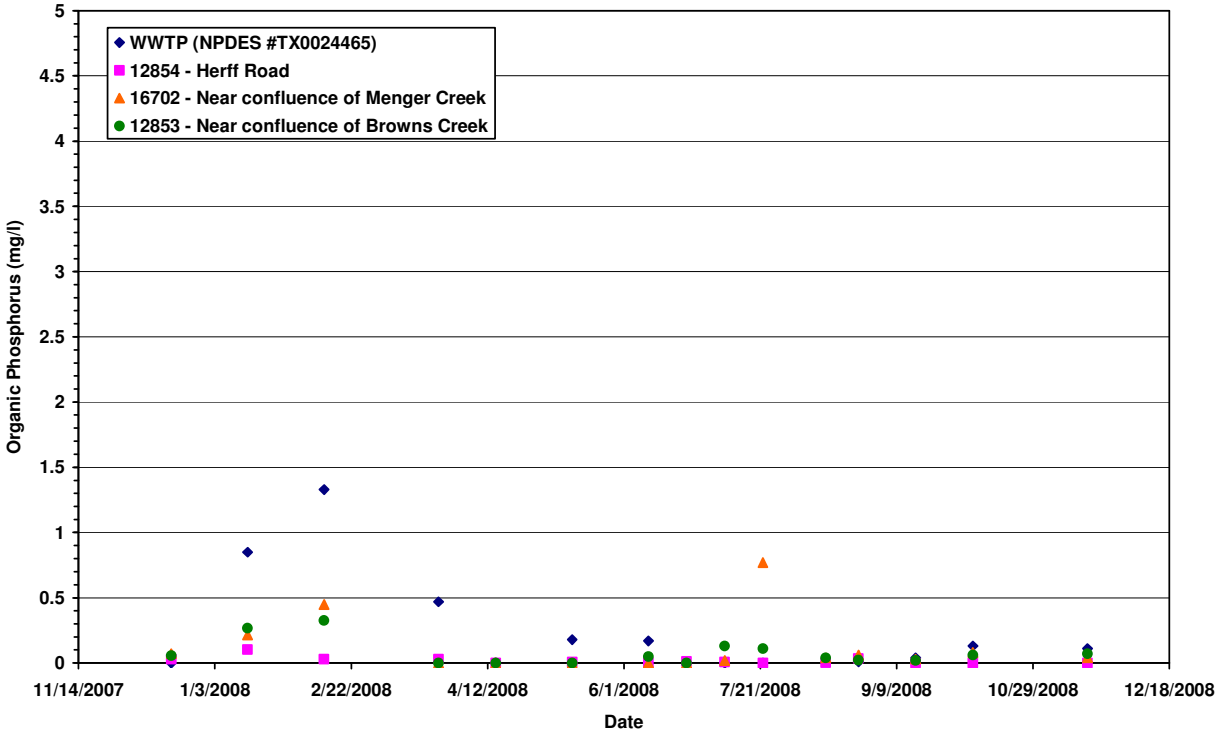


Figure A-21. Calculated organic phosphorus concentration

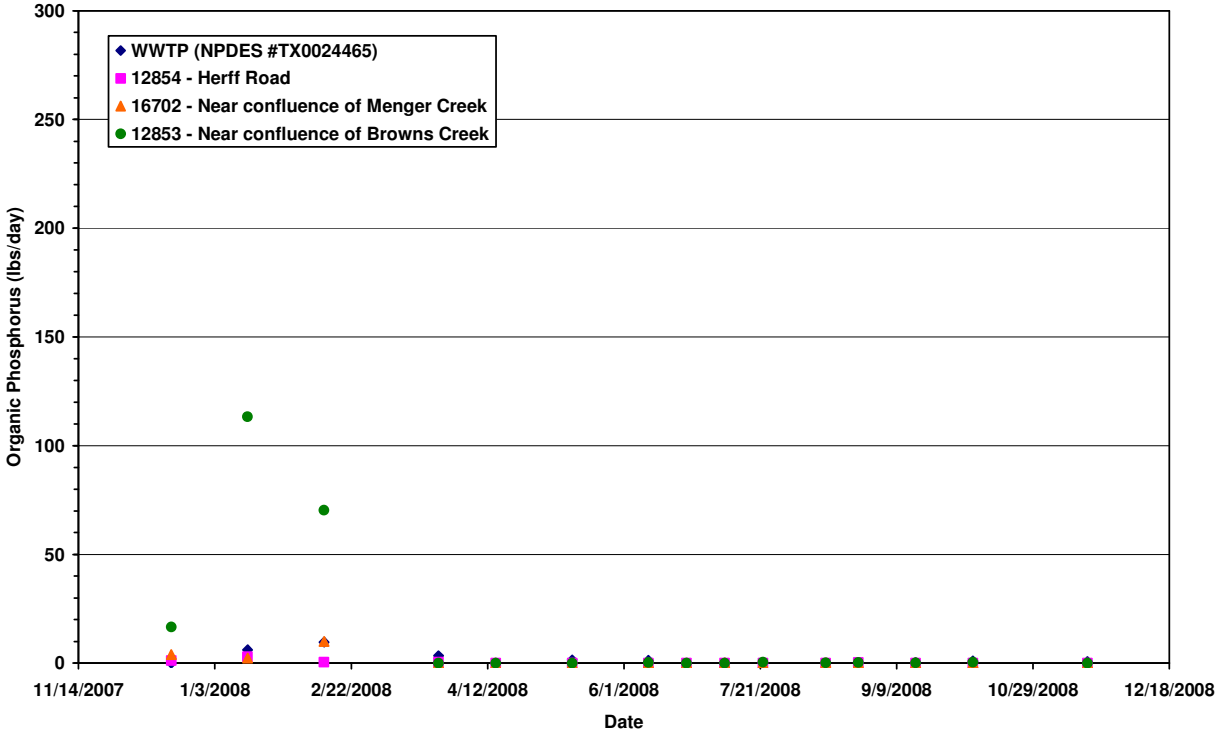


Figure A-22. Calculated organic phosphorus loading

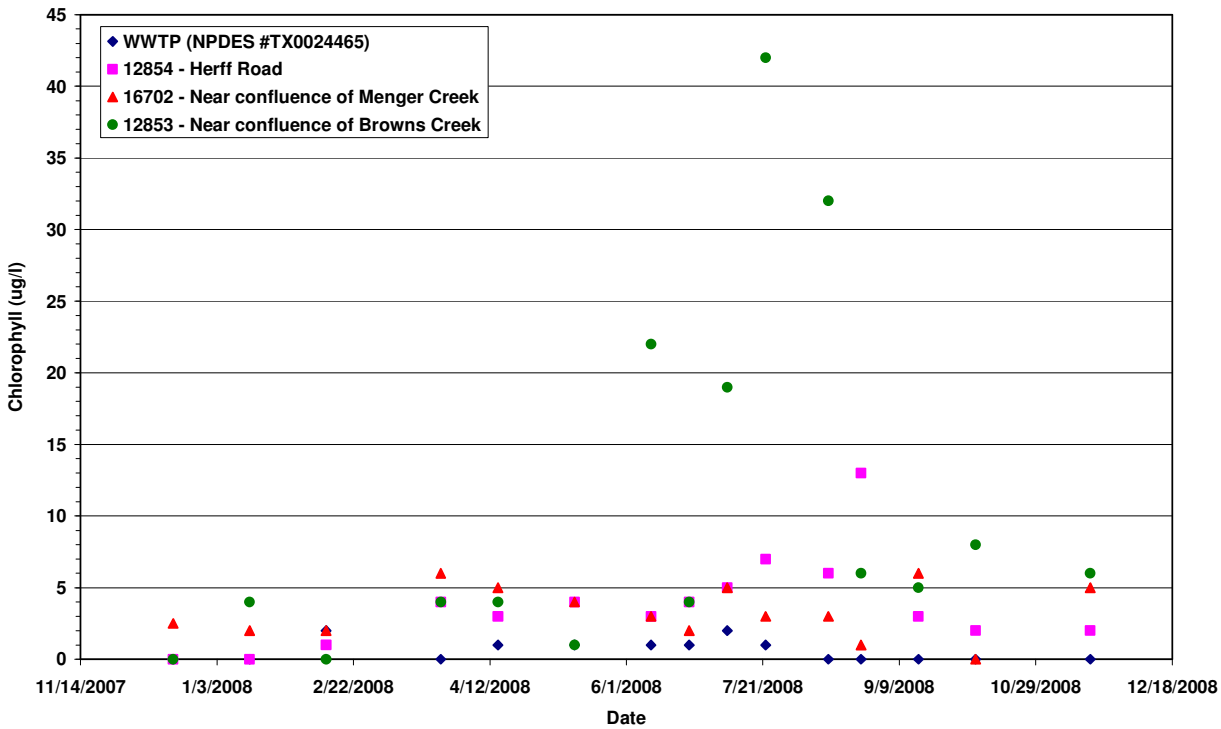


Figure A-23. Analytical laboratory results for chlorophyll

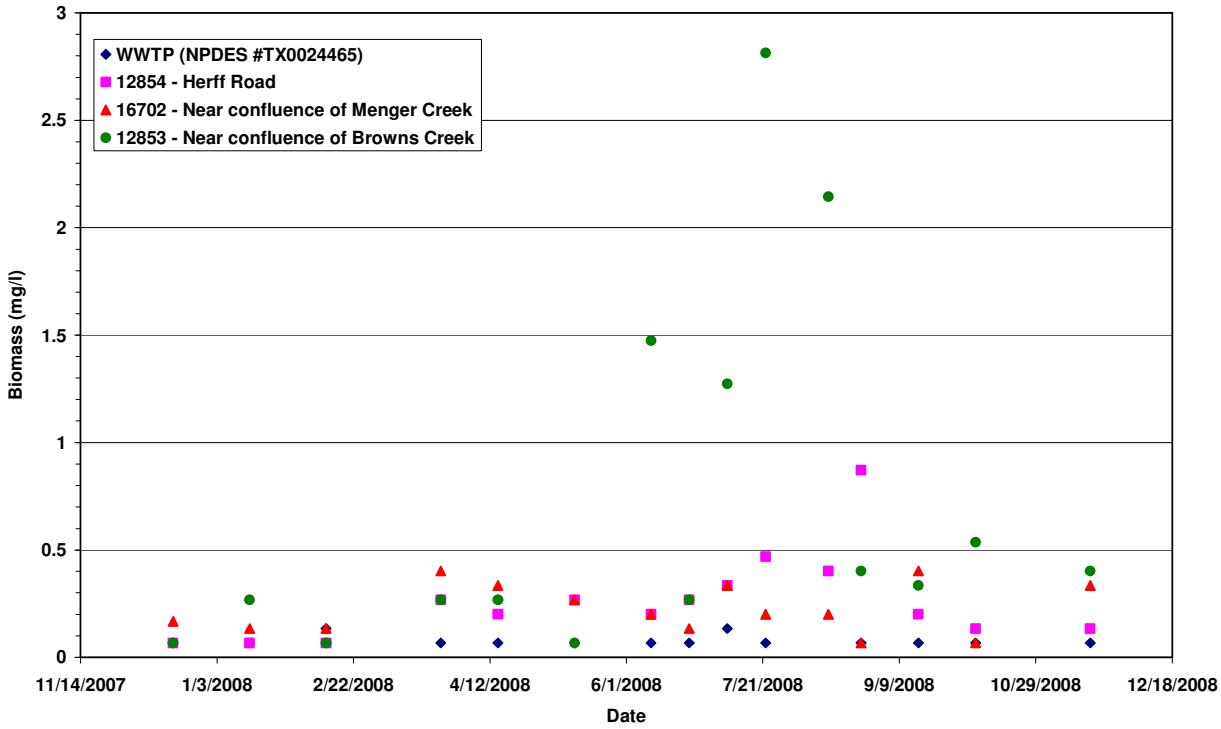


Figure A-24. Calculated biomass concentration

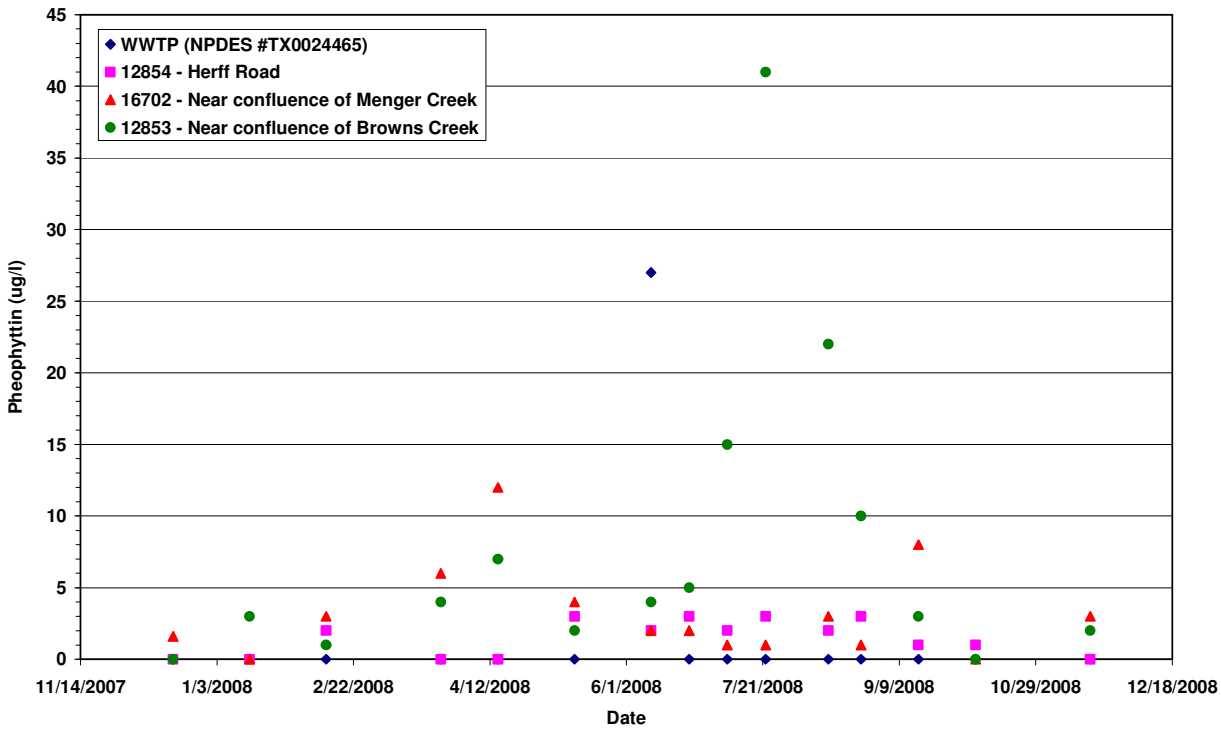


Figure A-25. Analytical laboratory results for pheophytin

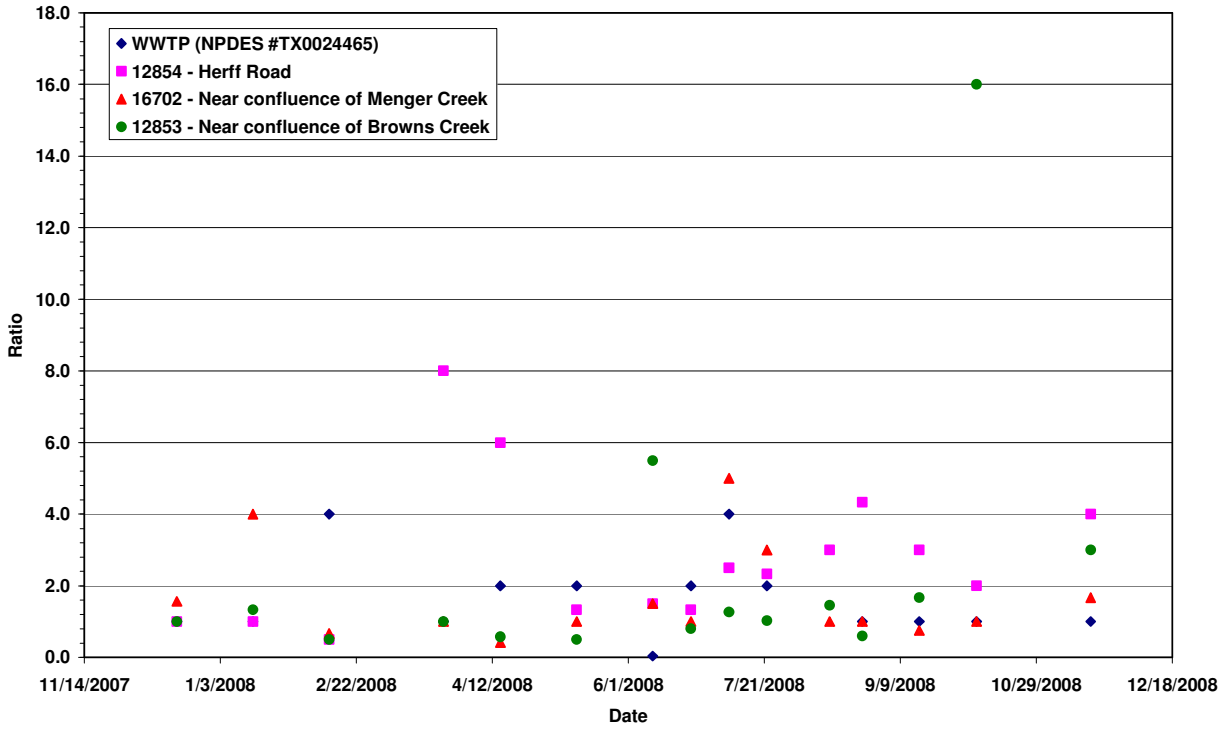


Figure A-26. Calculated chlorophyll to pheophytin ratio

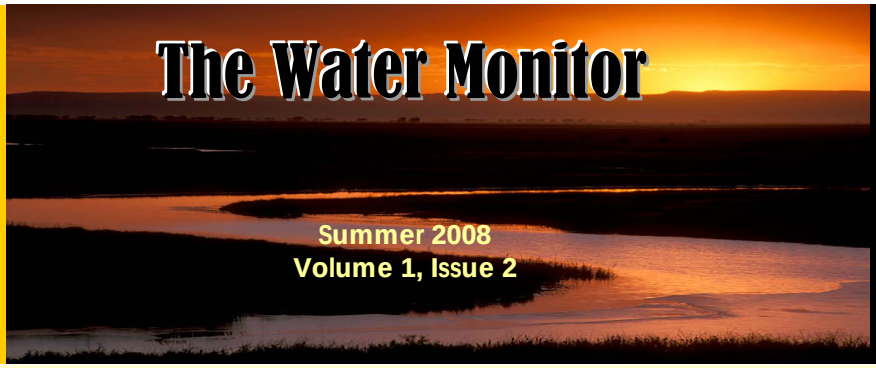
Appendix B
Stream Photos Corresponding to Sample Events

Appendix C
Laboratory and Field Reports

Appendix D
TCEQ Water Quality Monitoring and Assessment Section newsletter

D-1 TCEQ Newsletter

For reference purposes, the Summer 2008, Volume 1, Issue 2 of the TCEQ Water Quality Monitoring and Assessment Section newsletter "The Water Monitor" is included as an appendix. Written by Michele Blair of TCEQ's Surface Water Quality Monitoring Section, the article regarding Cibolo Creek's current state is entitled "Cibolo Creek – A Success Story" and appears on pages 11 and 12 of the newsletter.



Texas Commission on Environmental Quality—Water Quality Monitoring and Assessment Section

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"Water is the best of all things."
Pindar (c. 522 BC - c. 438 BC), Olympian Odes

Welcome to The Water Monitor

Welcome to second issue of ***The Water Monitor***, a newsletter focusing on issues related to monitoring and protecting surface water quality. Each quarter this newsletter will bring updates on the activities within three of the TCEQ's water quality programs: Surface Water Quality Monitoring, Texas Clean Rivers, and Nonpoint Source. This newsletter will be reporting on statewide activities and work being done through these programs as well as other field happenings and water-related topics.

DSHS Issues Fish Consumption Advisory for Galveston Bay

by the DSHS Seafood and Aquatic Life Group

The Texas Department of State Health Services (DSHS) has issued an advisory warning people to limit their consumption of spotted seatrout and catfish from Galveston Bay. The advisory, which includes Chocolate Bay, East Bay, West Bay, Trinity Bay and contiguous waters, was issued after a two-year study showed elevated levels of dioxins and polychlorinated biphenyls, or PCBs, in the two fish. Other fish species such as red drum, black drum and flounder were sampled and an advisory was not necessary.

Adults are advised to limit consumption of the two fish to no more than one 8-ounce meal a month. Women who are nursing, pregnant or may become pregnant, and children should not eat any catfish or spotted seatrout from these waters.

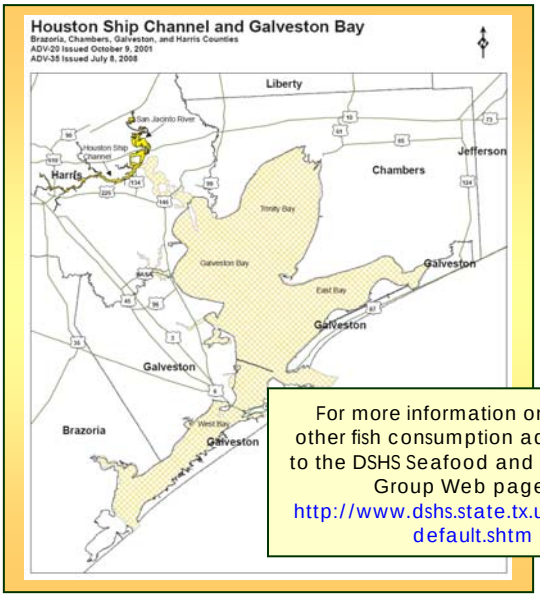
PCBs are industrial chemicals once used as coolants and lubricants in electrical transformers and capacitors.

The EPA banned PCBs in 1979, and older items containing them have to be replaced. PCBs degrade slowly in the environment. Dioxins are formed as unintentional by-products of many industrial and chemical production processes and incomplete combustion.

Long term consumption of PCBs may cause cancer, reproductive, immune system, developmental, and liver problems. Dioxins can cause skin rashes, liver damage, weight loss, reproductive damage and may increase the risk of cancer.

Spotted seatrout, also knows as speckled trout, is a favorite among recreational anglers in coastal waters. The DSHS advisory does not prohibit catching or possessing either fish species.

The contaminants do not pose a threat to other recreational uses of the bay such as swimming or other contact recreational activities.



For more information on this and other fish consumption advisories, go to the DSHS Seafood and Aquatic Life Group Web page at http://www.dshs.state.tx.us/seafood/default.shtm

Nonpoint Source Pollution Management is Celebrated at the 2008 Texas Environmental Excellence Awards

Rocky Freund, Deputy Executive Director and Sky Jones-Lewey, Resource Protection and Education Director accepting the award for the Nueces River Authority.

The NRA Watershed Model

Learn more about the Texas Environmental Excellence Awards at www.teea.org or watch a video of Nueces River Authority's award-winning watershed model at www.teea.org/win08_edu.htm.

The TCEQ annually presents the Texas Environmental Excellence Awards to environmental projects across the state that demonstrate excellence in resource conservation, waste reduction and pollution prevention. The award-winning programs of the 2008 ceremony aptly reflect the goals of the TCEQ: to protect our state's human and natural resources and ensure clean air, clean water, and safe management of waste. The awards celebrate the bold efforts of citizens, communities, businesses, and organizations that preserve and protect the Texas environment. Under the Waste Reduction Policy Act of 1991, the TCEQ initiated the Texas Environmental Excellence Awards in 1993. Presented every spring, the awards are given in 10 diverse categories across the public and private sectors.

The Nueces River Authority wins the Education Category in 2008: Helping Students Understand Water's Future

The Nueces River is the lifeblood of a region, and that awareness led the Nueces River Authority to mount an ambitious effort to preserve and protect the headwaters of the Frio, Sabinal, Leona, Nueces and West Nueces rivers in South Texas. With a Clean Water Act §319(h) grant from the Texas State Soil and Water Conservation Board, the Authority implemented an innovative education project aimed at improving and protecting water quality in the five Nueces Basin headwater watersheds.

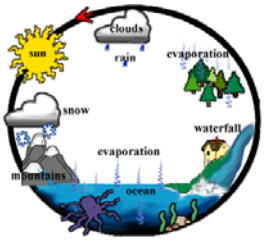
The campaign's centerpiece is a 24-square foot scaled relief model of the Nueces River Basin, which educators take to 5th and 6th grade classrooms in a five-county area each year. Using food coloring to illustrate pollutants and spray bottles to make rain, students witness how tainted runoff makes its way downstream. This hands-on approach enables students to run their fingers over the terrain and trace the connections between creeks, rivers and bays.

The watershed model demonstration is followed by a unique educational campaign, called *Up 2 U*, which asks students to consider how their personal choices impact water quality. The Nueces River Authority reinforces its *Up 2 U* message through bookmarks, billboards and bilingual posters. In addition, 64 local river-related businesses hand out mesh litterbags for visitors to use while enjoying the river and riding its current on inner tubes. The campaign is underwritten in part by contributions from local businesses, private groups, and governmental organizations that have a direct interest in water quality.

Since its inception in 2005, the Nueces Basin Headwater Stewardship Project has invested approximately $300,000 in pollution-prevention education strategies, touching more than 5,000 young lives. The project's success has led two other river authorities in Texas to adopt the program and create their own models. Through this creative educational effort, youngsters of a new generation will learn responsibility and become empowered to make choices that have a positive effect on the world around them.

Upper Colorado River Authority's North Concho Best Management Practices qualifies as a finalist in the Government Category

In the Spring 2008 issue of ***The Water Monitor***, The Rio Concho "Downtown" NPS Project described an innovative best management practice (BMP) funded by Clean Water Act §319(h) grants through the TCEQ. In 2008, the project was one of the finalists in the Government Category at the Texas Environmental Excellence Awards.



To sign-up for automatic notification of new issues of the "The Water Monitor" newsletter go to www.tceq.state.tx.us, click on the "sign up for e-mail updates" icon and follow the instructions.

Sign up for e-mail updates.

Twin Buttes Reservoir Cyanobacteria Bloom

by Stephen Twidwell, TPWD San Marcos

Effects of the *Aphanizomenon* bloom on Twin Buttes Reservoir.

What is Geosmin? ***Geosmin*** literally translates to "*earth smell*". It is an organic compound with a distinct earthy flavor and aroma and is responsible for the earthy taste of beets. The human nose is extremely sensitive to *geosmin*, able to detect it at concentrations down to 5 ppt.

Geosmin is produced by several classes of microbes [including cyanobacteria, actinobacteria, and streptomyces] and is released when these microbes die. Communities whose water supply depends on surface water can periodically experience episodes of unpleasant tasting water when a sharp drop in the population of these bacteria releases *geosmin* into the local water supply. Under acidic conditions, *geosmin* decomposes into odorless substances.

NEW—U.S. Geological Survey Fact Sheet 2008–3009
Monitoring Indicators of Harmful Cyanobacteria in Texas
By Richard L. Kiesling, Robin H. Gary, and Marcus O. Gary
http://pubs.usgs.gov/fs/2008/3009/

On May 1, Boyd Guthrie from the TCEQ Region 8 Office was first to notice an unusual algal bloom in Twin Buttes Reservoir near San Angelo. What made the bloom appear so unusual was the brilliant green color; it looked like someone had poured green paint into the water. Near shore by the dam, the alga was so dense that it formed a surface floating scum resembling a thick paste.

The following day, Chuck Brown from the Upper Colorado River Authority (UCRA) was on the reservoir conducting routine water quality monitoring. Field measurements made in the middle of the bloom indicated the bloom had little influence on water quality as dissolved oxygen concentrations and pH levels remained normal in profile. Further, the bloom did not appear to be producing toxins. In the bloom area, fish were observed swimming and local residents were fishing. Steve Twidwell, TPWD, took a sample for algal identification to the University of Texas Phycology Lab. Dr. Jerry Brand identified the bloom as *Aphanizomenon sp*.

Aphanizomenon, with *Anabaena* and *Microcystis*, is one of three cyanobacteria genera (formerly called "blue-green algae) that account for the vast majority of blooms. *Aphanizomenon* is notorious for producing a variety of cyanotoxins: dermatoxins that affect the skin; neurotoxins that affect the nervous system; and hepatoxins that affect the liver. These toxins can make people, their pets, and other animals sick. In addition to the cyanotoxins it can produce, *Aphanizomenon* is also known to produce ***geosmin***, making the water taste and smell bad.

Throughout the middle of May, the *Aphanizomenon* bloom seemed to pulse on a daily basis, from declining densities and appearing evenly dispersed in the water column, to escalating densities and localized patchiness. Toward the end of May, with the prevailing winds picking up from the South, the bloom became concentrated in several coves near the dam on the north side of the reservoir. The character of the bloom changed dramatically at this point. Dissolved oxygen in the cove areas declined to less than 1 mg/L, suggesting that the bloom was beginning to die and bacterial decay was consuming the oxygen. Dead shad, catfish, and carp were found in the cove areas. There was also an indication that cyanotoxins were being released, as field investigators from the TCEQ, UCRA, and TPWD observing the bloom began experiencing scratchy and sore throats and asthma like symptoms due to exposure.

Meridith Byrd, TPWD's Harmful Algal Bloom Coordinator, began working with the Department of State Health Services (DSHS) to get a public health advisory issued. On Friday, May 23, in advance of Memorial Day weekend, the DSHS issued a public health advisory warning local citizens of the algal bloom on Twin Buttes Reservoir.

There are several questions regarding the bloom that remain unanswered. First, what caused the bloom in the first place? Cyanobacteria blooms can occur at any time, but typically develop in late summer or early fall when water temperatures are elevated. Heavy rains in the San Angelo area in April may have washed excessive nutrients into the reservoir. Inflowing water also raised the water level in Twin Buttes Reservoir several feet, thus inundating many acres covered by vegetation. The nutrient data indicates that the water at the time of the cyanobacteria bloom peak was deprived of nitrogen (NO_2-N + NO_3-N and NH_3-N, less than detection) while phosphorus was in abundance (TP, 0.35 mg/L). This scenario gives the cyanobacteria a competitive advantage, since they are able to fix gaseous nitrogen from the atmosphere into a useable nutrient form to continue growing and reproducing, while other algal forms are essentially limited by the lack of nitrogen in the water. According to researchers at USGS, a cyanobacteria bloom occurring this early in the season is likely to linger through the summer months.

The *Aphanizomenon* bloom is also puzzling due to episodic production of cyanotoxins. The literature indicates that not all cyanobacteria blooms are toxic. Even blooms produced by a known toxin producer like *Aphanizomenon* may not produce toxins or produce them at undetectable levels. Since cyanobacteria toxins can be lethal in relatively small amounts, caution should always be taken when a bloom occurs. Scientists do not know what triggers toxin production by cyanobacteria, but the probability that an individual bloom containing *Aphanizomenon, Anabaena,* or *Microcystis* will produce toxins is as high as 75%. Many times toxins may not be produced during the peak of the bloom by cyanobacteria, but they may be released when the cells die and their contents are released to the water. TPWD has sent a sample to the USGS Lawrence, Kansas Research Laboratory to see if toxins are being produced by the bloom. Results from that laboratory analysis are pending. As of July 7, the bloom appeared to be disappearing.

For additional information contact,

Meridith Byrd
TPWD Harmful Algal Bloom Coordinator
Meridith.Byrd@tpwd.state.tx.us

"The life of every river sings its own song, but in most the song is long marred by the discords of misuse"

-Aldo Leopold (1886-1948), Sand County Almanac

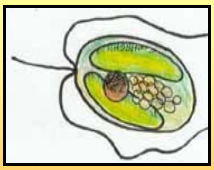
TEXAS CHAPTER AMERICAN FISHERIES SOCIETY

Fisheries & Harmful Algae: Can They Co-Exist?

TEXAS PARKS & WILDLIFE DEPARTMENT

For information on Harmful Algal Blooms in Texas, visit the TPWD website at www.tpwd.state.tx.us/hab

The site contains updates on current **Red Tide** and **Golden Alga** blooms, ongoing research and other related information.



Mark Your Calendars - International Golden Algal Symposium Announced

The Texas Chapter of the American Fisheries Society (TCAFS) and Texas Parks and Wildlife Department (TPWD) are hosting a 4-day conference which will include an International Golden Alga Symposium and the TCAFS Annual meeting.

The combined meeting will convene ***January 27– 31, 2009 in Fort Worth, Texas*** at the Radisson-Fort Worth Fossil Creek Hotel.

The TCAFS and TPWD cordially invite all American Fisheries Society members, water quality professionals, harmful algae experts, academics, governmental agency staff, river authorities, and other stakeholders to attend this combined conference of the annual TCAFS meeting and Golden Alga International Symposium.

The TPWD Golden Alga Task Force has invited international, national, and Texas researchers to present their most recent findings in control, bloom dynamics, toxicity, management, and genetics of golden alga. The keynote speaker will be Dr. Don Anderson from the Woods Hole Oceanographic Institute.

Confirmed international and national speakers include:

- Dr. Edna Graneli (Sweden)
- Dr. Wenche Eikrem (Norway)
- Dr. Linda Medlin (Germany)
- Dr. John LaClaire (UT-Austin)
- Dr. Jim Grover (UT-Austin)
- Dr. Dan Roelke (Texas A&M)
- Dr. Kevin Schug (UT-Austin)
- Dr. Bryan Brooks (Baylor University, Texas)
- Dr. John Rogers (Clemson University)
- Dr. Johannes Hagstrom (UT, Marine Science Institute)

TPWD golden alga researchers will also present topics on the Texas experience, including statewide distribution and genetics, and recent developments for control in small impoundments.

The meeting will include a special contributed session for inland and coastal harmful algal bloom topics (red tide, blue-green algae) as well as a general fisheries and poster session.

The meeting will also feature the lively annual raffle and banquet, student awards, Texas fisheries workers awards, student/mentor luncheon, and student social. Conference registration includes admittance to exhibits, breaks, Tuesday afternoon mixer, Wednesday lunch, Thursday dinner and banquet, and Friday afternoon social.

Information will be posted on the TCAFS website. For updates, visit www.sdafs.org/tcafs/

or contact

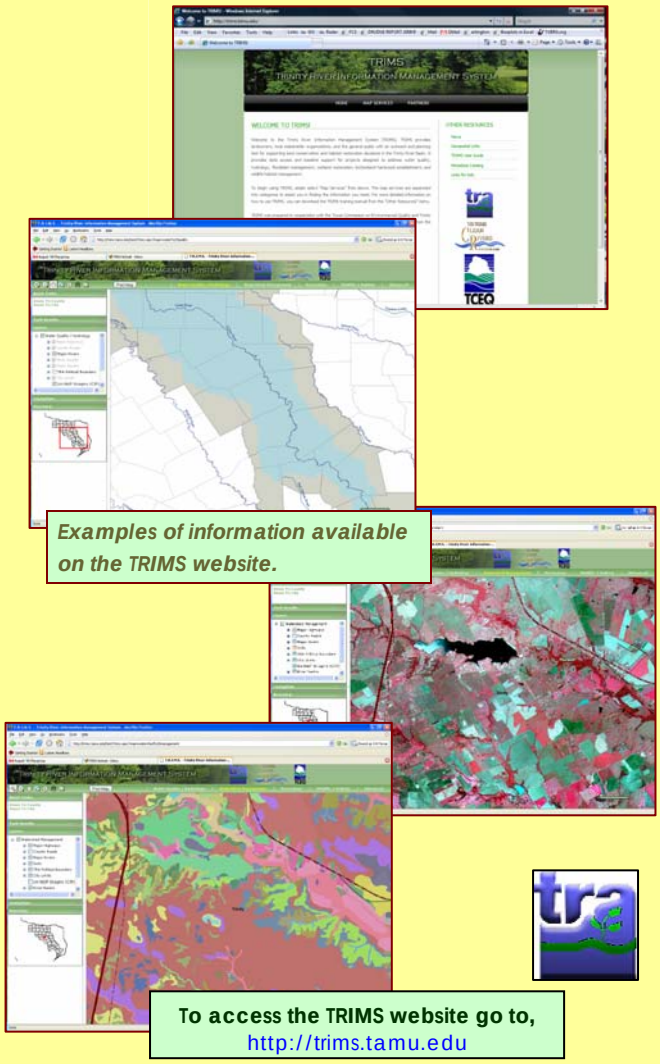
Brian VanZee at brian.vanzee@tpwd.state.tx.us

Access Texas SWQM Data Online

The ***Surface Water Quality Web Reporting Tool*** will allow you to select TCEQ water quality monitoring stations to view and optionally download sample data. This data comes from the TCEQ's new Surface Water Quality Monitoring Information System (SWQMIS). www8.tceq.state.tx.us/SwqmisWeb/public/index.faces

Trinity River Information Management System (TRIMS)

by Web Mangham, Trinity River Authority



Examples of information available on the TRIMS website.

To access the TRIMS website go to,
http://trims.tamu.edu

With over 5.5 million residents, the Trinity is the most populated river basin in Texas. From her headwaters north of the Dallas-Fort Worth metroplex to her outlet into Galveston Bay, the 512 mile river and its 1,983 miles of major tributaries drain 18,000 mi² of Texas. In addition, the Trinity River basin supplies drinking water to over half of Texas' population. In September 2006, Governor Rick Perry announced the Trinity River Basin Environmental Restoration Initiative (TRBERI) as part of a comprehensive effort to improve the quality of life, economic sustainability and ecological integrity of areas associated with the Trinity River basin through a coalition of local communities, NGO's and stewards of private and public lands.

TRIMS—Trinity River Information Management System— was the first project developed under the TRBERI. Funded by the Trinity River Authority (TRA) through TCEQ's CRP, TRIMS was developed by the Texas A&M Institute of Renewable Natural Resources with design input from TRA. Based on ESRI's ArcServer technology, this browser-based internet mapping system is designed to address the need for local stakeholders to easily access and use geospatial data for making land use decisions in the Trinity River Basin.

Accessed through an internet browser, TRIMS provides the general public with an outreach and planning tool without the need for expensive, sophisticated Geographic Information System programs. In addition, the extensive metadata available from the website can assist GIS users in locating actual datasets. Along with over 30 other data layers, TRIMS provides access to recent high-resolution aerial images, the original Texas Land Survey, 2000 Census Block Data, live USGS gage data, and digital elevation data for the entire Trinity Basin. This tool provides data access and baseline support for projects designed to address water quality, hydrology, floodplain management, wetland restoration, bottomland hardwood establishment, and wildlife habitat management.

In addition to the TRIMS mapping system, the website contains geospatial links, a user guide, and links designed to teach children about the environment and generate an interest in Geography. Tools that anyone with an internet connection can access include:

- Measure area
- Stack data layers together
- Information button that drills through active layers allowing users access to databases
- View recent aerial photos
- Produce printable maps
- Access specific tasks and query options.

Water Topics Featured in TCEQ's "Natural Outlook"

Several water topics are highlighted in the summer 2008 edition of TCEQ's ***Natural Outlook***:

— ***Water Wizards***: Advances in monitoring provide a more comprehensive picture of water quality. CWQMN highlights.

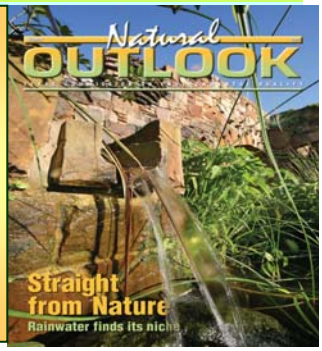
— ***Multiple Strategies at Play***: Cleanup projects underway in the North Bosque River.

— ***Need Water? Look to the Sky***: An article on the capture, storage, and use of rainwater.

— ***Comeback on the Coast***: Restoration of the Bahia Grande wetlands near Brownsville.

For a free subscription, write to:
Natural Outlook, MC 118
TCEQ
P.O. Box 13087
Austin, TX 78711-3087
or

Phone 512-239-0010
E-mail ac@tceq.state.tx.us
Fax 512-239-5010



To access the ***Natural Outlook*** online go to,
www.tceq.state.tx.us/comm_exec/forms_pubs/pubs/pd/020/08-03/index.html

Richland Chambers Constructed Wetlands

by Art Crowe, TCEQ, Region 5-Tyler

In honor of World Wetlands Day, TCEQ employees from Tyler, DFW, and Waco regional offices, along with the Northeast Texas Municipal Water District, the City of Waco, and Baylor University met at the Richland-Chambers constructed wetlands. This constructed wetland is a joint project between the Tarrant Regional Water District and Texas Parks and Wildlife Department (TPWD).

Effluent dominated water from the Trinity River south of Corsicana is passed through 250 acres of wetlands where much of the sediment and nutrients are removed. Testing has shown the following improvements in Trinity River water on the downstream end of the wetland: 96% reduction in TSS, 61% reductions in total nitrogen, and a 39% reduction in total phosphorus. In the mean time, ideal wildlife habitat is created for all types of waterfowl including ducks, wading birds, and top predators like osprey and eagles.

The first phase of the field scale project is scheduled to come on line in 2008. When completed, 15 MGD of water will be pumped from the wetlands to Richland Chambers Reservoir. Construction is currently underway for an additional 200-acre wetland cell. When fully complete the constructed wetlands will encompass roughly 1,000 acres and supply 150 MGD of treated water to Richland Chambers Reservoir. There is currently a 96-inch water supply pipe from the reservoir to the City of Fort Worth. When operational, water will have traveled approximately 200 miles round trip from Dallas back to Forth Worth. This project has the triple benefit of water reuse, nutrient reduction, and the creation of waterfowl habitat.

Staff viewing the outlet from the Richland Chambers constructed wetland.

"This project has the triple benefit of water reuse, nutrient reduction, and the creation of waterfowl habitat."

Trinity River water inlet to the constructed wetlands.

The EPA's National Rivers and Streams Assessment

The EPA's national monitoring studies are designed to report on the condition of the nation's lakes, streams, rivers, wetlands, and coastal waters. In 2008, TCEQ staff will participate in the National Rivers and Streams Assessment (NRSA). The EPA assigned Texas 32 NRSA sites to complete over a two year period.

The goal of the NRSA is to address two key questions on a national level:

1. What percent of the nation's rivers and streams are in good, fair, or poor condition for the key indicators of trophic state, ecological health, and recreation?

2. What is the relative importance of key stressors such as nutrients and pathogens?

3. What are the trends in stream conditions since the 2004 Wadeable Streams Assessment?

The survey will measure a wide variety of variables intended to characterize the chemical, physical, and biological condition of the Nation's flowing waters. These include water chemistry, nutrients, chlorophyll a, sediment enzymes, enterococci, fish tissue, physical habitat characteristics, and biological assessments including phytoplankton, periphyton, benthic macroinvertebrates, and fish communities.

In April 2008, TCEQ and TPWD staff attended a three-day training seminar in southeastern Oklahoma. Field work is set to begin at the first 16 sites this summer.

Staff from the TPWD River Studies team led by Roy Kleinsasser and staff from TCEQ SWQM Program in Austin and field staff from Houston, Tyler, San Antonio, DFW, and Waco will be participating this summer.

Study participants learning to use survey equipment to measure bed slope and reviewing fish collection protocols.

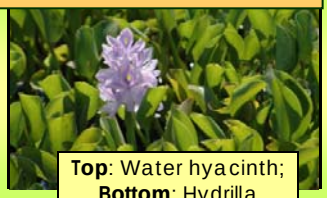
For more information, contact:

Bill Harrison
SWQM Program
NRSA Project Lead
bharriso@tceq.state.tx.us

EPA National Rivers and Streams Assessment
www.epa.gov/owow/riverssurvey/

What is an invasive species?

To find out more about the "Invasive Species in Texas" go to www.ucsusa.org/invasive_species/state-invasion-portfolios.html



Top: Water hyacinth; **Bottom**: Hydrilla

Invasive Species in Texas

What is an invasive species? An "invasive species" is defined as a species that is non-native (or alien) to a given ecosystem and whose introduction causes or is likely to cause economic or environmental harm or harm to human health (Executive Order 13112).

Invasive species are also referred to as exotic, alien, or non-indigenous species. The problem with these names is that they only refer to the non-native part of the definition above. Many exotic or alien species do not cause harm to our economy, our environment, or our health. In fact, the vast majority of "introduced" species do not survive and only a few become "invasive" or harmful.

An invasive species grows, reproduces and spreads rapidly, establishes over large areas, and persists. Species that become invasive succeed due to favorable environmental conditions and lack of natural predators, competitors and diseases that normally regulate their populations.

There are six species of most concern in Texas:

- Aquatic Plants
  Hydrilla, giant salvinia, water hyacinth
- Riparian Plants
  Salt cedar, Giant reed
- Animals
  Armored catfish

Source: TexasInvasives.org

"This successful event response has demonstrated that continuous and automated methods for monitoring coastal waters can provide real-time detection and early warning of harmful algal bloom events."

New Technology-Imaging Flow Cytobot

by Christine Kolbe

Dinophysis acuminata is a dinoflagellate that produces okadaic acid, the toxin responsible to diarrhetic shellfish poisoning (DSP). Toxic blooms of *D. acuminata* are a serious problem in Europe. The US has been relatively unaffected by toxic *Dinophysis* blooms, until recently. In early February 2008, a *Dinophysis* bloom was forming near Port Aransas. Without early detection this bloom could have had serious consequences along the Texas coast. A potential health crisis was averted due to technology developed at the Woods Hole Oceanographic Institution and the work being done by Dr. Lisa Campbell at Texas A&M University.

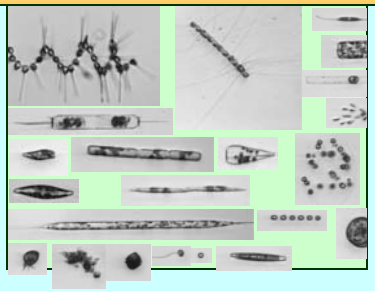
"Early warning of this first toxic Dynophysis bloom was provided by a new automated particle imaging system. Imaging FlowCytobot (IFCB) combines video and flow cytometric technology to capture images for phytoplankton identification and to measure chlorophyll fluorescence associated with each image. From the high resolution images, organisms ranging from 10 to ~100µm can be identified, often to genus or even species." In September 2007, the IFCB was installed in Port Aransas at the University of Texas-Marine Sciences Institute pier as part of a project to monitor *Karenia brevis*, another toxic dinoflagellate that blooms in the Gulf of Mexico.

After noticing an increasing number of *Dinophysis* cells, Dr. Campbell alerted the Texas Department of State Health Services (DSHS) who then conducted manual sampling to confirm the species, toxicity, and abundance. By March 2008, the DSHS confirmed the accumulation of DSP toxins in shellfish samples. The result was a closure of shellfish harvesting in Aransas, Corpus Christi, and Copano Bays and a product recall. Timing of the closure and recall of locally harvested oysters was fortunate. This allowed organizers of "Oysterfest"—an annual event that typically attracts more than 30,000 people to Fulton, Texas—to purchase oysters elsewhere.

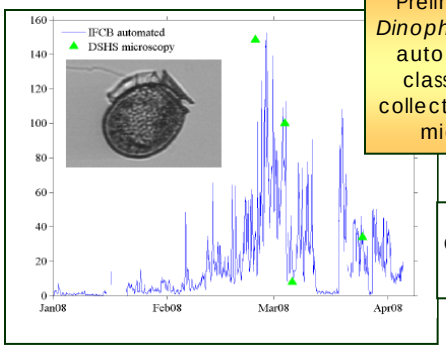
"This successful event response has demonstrated continuous and automated methods for monitoring coastal waters can provide real-time detection and early warning of harmful algal bloom events."

For the complete article "First Toxic *Dinophysis* Bloom Observed in the Gulf of Mexico, USA" in *Harmful Algae News* go to, http://www.ioc.unesco.org/hab/HAN36_comp.pdf

For details on the state response to the bloom go to the DSHS Seafood Safety Web site and select "Red Tide." http://www.dshs.state.tx.us/seafood/



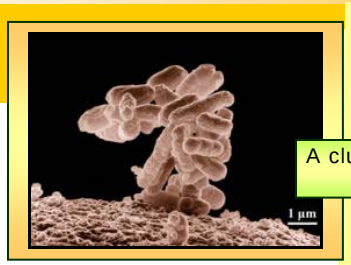
Top: IFCB in the field at Port Aransas
Bottom: Images generated by the IFCB



Preliminary time series of *Dinophysis* abundance from automated analysis and classification of images collected by IFCB and DSHS microscope counts.

Graphics from Dr. Lisa Campbell, Texas A&M University

E.coli Holding Time Update



A cluster of *E. coli* magnified x10,000

In 2007, an *E. coli* "Holding Time Study" was done in an effort to comply with new requirements from the Texas Legislature. These new requirements make it mandatory for surface water bacteria samples to be analyzed in a NELAC accredited lab. Since the few accredited Texas labs are geographically dispersed it has become necessary to consider the option of shipping water samples, often long distances, in order to meet holding time requirements of bacteria samples. Though the holding time for bacteria samples is 8 hours, this study shows that *E.coli* samples can be held for up to 48 hours when the samples are held at 4 °C and not allowed to freeze.

As of June, 2008, EPA Region-6 has conditionally approved SWQM method changes based on these findings. Additional sampling is scheduled for 2008 to provide further confirmation that *E. coli* results do not change significantly over time.

The approved holding times do not apply to those water bodies where *Enterococcus* is monitored routinely. A separate holding time study is currently being formulated to address the possibility of extending the holding time for these samples when necessary.

For additional information contact,
Steven Earnest
SWQM Program
searnest@tceq.state.tx.us

Words for the Quarter

Have you ever stayed awake at night wondering about the word *SAPROPEL?*

Sapropel —An unconsolidated ooze consisting mainly of putrefied plant remains found in anaerobic areas at the bottom of swamps, lakes, and shallow seas.

Can't talk about sapropel with out giving homage to the organisms that have to eat the stuff…

Saprotroph — An organism, especially fungus or bacteria, that eats sapropel.

The 22nd Annual SWQM Workshop

The twenty-second annual SWQM Workshop will be held ***October 20-23, 2008*** at the *Mayan Ranch Conference Center* in Bandera, Texas.

The workshop will begin on Monday, the 20th at 1:00 PM with a half-day session for TCEQ SWQM Program staff only. The regular session— open to all— begins on the 21st. The workshop will end after lunch on Thursday the 23rd.

The SWQM Program welcomes any ideas for workshop topics. We also welcome any offers to present findings of recent studies, new technologies, interesting aspects of monitoring in your region, or any related monitoring topics.

For additional workshop information, to suggest a topic, or to make a presentation, please contact Anne Rogers, at anrogers@tceq.state.tx.us; 512-239-4597.

Critter of the Quarter—Bowfin

Bowfins are an order (Amiiformes) of primitive ray-finned fish. Only one species, the bowfin *Amia calva*, family Amiidae, exists today, although additional species in six families are known from Jurassic, Cretaceous, and Eocene fossils. These included the huge Leedsichthys, the biggest fish that ever existed. The bowfin and the gar are two freshwater fish that exist today almost unchanged from prehistoric times.

The most distinctive characteristic of the bowfin is its very long dorsal fin running from mid-back to the base of the tail. Other noticeable features are the black "eye spot" usually found high on the caudal peduncle, and the presence of a gular plate. The gular plate is a bony plate located on the exterior of the lower jaw, between the two sides of the lower jaw bone.

When the oxygen level is low, the bowfin can rise to the surface and gulp air into its swim bladder, which is lined with blood vessels and can serve as a lung.

Bowfin are indiscriminant and voracious predators, known to eat a variety of prey from insects and crawfish to fish and frogs. Compared to many other species of their size, they have a tremendous appetite. Bowfins should be handled carefully. They are an ill-tempered, pugnacious fish, and consider themselves a match for anything—including humans. They have a mouthful of very sharp teeth. Just ask Bill Harrison.

With the exception of the Appalachian Mountains, the bowfin is native to eastern North America, ranging from extreme southeastern Canada to the Gulf Coast. In Texas this species is found in the Red, San Jacinto, and Sabine River systems, as well as the downstream reaches of the Brazos and Colorado Rivers.

Source: Wikipedia and TPWD

Bowfin — *Amia calva*

Illustration © TPWD

Upcoming Events

Watershed Protection Plan Meetings

Arroyo Colorado—
Aug 21
www.arroyocolorado.org

Bastrop Bayou
Last Tues & Thurs of each month
om.chawla@h-gac.com

Brady Creek —1 meeting prior to Aug 31
www.ucratx.org/

Buck Creek —Aug 28
http://twri.tamu.edu/buckcreek/

Caddo Lake —
Sept 16 - Stakeholder Meeting
www.netmwd.com

Cedar Creek — Aug 28
wfrossard@trwd.com

Dickinson Bayou —
Aug 14 & 28
www.dickinsonbayou.org

Plum Creek — Aug 14, Nov 13, Feb 12
http://pcwp.tamu.edu/

NEW Publication:
Quality of Water and Sediment in Streams Affected by Historical Mining, and Quality of Mine Tailings, in the Rio Grande/Río Bravo Basin, Big Bend Area of the United States and Mexico, August 2002

A USGS, TCEQ, and IBWC cooperative study.

http://pubs.usgs.gov/sir/2008/5032/

Interested in Learning More About Water Quality Standards?

In the field of water quality monitoring much of our work is driven by water quality standards.

Are you interested in knowing a little more about water quality standards? Don't have the time or funds to travel? EPA has just the thing for you...

An online course that introduces six key concepts related to water quality standards.

Each of the six modules of the online course is designed to be completed in about 15 minutes.

The modules present text-based information pages that include user interaction, links to further information and resources, and brief video clips that expand on important points.

To access the training modules go to,
www.epa.gov/waterscience/standards/academy/keyconcepts/index.htm

For an even quicker overview of water quality standards go to,
www.epa.gov/waterscience/standards/about/index.html

To access the *Texas Surface Water Quality Standards* go to,
www.tceq.state.tx.us/nav/eq/eq_swqs.html

Interesting Web Sites

- Texas Invasive Species: www.TexasInvasives.org
- USGS Invasive Species Program: http://biology.usgs.gov/invasive/
- Center for Aquatic and Invasive Species: http://plants.ifas.ufl.edu
- Center for Watershed Protection: www.cwp.org/
- General Information on Toxic and Harmful Algal Blooms: http://bigelow.org/hab/index.html
- Invasive Species of the Eastern US: www.invasive.org/eastern/
- Guide to Invasive Plants of the Galveston Bay Area: www.galvbayinvasives.org/
- Union of Concerned Scientists: www.ucsusa.org/invasive_species/
- USDA National Invasive Species Info Center, Aquatic Species: www.invasivespeciesinfo.gov/aquatics/main.shtml
- Aquatic Vegetation Management in Texas, A Guidance Document: www.tpwd.state.tx.us/publications/pwdpubs/media/pwd_pl_t3200_1066_1.pdf

The Leaky Wader

by Boyd Guthrie TCEQ, R-8, San Angelo

This is a rather humorous series of photos of Mark Finch taken during our contribution to the statewide fish tissue survey. Pat Bohannon came down with the fish shocking rig in November 2006. We lifted these fish out of the North Concho River. We used bass and channel catfish (not seen in these photos) for the survey. I guess Mark just felt like getting "down and dirty" with the carp.

"Primal Instinct and Raw Determination"

If the carp only had known that Mark was from the State—and he was just there to help— set him free!

Call for Papers and Posters

The Galveston Bay Estuary Program is pleased to announce that the *Ninth Biennial State of the Bay Symposium* will be held January 12-14, 2009 in Galveston, Texas.

The theme of this year's symposium is *"What is Needed to Sustain Our Estuary?"*

Habitat Protection
Species Protection
Freshwater Inflow and Bay Circulation
Spills and Dumping
Shoreline Management
Public Health Protection
Water and Sediment Quality
Non-Point Sources of Pollution
Point Sources of Pollution
Public Participation and Education
Economic Valuation and Impact of Estuarine Resources
Monitoring and Research

Abstracts are due no later than September 8, 2008.

Further information about the symposium will be placed on the Estuary Program website at www.gbep.state.tx.us as it becomes available.

For more information on submitting an abstract contact

Scott A. Jones
Galveston Bay Estuary Program
sjones@tceq.state.tx.us
(281) 486-1245

NELAC Accreditation Update

by Jennifer Delk

Starting on July 1, 2008, analytical data submitted to TCEQ that is related to assessing or characterizing an environmental process or condition must be generated by a National Environmental Lab Accreditation Conference (NELAC) accredited lab.

The Clean Rivers Program (CRP) informed participating laboratories that their NELAC applications had to be submitted by August 31, 2007. This was done for two reasons, (1) to coincide with the initiation of the start date of the new QAPPs, and (2) to ensure that labs would receive their accreditations by the June 30, 2008 deadline.

For the last four years, the CRP has been preparing for NELAC. The NELAC accreditation process was both labor and resource intensive. Labs devoted a substantial amount of time and money to updating SOPs, running performance test samples, filling out applications, preparing for audits, and responding to comments.

CRP staff would like to thank our partner laboratories for all of their hard work. We are proud to announce that they have all turned their NELAC applications in on time and have received full or interim accreditation status by the June 30th deadline.

The TCEQ Houston Lab also received NELAC accreditation on May 22, 2008.

Congratulations to all CRP partners and the Houston Lab!

For a list of NELAC accredited labs go to,

www.tceq.state.tx.us/compliance/compliance_support/qa/env_lab_accreditation.html

Water Quality Makes a Big Splash at the 2008 TCEQ Environmental Trade Fair and Conference

by Jill Csekitz

More than 4,100 people attended the 2008 TCEQ Environmental Trade Fair and Conference, an environmental forum held at the Austin Convention Center from April 29 to May 1. Visitors to the event were treated to a picturesque waterfall and pool exhibit, showcasing surface water quality monitoring efforts in Texas. The exhibit included native Texas materials, including granite boulders from the hill country, native herbaceous plants and Texas oaks. A continuous water quality monitoring station was installed alongside the pool, collecting measurements visitors could observe in real-time using laptops at the exhibit. Members of the Clean Rivers Program, Data Management, NPS Water Pollution Management, and Surface Water Quality Monitoring Teams staffed the exhibit and distributed outreach materials from each program.

The surface water quality monitoring booth was one of the most popular among the 363 exhibit booths and agency displays, drawing attention from local media outlets as well as conference visitors. News 8 Austin interviewed Jill Csekitz for an early morning story featuring the trade fair and continuous water quality monitoring. High profile booth visitors included each of the Commissioners, as well as former Executive Director Glen Shankle.

Staff from Data Management (Nancy Ragland), CRP (Patricia Wise), NPS (Anju Chalise), and SWQM (Michele Blair) working at the water booth.

SWQM exhibit at the TCEQ's Environmental Trade Fair.

CWQM Updates

New Stations

Three new continuous monitoring stations were installed in June and July. In June, a station was installed on Pine Island Bayou (C749) in the Neches River Basin. In July, two stations were installed on the Devils River (C763) and Independence Creek (C766) in the Rio Grande Basin. These sites are being operated by the LNVA, and TCEQ Laredo, and Midland regional staff, respectively.

Problem Solving

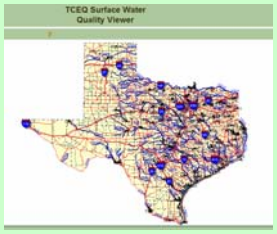
Since the installation of two sites on the Wichita River in December 2008, Dan Warren (TCEQ Region 3-Abliene) has been plagued with a build-up of fine sediment on the Greenspan multiprobe. To solve the problem, Lynn Robbins (Ambient Monitoring Section) designed a system to blow the sediment off the sensors. Using a solar powered 12-volt air compressor controlled by the Zeno data logger, the system blasts air across the sensors for 5-6 seconds each hour after the water quality measurements are made. After the installation the site went from no data to reporting at100%.

Typical conditions at the Wichita River CWQM site (top) and sediment build-up on the sonde (below)

Texas Surface Water Quality Viewer

Look up uses, standards, and information on water-quality assessment for bodies of surface water in Texas. Search using a Texas map, by the name of a water body, or by its segment number. Go to,

http://gis3.tceq.state.tx.us/website/Segments/



Cibolo Creek—A Success Story

by Michele Blair, TCEQ SWQM

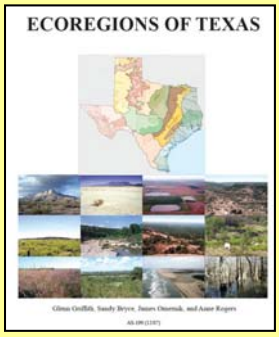
Most of us in the business of water quality have this job because we care very much for the environment around us. When we see something unique we want to help it stay that way.

It started with a waste-load evaluation. The City of Boerne wastewater treatment plant (WWTP) needed a permit amendment to accommodate future growth. During a trip to select monitoring sites for a wasteload evaluation (WLE) TCEQ staff found a gem. Actually we found several.

Upper Cibolo Creek (Segment 1908-San Antonio River Basin) is a beautiful hill country stream lined with Cypress trees and springs. The area of focus was a short stretch of the creek that started just above the WWTP at at the SE edge of Boerne and meandered through public, the Cibolo Nature Center (CNC), and private lands.

Our sampling took us through the Nature Center and as far as we could safely go until the creek plunges into a deep canyon and recharges the Trinity aquifer just downstream of this canyon marked by 100

(*continued on page 12*)



Freshwater Mussel (*Not Muscle*) Training

by Art Crowe, TCEQ, Region 5 Tyler

Freshwater mussels are an important and fascinating component of the freshwater ecosystem. The USA has more freshwater mussel species (~300) than any other similar sized area in the world. Unfortunately, 70 species are federally listed as threatened or endangered and 35 species are extinct. There are over 50 species found in Texas.

TCEQ currently does not have a program to monitor mussel populations, or utilize them as part of a water quality assessment, or in the development of water quality standards. In an attempt to raise mussel awareness and to see if they might fit into future assessment plans, a training conducted by Dr. Neil Ford at the University of Texas at Tyler this July.

He is a world-renowned herpetologist who has recently developed an interest in freshwater mussels. According to Dr. Ford, mussels make great subjects for his students. They are easier to catch than water moccasins. Currently there is more grant money available as well.

The second day of training was in the field. The first stop was at the Old Sabine Bottoms (OSB). The 6000-acre wildlife management area supports some of the best bottomland hardwood forest left in Texas. It is located north of Tyler between the current and an old channel of the Sabine. Dr. Ford and his graduate students have been studying the area for a number of years and have a several publications—including Texas J. of SCI. 58(3): 243-254. The morning was spent at the OSB doing timed surveys of transects, counting and identifying species, and looking for marked mussels.

The afternoon was spent on the main channel of the Sabine River near SH14.

(*continued on page 13*)

NEW Publication

Ecoregions of Texas

(TCEQ AS-199)

Companion Book to the *Ecoregions of Texas* map/poster produced by the EPA.

Available online at http://www.tceq.state.tx.us/assets/public/comm_exec/pubs/as/199.pdf

For a hard copy contact Anne Rogers at anrogers@tceq.state.tx.us

or TCEQ Publications at http://www.tceq.state.tx.us/comm_exec/forms_pubs/search_pubs.html

Upper Cibilo Creek—A Success Story

(*continued from page 11*)

Upper Cibolo Creek upstream of Herff Falls.

To learn more about the Cibolo Nature Center go to http://www.cibolo.org/

foot walls. The top of this canyon is called Herff Falls and is comprised of a fossilized reef of cretaceous univalve clams and star corals. What is unique about this reef is the surface location. These are generally buried deep below the earth's surface. The area downstream of the WWTP is an area rich in diverse and complex habitats. There were long open runs, deep shaded pools, riffles, springs, you name it. It was clear, after seeing this for ourselves, this place was special.

The next thing we noticed was a huge clearing adjacent to the fossil beds. KB Homes was building 600, high density, single family homes, right on the edge of the creek! Like any SWQM type, alarm bells went off. What can we do to protect the creek in light of the pressures sure to come with increased building and density in the area?

Back in the office, we asked for permission to start aquatic life monitoring (ALM) in order to get some baseline conditions before all of the new construction really began. We got the okay and were off and running. We completed the first monitoring event (August 1-2, 2006), including benthics, fish, habitat, and typical field measurements. There were so many fish and so much diversity in this creek, it was becoming clearer that we may be seeing not only high but exceptional aquatic life use, in an effluent dominated creek!

Bill Lende at the bottom of the canyon downstream of Herff Falls.

A year and many floods later, we completed the 2nd ALM monitoring event in June 2008 with the same results. Though the final counts are not in, there is no doubt, Cibolo Creek is an exceptional water body well worth every protection we can afford it.

We also completed the WLE in mid-August 2006. As suspected, the water quality data was indicative of effluent with no nutrient limits. Phosphorus was relatively high (3.5 mg/L), compared to natural systems. The impact of the phosphorus was evident. Filamentous algae were abundant and the locals recounted the increased blooms over the past 20 years. However, what was also evident was an abundance of aquatic life. And this was in a stream that was effluent dominated and in drought! Using both the WLE and ALM data we were able to get a total phosphorus permit limit set at 0.5 mg/L for the new WWTP.

Through all of the monitoring, we have been fortunate enough to forge great relationships with the local folks. We have regularly met with the CNC staff in order to exchange data and ideas and provide literature for their local efforts such as xerascaping, fertilizing, water conservation, and general environmental education. We have all had the great fortune to become friends with Bill Linde, the owner of the area downstream of the CNC which includes Herff Falls. He has provided us unlimited access and great companionship along the way. Bill is committed to the land and creek and taken every step possible to restoring the hill country habitat on his ranch. He has hosted two meetings on his breezy veranda where we, CNC staff, TPWD, City Council, and WWTP staff have all shared thoughts on how best to protect Cibolo Creek. During one of our meetings, we suggested they apply for a $250,000 grant to create a Watershed Protection Plan. The City of Boerne and the CNC have written and submitted their proposal together and all indications are that they will be funded this year.

For us, this project has been a real reward! We have been able to connect with a group of people who are doing amazing things to protect a very unique environmental resource. We all connected at the right time.

Since the start of this project, Bill Linde, in partnership with the CNC, has recently converted all of his lands, with the exception of the old ranch house, to a trust. The land is to be preserved for research purposes and the CNC as stewards are charged with continuing Bill's legacy of restoration. It certainly was an honor and a pleasure to work with all of these dedicated people.

Upper Cibolo Creek at the top of Herff Falls.

"Unless someone like you cares a whole awful lot, Nothing is going to get better. It's not."

— Dr. Seuss, from *The Lorax*

Freshwater Mussel (*Not Muscle*) Training (continued from page 11)

We kayaked or canoed downstream about a quarter of a mile to a riffle area. At this site, we broke into three groups and did a density survey using a technique called systematic sampling with multiple random starts. The following morning we gathered back at UT-Tyler and entered the data into an Excel spreadsheet and did a Single Factor Analysis-ANOVA to determine if there were differences between groups—there wasn't.

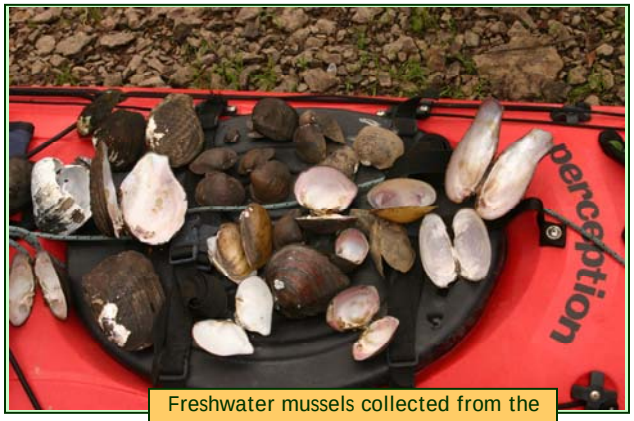
Freshwater mussels are fascinating. Most have a complex reproductive cycle that involves a parasitic stage on fish. Some have developed fish-like lures to attract the correct host species. Many are quite beautiful on the inside with colors ranging from rose to purple. Just the common names make you want to learn more—Louisiana fatmucket, Texas pigtoe, Tampico pearlymussel, rock-pocketbook, bluefer, and Rio Grande monkeyface are some examples.

Washboard

But the real importance of freshwater mussels in Texas may lie in their sensitivity to certain pollutants, such as ammonia, copper and certain fungicides. The October 2007 issue of the journal *Environmental Toxicology and Chemistry* has a special section on the pollutant sensitivity of freshwater mussels. Mussels appear to be more sensitive to ammonia than other animals that are used to develop water quality criteria and standards.

Where to go from here? One idea is to do a "Special Study" of mussel populations at the least-impacted reference sites throughout Texas. This would be an interesting addition to the diurnal DO survey that was recently completed at these sites. It would also be an opportunity to learn the different species that should be found in your region or river basin.

Here's a link to the series title *Contaminant Sensitivity of Freshwater Mussels*: www.setacjournals.org/perlserv/?request=get-toc&issn=1552-8618&volume=26&issue=10.

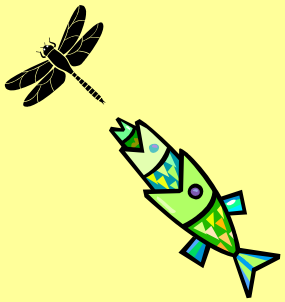


Freshwater mussels collected from the Sabine River at SH 14

Shawna Simpson (TCEQ SWQM Team) and Boyd Guthrie (TCEQ Region 8 San Angelo) getting into their work collecting mussels.

Changing Times

Last but definitely not least—after many years of dedication to TCEQ's SWQM Program and recently to the Water Monitoring and Assessment Section, Patrick Roques is ready to say good-bye. As of August 1st Patrick will begin to enjoy a much deserved rest and start enjoying all those things he's been missing riding herd on a very lively bunch. His absence will be felt for a long time.



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THE TEXAS CLEAN RIVERS PROGRAM

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