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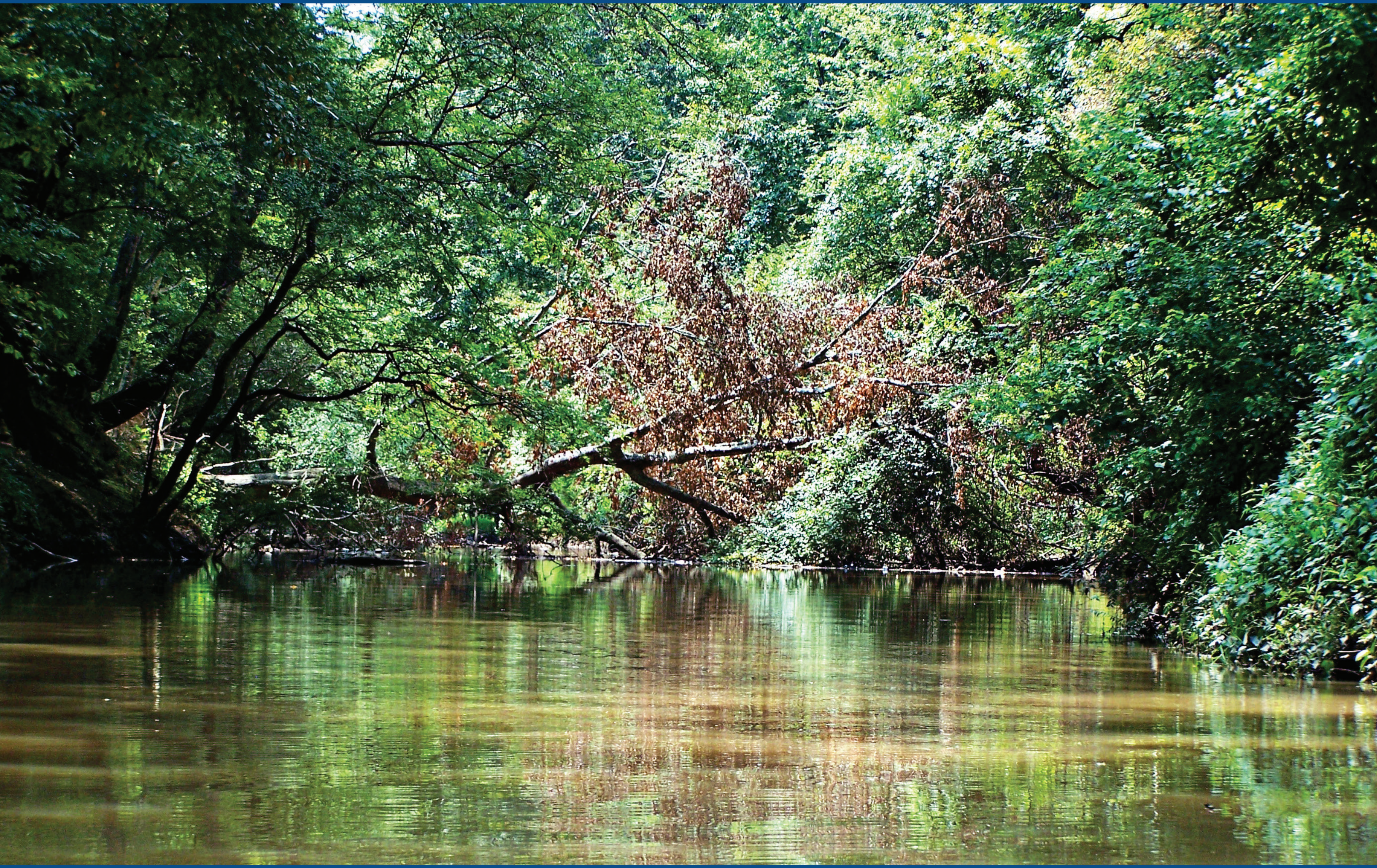

Attoyac Bayou Surface Water Quality Monitoring Report

Sarah Schwab and Matthew McBroom, Arthur Temple College of Forestry and Agriculture
Lucas Gregory, Benjamin Blumenthal, Kirstin Hein, and Kevin Wagner, Texas Water Resources Institute
Brian Sims, Angelina Neches River Authority

Texas Water Resources Institute
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Attoyac Bayou Surface Water Quality Monitoring Report

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Investigating Agencies:
Stephen F. Austin State University
Angelina Neches River Authority
Texas A&M AgriLife Research, Texas Water Resources Institute

Prepared by
Sarah Schwab and Matthew McBroom, Arthur Temple College of Forestry and Agriculture
Brian Sims, Angelina Neches River Authority
and
Lucas Gregory, Benjamin Blumenthal, Kirstin Hein, and Kevin Wagner, Texas Water Resources Institute

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List of Abbreviations

ANRA	Angelina & Neches River Authority
AU	Assessment Units
CRP	Clean River Program
CFS	Cubic Feet per Second
CFU	Colony Forming Unit
DO	Dissolved Oxygen
EPA	Environmental Protection Agency
Mg/L	Milligram per liter
mL	milliliter
SFASU	Stephen F. Austin State University
TAC	Texas Administrative Code
TCEQ	Texas Commission on Environmental Quality
TDS	Total Dissolved Solids
TSWQS	Texas Surface Water Quality Standards
USGS	United States Geological Survey
WET Center	Waters of East Texas Center
WWTF	Wastewater Treatment Facility

Introduction

The Attoyac Bayou watershed is part of the larger Neches River Basin and covers 354,629 acres in Nacogdoches, Rusk, San Augustine and Shelby counties. The Attoyac Bayou flows into Sam Rayburn Reservoir south of FM 103. The Attoyac Bayou originates north of US 84 in Rusk County, and flows into Nacogdoches County, South into San Augustine County, and ending in Shelby County.

Designated uses of the Attoyac Bayou included aquatic life, contact recreation, and fish consumption. The main uses of the watershed are agriculture and forestry. For assessment purposes, TCEQ splits the Attoyac Bayou watershed into three assessment units (AU) 0612_01, 0612_02, and 0612_03. The Angelina and Neches River Authority (ANRA) has been monitoring the bayou as part of the Texas Commission on Environmental Quality's (TCEQ) Clean Rivers Program (CRP) for many years. Water quality data collected eventually illustrated that it did not meet the standards set for bacteria (126 cfu/100 mL of *E. coil*), leading to the Attoyac Bayou to be listed on the 2004 303(d) list for impaired water bodies. Sites monitored by ANRA include the Attoyac at US 59 (16076), Attoyac at State Highway 7 (15253) and the Attoyac at State Highway 21 (10636). Initially, these water body segments were listed as needing additional water quality data collection but are now undergoing a standards review to determine if the applied water quality standard is appropriate.

Prior to the standards review effort, this project was developed to provide additional water quality data from across the watershed to aid in determining the extent of the bacteria impairment in the watershed. Indicator bacteria, such as *E. coli*, are normally found in the intestinal tract and fecal material of birds and warm-blooded animals and are not normally harmful to human health, but can indicate the presence of pathogens that can cause disease. Typical sources of these bacteria in watersheds include birds and mammals (humans, livestock, wildlife, etc.) and are either directly deposited into a water body or enter diffusely through surface runoff.

This study was designed to better understand where and when bacteria levels exceed applicable water quality standards in the Attoyac Bayou watershed. Using an expanded spatial and temporal monitoring regime for a focused period of time allowed for a more refined look at water quality seasonally, as influenced by hydrologic conditions and in relation to watershed land uses. Paired with other information from the watershed such as landuse and land cover, bacterial source tracking and watershed modeling, this data will aid in the development of the Attoyac Bayou Watershed Protection Plan and facilitate informed decision making by local watershed stakeholders.

Monitoring Approach

Increasing the spatial and temporal distribution of available water quality and stream flow data was the goal of this project. To accomplish this, an expanded monitoring regime was temporarily implemented in the watershed. Building upon historical data collection by ANRA through the CRP program and the TCEQ Regional office, a plan was developed that called for the addition of 7 more monitoring stations on the Attoyac Bayou and several of its tributaries. This regime integrated routine sampling at all sites with automated storm sampling conducted at 2 sites.

Routine Sampling

Bi-weekly (twice per month) grab samples were collected at the 10 established water quality monitoring sites across the watershed (Figure 1) when water was flowing. Sampling occurred on a routine schedule at the beginning of the week either on a Monday or a Tuesday for the course of the study and did not specifically target any defined flow condition. Sampling was initiated on July 26, 2010 and continued through August 20, 2012. Originally, a 2 year monitoring regime was planned; however, the exceptional drought that gripped Texas in 2011 prevented many samples from being taken and necessitated that sampling be extended for several months.

When sufficient flow was present, measurements were taken using an electronic Marsh McBirney flow meter. Field based water chemistry including dissolved oxygen, pH, specific conductance, and water temperature was measured using a YSI 556 multi probe. Data collected were recorded onto a field data report (Appendix A). The number of days since the last significant rain event, the current weather condition, and the flow severity of the stream as well as any comments about the stream or the surroundings of the bank appearance (such as biological activity) were recorded as well.

Once collected samples were all placed into their appropriate pre-labeled sampling container, they were transported back to the ANRA Environmental Laboratory on ice, along with a chain of custody record (Appendix B) indicating the sample ID, date, time sample was taken, and the number of containers that were collected at that site. Additionally, a subset of water samples were collected and processed for bacterial source tracking. Once a month during routine sample collection, a bacteria sample was collected at each site and transported on ice to the Stephen F. Austin State University, Waters for East Texas Center (WET) Lab for analysis along with its chain of custody form.

In addition to grab sampling, field parameters were also recorded during each monitoring event. Observational information such as present weather, flow severity, and days since last rainfall were noted. Parameters measured in the field included pH, dissolved oxygen (DO), specific conductance, air temperature, water temperature, total water depth and the instantaneous flow rate.

Of the monitored parameters, flow rate, flow severity, water depth, ammonia, and *E. coli* were considered critical parameters. In the event of adverse weather conditions such as lightning or flooding, sampling was delayed until safe conditions returned.

Storm Sampling

Storms sampling was conducted at two sites; the Attoyac Bayou at State Highway 21 and Big Iron Ore Creek at FM 354. Automated storm samplers were set up at the beginning of the project with an up-looking Doppler flow meter that recorded stream flow rates continuously at 5 minute intervals. Due to the high sediment load in the instrumented streams, the flow meters were intermittently covered with sediment preventing them from recording flow. These automated storm samplers were programmed to collect flow-weighted composite samples, using an ISCO Avalanche. Sampling was initiated when a 5% above ambient water level was detected. Once sampling began, the Attoyac Bayou site collected samples after every 100,000 cubic feet of water passed the sampler while the Big Iron Ore sampler collected samples after each 15,000 cubic feet of flow. Samplers were intended to automatically collect the sample; however, several instrument failures during the course of the study led to grab samples being taken at both sites following storm events. On several occasions, automated samplers failed to pull samples for various reasons (stolen solar panel, flow meter offline, etc.). In those instances, grab storm- event samples were collected. Sampling procedures and analysis mirrored that of routine grab sampling and samples were taken to both ANRA and to the SFASU WET Lab for the bacterial analysis.

Point Source Sampling

Effluent samples from 4 Texas Pollution Discharge Elimination System permitted treatment facilities that exist in the watershed were also collected. A total of 5 sampling events were completed on a quarterly interval. Once collected, samples were transported to and processed by ANRA for the suite of water quality parameters described in the "Routine Sampling" section. Field parameters of pH, DO, specific conductance and temperature were also measured.

Monitoring Sites

Ten sites at public road crossings were chosen for routine, bi-weekly sampling. Five of these sites are on the Attoyac Bayou and extend from near the head waters (State Highway 84; Station 20842), and move downstream toward Sam Rayburn Reservoir. Sites were located near the City of Garrison at the US 59 road crossing (Station 16076), east of the city of Garrison on FM138 (Station 20841), near Martinsville at the State Highway 7 crossing (Station 15253) and near the outlet of the watershed east of Chireno at the State Highway 21 crossing (Station 10636). Five additional sites were located on selected tributaries to the Attoyac Bayou. These sites were selected based on prior monitoring (Terrapin Creek at FM 95, Station 16084; Waffelow Creek at FM 95, Station

16083) as well as their distribution across the watershed and the size of the overall watershed they represented (Big Iron Ore Creek at FM 354, Station 20844; Naconiche Creek at FM95, Station 20843; West Creek at FM2913, Station 20845). These sites are illustrated in Figure 1 and described in Table 1.

In addition to stream monitoring, 4 TPDES permitted facilities in the watershed were also sampled. The City of Garrison's wastewater treatment facility (WWTF) (Site 11 WWTF), Martinsville ISD's WWTF (Site 12 WWTF), Chireno ISD's WWTF (Site 13 WWTF) and the City of Center's potable water treatment system's backwash water on Lake Pinkston (Site 14 WWTF) were sampled 5 times throughout the course of the project. These sites are also denoted in the map and listed in Table 1.

Table 1. Sampling site information and monitoring type

Site #	*TCEQ Station #*	*Sample Type*	*Sampling Site Name*	*GPS Coordinates Lat: 31 ° N*	*GPS Coordinates Long: 94 ° W*
			Stream Sampling Sites		
1	10636	Routine	Attoyac Bayou @ SH 21	30'15.05"	18'13.99"
2	15253	Routine/ Storm	Attoyac Bayou @ SH 7	*38'54.00"*	23'50.00"
3	20841	Routine	Attoyac Bayou @ FM 138	46'6.61"	25'34.50"
4	16076	Routine	Attoyac Bayou @ US 59	51'24.14"	27'49.89"
5	20842	Routine	Attoyac Bayou @ US 84	55'26.97"	30'41.07"
6	16083	Routine	Waffelow Creek @ FM 95	41'29.99"	26'16.00"
7	16084	Routine	Terrapin Creek @ FM 95	38'20.01"	24'53.08"
8	20843	Routine	Naconiche Creek @ FM 95	42'43.80"	26'57.86"
9	20844	Routine/ Storm	Big Iron Ore Creek @ FM 354	*33'57.43"*	17'22.05"
10	20845	Routine	West Creek @ FM 2913	41'13.10"	23'0.09"
			Wastewater Treatment Facility Sampling Sites		
11	N/A	Quarterly	City of Garrison WWTF	49'21.86"	29'2.82"
12	N/A	Quarterly	Chireno ISD WWTF	30'3.13"	21'6.30"
13	N/A	Quarterly	Martinsville ISD WWTF	38'32.29"	24'52.99"
14	N/A	Quarterly	City of Center WWTF	41'38.80"	19'56.66"

Experimental Procedures

Samples collected were returned to the ANRA Laboratory within prescribed sample holding times and analyzed for *E. coli*, total suspended solids, ammonia-N, nitrate+nitrite-N, dissolved ortho-phosphorus, and total phosphorus. The specific analytical methods utilized were the same as those methods used when processing samples collected through TCEQ's CRP program. The use of identical methods was planned to ensure method consistency between CRP data and data collected through this project, thus enabling the direct comparison of the separate data sets.

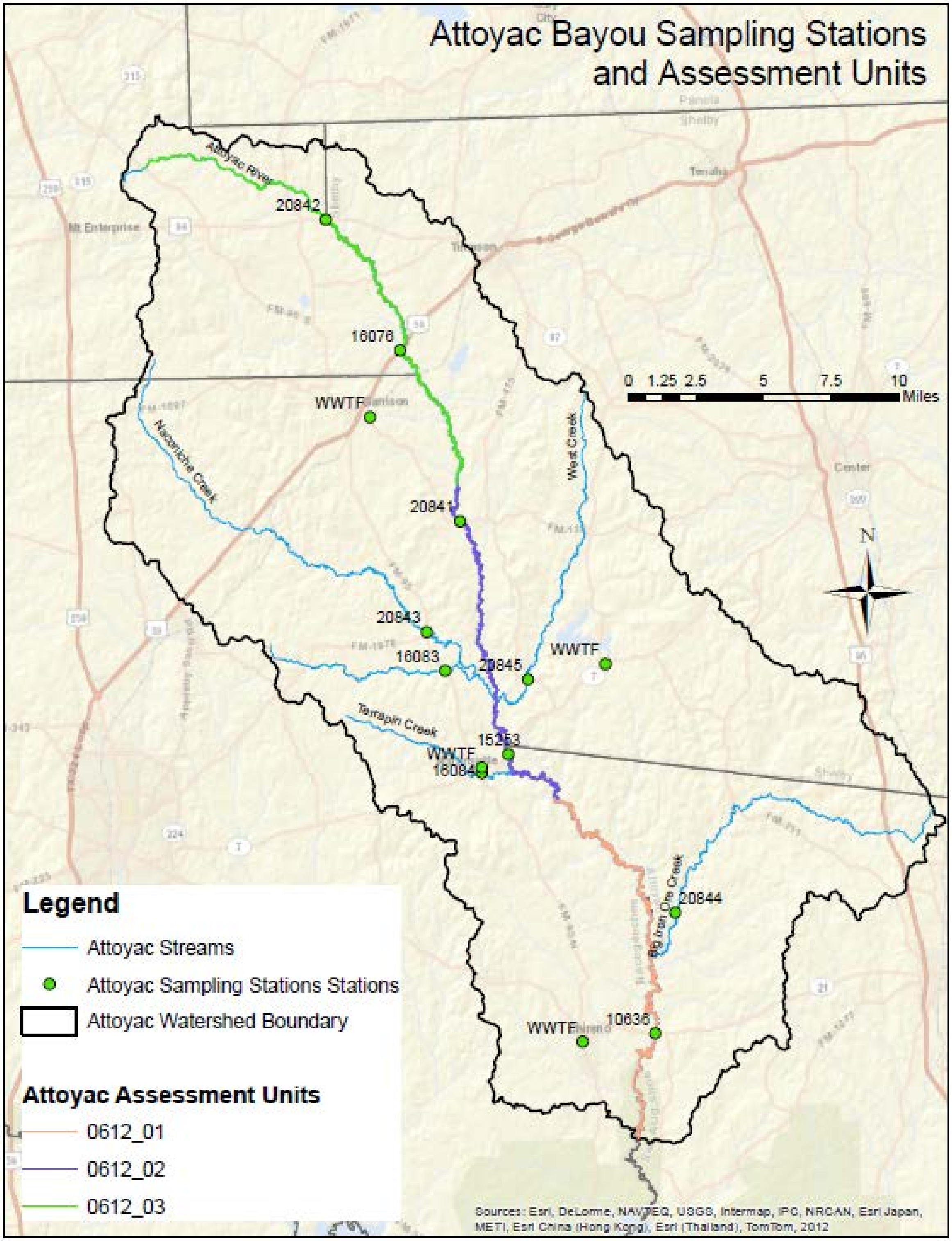

Figure 1. Sampling locations and Station ID Numbers for the Attoyac Bayou watershed

Water Quality Assessment

The Texas Commission on Environmental Quality (TCEQ) conducts a water body assessment on a biennial basis with the most recent approved assessment from 2012. In years past, this assessment was called the *Texas Water Quality Inventory and 303(d) List*, but was renamed to the *Texas Integrated Report for Clean Water Act Sections 305(b) and 303(d)* in 2010 and is often referred to as the *Integrated Report*. TCEQ uses the most recent 7 years of available water quality data available to assess a water body's ability to support its designated uses. For example, the *2012 Integrated Report* takes into consideration data collected between December 1, 2003 and November 30, 2010 (TCEQ 2012). TCEQ data assessors also have the option of including more recent data if they are available or older data collected up to 10 years prior to the assessment date if they deem necessary.

Designated Uses

TCEQ assigns water bodies as either classified or unclassified with the classified segments individually defined in the *Texas Surface Water Quality Standards* (TCEQ 2004). Applicable water quality standards designated for unclassified water bodies are defined by TCEQ according to the flow type exhibited by the given stream (2010). Designated uses dictate what water quality assessment criteria a water body must adhere to. Unclassified segments are usually assigned the same designated uses as the classified segment that they are associated with, but this is not always the case.

TCEQ requires Attoyac Bayou to support high aquatic life, general use, contact recreation, and public water supply water quality standards. Aquatic life use is simply defined as a water body's ability to support a healthy aquatic ecosystem and is measured through evaluation of DO criteria, toxic substances in water or sediment, and indices for habitat, benthic macroinvertebrate and fish community. Recreation use is designed to evaluate the ability of a water body to support designated levels of recreation and is assessed by quantifying levels of bacterial indicator organisms in 100 mL of water. *Escherichia coli (E. coli)* is the bacterial indicator used in the Attoyac Bayou to assess this use. General use is a set of water quality criteria that are monitored to assess general water quality and include water temperature, pH, chloride, sulfate and total dissolved solids (TDS); additionally, concerns for meeting the general use are also quantified with screening levels for nutrients and chlorophyll a (TCEQ 2010).

Assessment Units

Following designation, water bodies are provided with a written description of the segment and are further subdivided into assessment units (AU). According to TCEQ (2010), "AUs are the smallest geographic area of use support reported in the water body assessment." The Attoyac Bayou is defined by three AUs, 0612_01, 0612_02 and 0612_03 which extend from "a point 3.9 km (2.4 miles) downstream of Curry Creek in Nacogdoches/San Augustine County to FM 95 in Rusk County."

During water body assessments, data collected from a designated AU are used to assess each AU independently of other AUs in that segment. Figure 1 illustrates the locations of these AUs as defined by their respective descriptions and the mapped extent of the stream segment.

Index Sites

Ideally, one monitoring location within each AU would be selected as an index site for that AU. Preferably, sites that are considered most representative of the specific AU and will be monitored long-term are selected. As mentioned, the Attoyac Bayou is divided into 3 AUs creating upper, middle and lower portions of the bayou. In the lower portion, AU 0612_01, Station 10636 was selected as the index site. This station has been monitored since 1972 and has the longest and most extensive data record of all monitoring stations in the Attoyac Bayou watershed. Station 15253 was chosen to represent the middle part of the bayou, AU 0612_02. This station is located in the middle portion of the AU, has the most extensive data set available and is routinely monitored by ANRA through the CRP program. Despite being monitored quarterly through the CRP program, station 16076 at US 59 in the upper AU (0612_03) had an insufficient number of stream flow measurements to conduct loading analysis and was thus not selected as an index site. The physical characteristics of this site make recording stream flow rates extremely difficult. No other station in the upper AU had a sufficient data record either. As a result, only 2 index sites were selected for the Attoyac Bayou. These locations are denoted in Table 1 and Figure 1.

Texas Surface Water Quality Standards for the Attoyac Bayou

TCEQ designates applicable water quality standards for each water body assessed in the state as outlined in the Texas Surface Water Quality Standards (TSWQS). Some of the primary measures used to quantify a water body's ability to meet its designated uses are: 1) dissolved oxygen standards for aquatic life use; 2) *E. coli* standards for recreation use and 3) nitrate and chlorophyll-a screening levels for designated general uses.

It must be noted that the nutrient screening levels are not a water quality standard, but instead a measure used to determine if a concern exists or not for that specific water quality constituent. Each of the above listed water quality standards/concerns are described in detail below.

Dissolved Oxygen (DO)

DO is considered the main factor in determining a water body's ability to support existing, designated and attainable aquatic life uses. If DO levels in a water body drop too low, fish and other aquatic species will not survive. According to TCEQ (2010), a perennial stream should maintain a 24-hour average for DO of 5.0 mg/L with a minimum of 3.0 mg/L. When evaluating DO levels in a water body, TCEQ considers an index period and a critical period. The index period represents the warm-weather season of the year and spans from March 15th to October 15th. The critical period of the year is July 1st to September 30th and is the portion of the year when minimum stream flow, maximum temperatures and minimum DO levels typically occur across Texas. At least half of the samples used to assess a stream's DO levels should be collected during the critical period with the remainder of the samples used coming from the index period. DO measurements collected during the cold months of the year are not considered because flow and DO levels are typically highest during the winter months according to §307.7 and §307.9 of the Texas Administrative Code (TAC) (TAC 2013).

Bacteria

Bacteria standards set for contact recreation are applied to all freshwater bodies in the state unless otherwise designated in the TSWQS. This standard has been established to gauge the ability of a stream to support its designated contact recreation use. This standard was established as a measure to gauge the level of risk that someone engaged in primary contact recreation will have of contracting a fecal contamination derived ailment. Primary contact recreation can be defined as activities that are presumed to have a significant risk of water ingestion such as wading by children, swimming, and tubing among others. As a result, a geometric mean of 126 cfu/100 mL must be maintained (TAC 2013, TCEQ 2010); otherwise, there is considered to be an elevated risk of ingesting pathogenic organisms associated with fecal material during contact recreation. In order for the bacteria standard to apply, a minimum of 20 samples collected within a 7-year period are required. Once 20 samples have been collected, the geometric mean of all samples collected within the most recent 7-year time frame must remain at or below the geometric mean to support contact recreation. Samples used in water body assessments must not include extreme hydrologic conditions such as very high-flows and flooding. This applies for a 24-hour period following the last measured or estimated determination that extreme hydrologic conditions exist according to TAC §307.9 (TAC 2013).

Nutrients

Nutrient screening levels developed for statewide use (Table 2) were established to protect water bodies from excessive nutrient loadings and support their primary, secondary, and noncontact recreation, aquatic life, and public water supply uses. By assessing statewide data collected from similar water bodies in Texas, the 85th percentile of all data was set as the 'screening level.' If a water body exceeds these established screening levels more than 20% of the time, that water body is on average experiencing pollutant concentrations higher than 85% of the streams in Texas. Screening levels have been designated for ammonia, nitrate, orthophosphorus, total phosphorus and chlorophyll-a.

Temperature

The Attoyac Bayou has a maximum temperature standard described in TAC §307.10 of 32.2°C which is established primarily to protect aquatic life resources (TAC 2013). Temperature criteria are also in place to establish limits that will allow for reasonable uses of the waters. Tributaries do not have specific temperature requirements, so they default to the standard for the receiving water body; the Attoyac Bayou in this case.

Table 2. Nutrient screening criteria for freshwater streams

Nutrient	Screening Level
NH3-N (Ammonia)	0.33 mg/L
NO3-N (Nitrate)	1.95 mg/L
OP (Orthophosphorus)	0.37 mg/L
TP (Total Phosphorus)	0.69 mg/L
Chl a (Chlorophyll a)	14.1 µg/L

Specific Conductance and pH

The Attoyac Bayou does not have an express written specific conductance standard; however, it does have a total dissolved solids (TDS) standard which TCEQ uses as an analogous measure. According to the TCEQ's assessment guidance (TCEQ 2010), specific conductance values are multiplied by 0.65 to determine TDS levels. As such, this allows an equivalent specific conductance standard to be calculated. Applying this conversion, specific conductance should not exceed 307.7 µS/cm more than 25% of the time. The allowable range for pH readings is 6.0-8.5.

Monitoring Findings

Flow Regime

Volumetric stream flow rates are one of the two critical parameters in calculating a pollutant's loading rate. Measuring stream flow can be quite challenging without the presence of an automated measurement device situated in a fixed channel cross-section (concreted low water crossing or bridge abutment) where a known water level can be correlated to an established flow rate. If this type of situation is not present, two other options can be utilized: 1) instantaneous flow rate measurements or 2) automated measurements paired with repeated cross-section delineations. For this project, both instantaneous and automated methods were utilized.

Instantaneous Stream Flow

An instantaneous flow measurement was taken during the routine bi-weekly visits to the 10 sites to determine the volume of stream flow at the time each sample was taken. This information is critical in understanding the bacterial load that is present in the bayou and creeks at a given point and time. Each time a grab sample was taken a flow measurement was taken unless unsafe conditions existed or if the site was too deep to wade. Alternatively, when the area experienced exceptional drought conditions in the summer of 2011, monitoring sites were often pooled or dry thus preventing flow measurements (Table 3).

Throughout the course of monitoring, instantaneous stream flows recorded ranged from 0 to 241.34 cfs. Numerous monitoring sites were either dry or pooled during the drought and had no actual flow. The highest recorded flow value occurred on the bayou at SH 21 (Station 10636) in April 2012 at a recorded 241.34 cfs and occurred after 3 rain events larger than 1.5 inches.

Table 3. Measured stream flow at monitored stations over the two year study, mean, lowest and highest flow rate (cfs)

Name	Site #	# of Readings with Recorded Flow	Flow Rate (cfs)		
			Mean	Minimum	Maximum
Attoyac at State Highway 21	10636	43	26.02	0.05	241.34
Attoyac at State Highway 7	15253	43	9.42	0.06	91.55
Attoyac at FM 138	20841	34	3.67	0.0	44.17
Attoyac at State Highway 59	16076*	1	N/A	0.0	0.06
Attoyac at US Highway 84	20842**	2	N/A	0.0	0.43
Big Iron Ore Creek at FM 354	20844	48	13.56	0.0	58.18
Terrapin Creek at FM 95	16084	31	2.19	0.0	19.85
West Creek at CR 2913	20845	40	1.85	0.0	22.94
Waffelow Creek at FM 95	16083*	15	0.65	0.0	3.79
Naconiche Creek at FM 95	20843	50	7.97	0.0	55.65

* sites plagued by beaver dams that prevented flow and caused stream channel to be too deep to wade; alligator often present at site 16083 as well

** site dry or pooled on all but 2 sampling events due

While this monitoring approach provides much needed instantaneous stream flow data, it does not portray the entire flow record; especially high flow events. At most, stream flow readings were made 52 days per year leaving the bulk of days unmonitored.

Automated Stream Flow

In an effort to better understand stream flow dynamics of the Attoyac Bayou watershed, the Attoyac Bayou at SH 21 (Station 10636) and Big Iron Ore Creek at FM 354 (Station 20844) were instrumented with automated flow recording devices. The goal of this effort was to achieve a continuous flow record at each site thus allowing for an improved understanding of the watershed's hydrology. Nature and man both led to a less than continuous flow record. The drought of 2011 caused stream levels to drop below the minimum threshold that could be recorded on several occasions and the solar panel powering automated instrumentation on Big Iron Ore Creek was stolen shortly after the device was deployed.

At each of these locations, an Argonaut SW 9000-01060 real-time 2 dimensional acoustic Doppler current meter was utilized. Based on established stream cross-sections and the depth of water and velocity of flow, these devices estimated stream discharge rates. This device is an up-looking flow meter meaning that it is located on the bottom of the stream and records the speed of particles moving in the waterbody. The device is only operable in 3 inches of water or more and as such cannot record very low flows. Extremely turbid waters also increase the chance for erroneous values. With these considerations in mind, it became clear that the current meter was biased to returning low flows. Sitting on the bottom of an East Texas river, the instrument could easily be covered with debris or sediment yielding flows significantly less than the actual flow rate. It is also apparent that flows were such that this was usually only a problem for short (less than one day) durations.

Using this information, collected data were screened to remove recorded values that were most likely to be erroneous. While this improved the flow approximation recorded, the variability in recorded values over the course of a day continued to provide an exceptional amount of uncertainty in the automated flow data. For example, during a rain event induced, high flow event on the Attoyac Bayou at SH 21 on February 8, 2012, recorded flow volumes ranged from 7.57 to 605.4 cfs while the recorded stream depth only varied between 12.2 and 12.44 feet.

To approximate daily stream flow rates using these data, several methods were evaluated. Initially, a 75th percentile rolling average was calculated but it did not mitigate the intra-day variations observed. Selecting only maximum values was also attempted; however, this method clearly biased flows higher. After calculating daily minimums, maximums, averages and quartiles, the 3rd quartile appeared to provide the most reasonable estimate of daily flow rates at the automated sites. This variability in calculated flow rate stems largely from the recorded velocity since the depth varied only slightly and the stream cross-section used in the calculations remained static. The processed flow records for each site are presented in Figures 2 and 3.

Due to observed variability in automated measurements, these data were not considered suitable for estimating loading calculations; however, they did provide some insight into the flow variability observed in the watershed. An old USGS gaging station located on the Attoyac Bayou at SH 21 (Station 10636) also provided some insight into flow variability. This gaging station has an intermittent data record since continuous discharge collection was discontinued in 1985. However, peak discharges are still measured. The maximum recorded discharge rate was approximately 50,000 cfs and

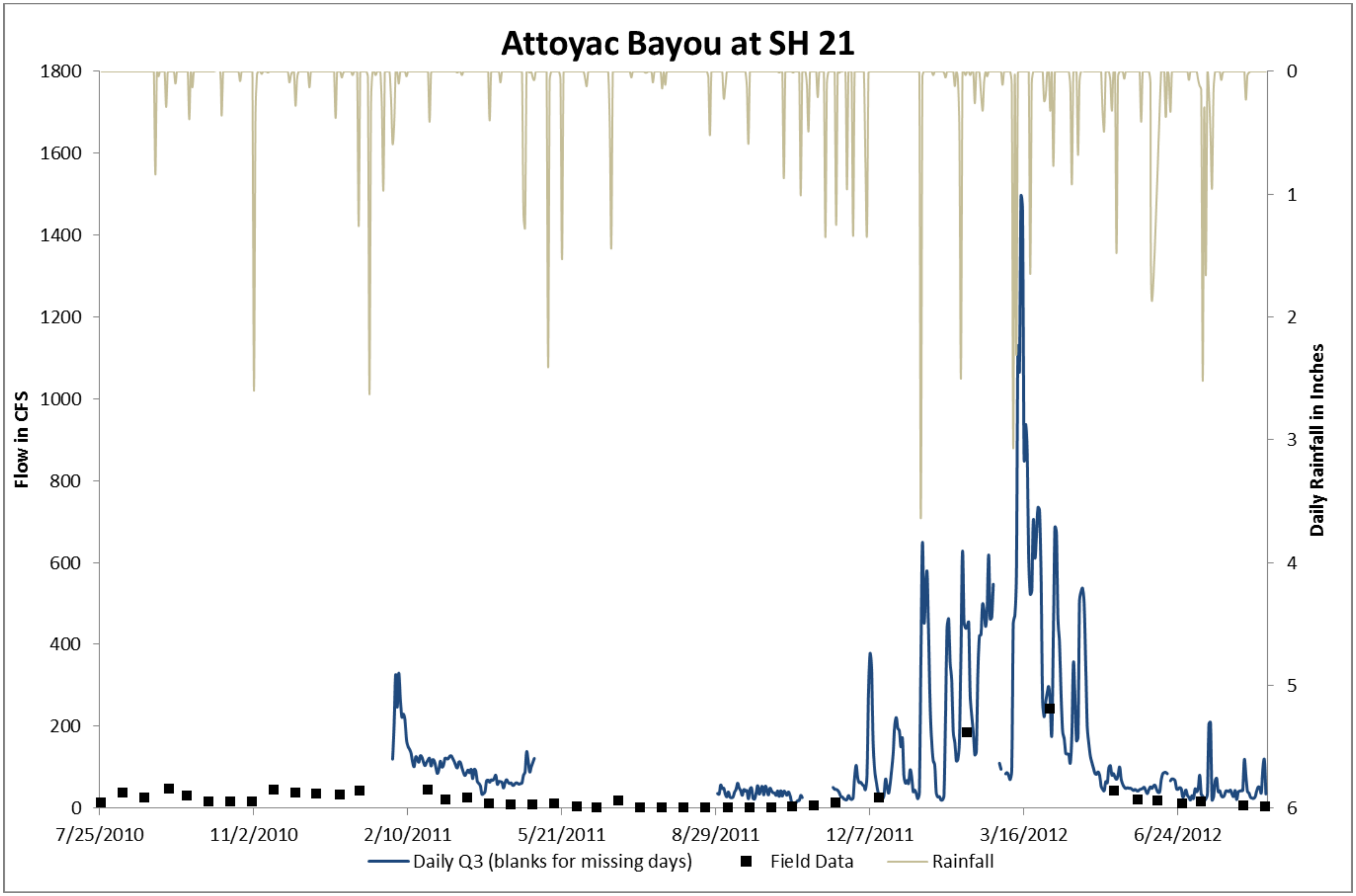

Figure 2. Automated stream flow and precipitation data recorded for the Attoyac Bayou at SH 21

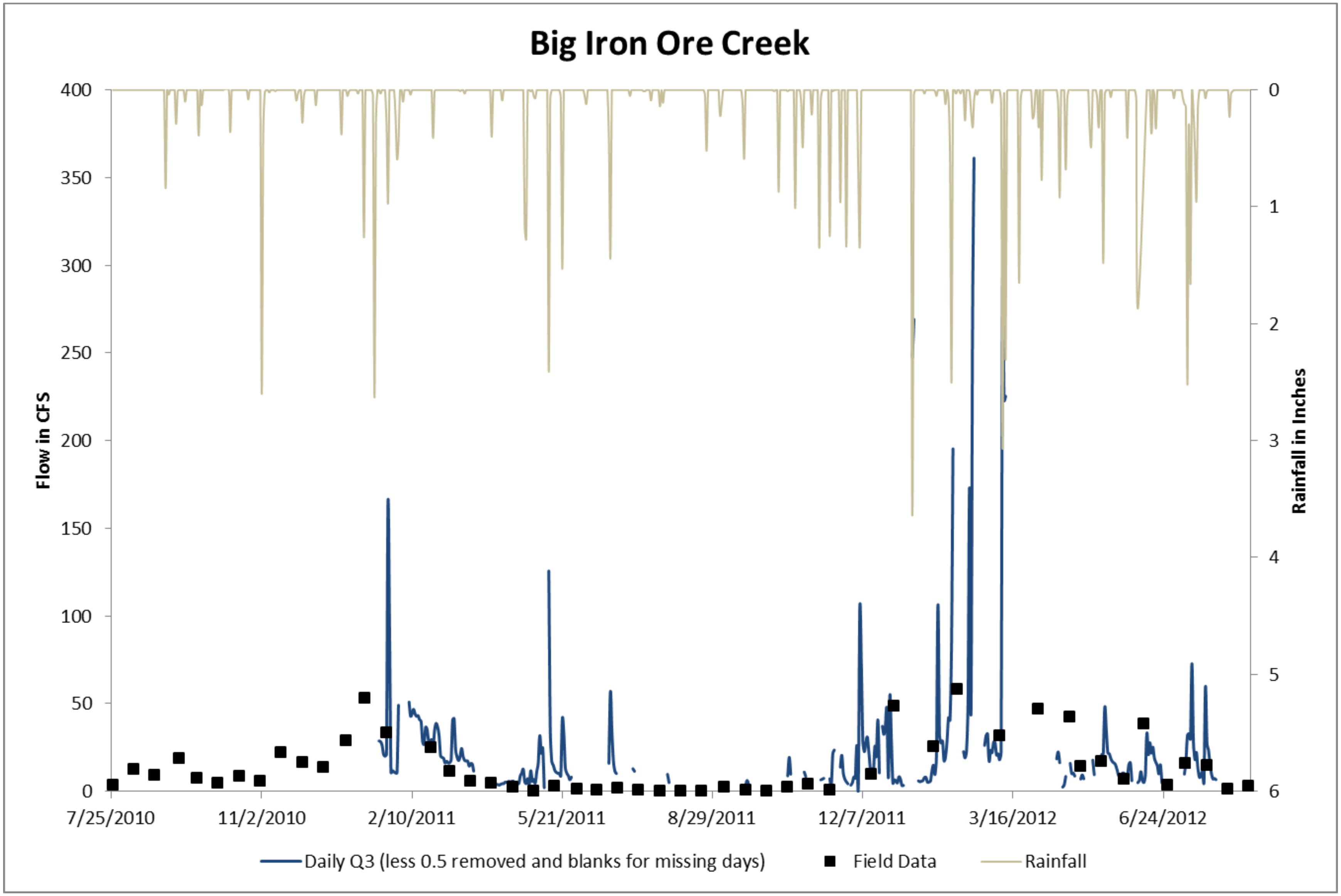

Figure 3. Automated stream flow and precipitation data recorded on Big Iron Ore Creek at FM 354

was recorded in 1902. In the last decade, maximum annual peak discharge rates have been around 10,000 cfs on several occasions and above 20,000 cfs in one instance (Figure 4). This illustrates the variable nature of flows in the watershed and reiterates the fact that instantaneous flow measurements only represent a very small amount of actual stream flows.

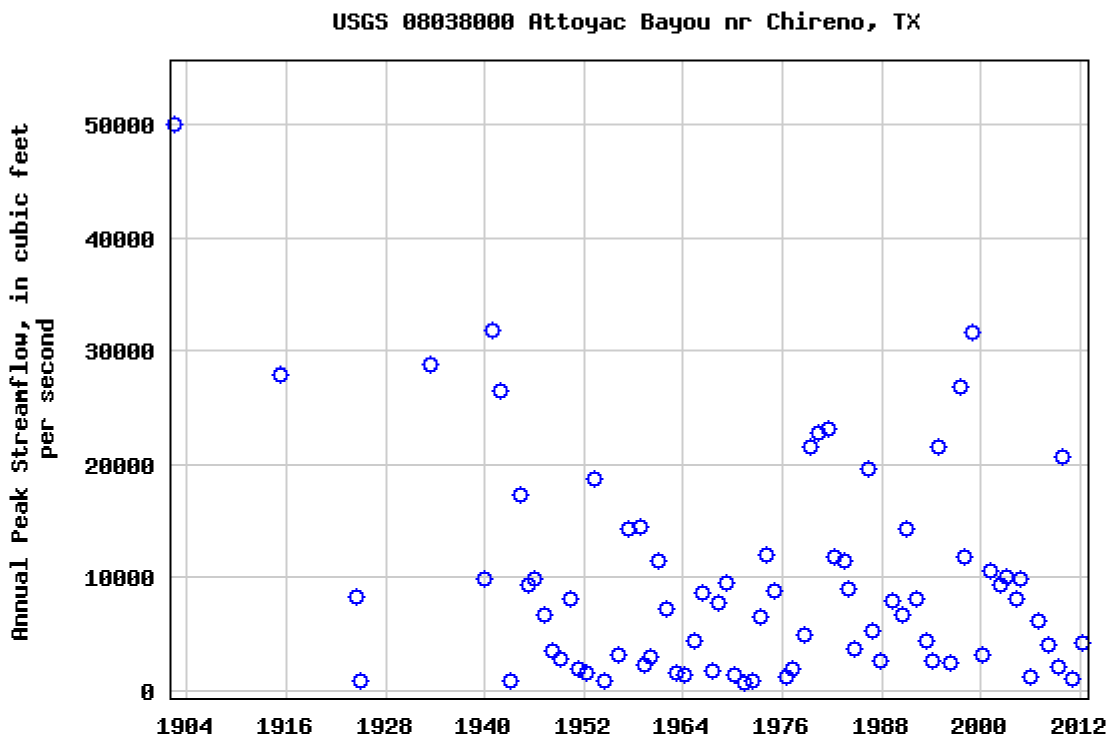

Figure 4. USGS peak discharge recorded on the Attoyac Bayou at SH 21 (Station 10636)

Throughout the course of this project, 3 sites experienced natural problems that greatly hindered flow. The monitoring station on Waffelow Creek (16083) was blocked repeatedly by multiple beaver dams upstream and downstream of the site. Attoyac Bayou at US 59 (Station 16076) was also impacted by beavers. The beaver dam at this site became so large that cattle from the surrounding area were able to walk across it. This dam created a large fishing area that people from the local area enjoy visiting. The most upstream sampling site on the Attoyac Bayou at US 84 (Station 20842) also experienced extremely low or no flow during much of the project. Also, the way in which the bridge at this site was constructed formed a small check dam in the channel that formed a pool upstream of the roadway. During monitoring, drought conditions resulted in insufficient water to flow over this artificial barrier.

Waffelow Creek at FM 95 (16083), 11/8/2010, beaver dam impeding flow.

Attyoac Bayou at US 84 (20842),2/8/2012 addition of silt screen and game fence.

Drought of 2011

The year of 2011 was considered to be one of the driest years the state has experienced since record keeping began. This one year period of drought began in December of 2010 and continued into the fall 2011. During this time period, the entire state experienced less than normal rainfalls. At the height of the drought in early October 2011, all of the state was in some stage of drought and 88% of the state was in exceptional drought; the most severe category. The Attoyac Bayou area normally gets 43 inches of rain throughout the year; during 2011, this area only had about 26.

These conditions resulted in streams and rivers ceasing to flow, leaving the base flows extremely low to intermittent. The upper portion of the Attoyac Bayou dried up as did the tributaries while the lower part was reduced to about ½ a foot deep. Area lake levels also dropped to near historic low levels. For example, Sam Rayburn Reservoir, which receives water from the Attoyac Bayou, was more than 13.6 below normal pool.

Big Iron Ore Creek (20844) 8/22/2011, during the 2011 drought. The creek had riffles and pools.

Water Quality Findings

Water quality in the Attoyac Watershed was monitored from July 2010 through August 2012 with this project and included collecting grab sampling at 10 locations bi-weekly and storm samples from two sites during storm events. Graphical water quality summaries of each sites are found in Figures 9 – 38 in Appendix C. ANRA has submitted data that were collected during this project to TCEQ for inclusion in their statewide water quality database and use in future water body assessments purposes.

Thermal Structure

Water temperatures were recorded in ^{0}C at each sampling location when flowing water was present and when pools were deep enough for the YSI multi probe to sit in. The maximum water temperature recorded along the main confluence of the Attoyac Bayou was at State Highway 21 on 8/8/2011 at 29.36^{0}C. Among the tributaries Big Iron Ore Creek was recorded as having the highest temperature of 29.4 ^{0}C on 7/26/2010. The lowest temperature recorded during the study for the river was at State Highway 21 on

2/7/2011, with a temperature of 5.13 ^{0}C, and the tributaries lowest temperature was 5.15 ^{0}C in Big Iron Ore Creek on 12/28/2010.

Dissolved Oxygen (DO)

DO grab samples were analyzed using the YSI multi probe meter at all 10 sites. The DO levels for the Attoyac Bayou and its tributaries are supposed to maintain a 24 hour average of 5.0 mg/L or greater and remain above an absolute minimum of 3.0 mg/L. Throughout this study no 24 hour sampling profiles were conducted. Recorded DO levels in the Attoyac Bayou ranged between 12.5 and 0.5 mg/L and averaged 6.35 mg/L. Low readings recorded on the main stem of the Attoyac Bayou occurred during the summer months when the flow was extremely low and the Bayou was experiencing exceptional drought conditions. Out of the 182 measurements taken under flowing conditions, only 15 were below the 3.0 mg/L minimum standard.

The Attoyac Bayou at State highway 84 was not included in this assessment due to non-normal flow conditions. The site was a quiescent pool with no flow in or out. As a result, only 39 measurements taken; of those, only 10 were above the standard.

For the tributaries which are considered unclassified segments of the watershed, 195 measurements were taken under flowing conditions. Readings ranged from a high of 12.3 to a low of 1.4 mg/L and averaged 6.82 mg/L, with only 11 of those measurements being below the minimum standard of 3.0 mg/L. Each of these low readings occurred during the height of the drought conditions experienced in 2011.

Specific Conductance and pH

During the course of the study, pH ranged from 7.0 to 9.2 in the Attoyac Bayou. Of the 188 pH readings made in flowing water, 18 exceeded the upper limit of the acceptable range of 6.0 to 8.5. In the tributaries the lowest pH recorded was in Terrapin Creek at 5.0 on 8/9/2010 and the highest being 9.6 recorded at Big Iron Ore Creek on 6/27/2012 and again on 8/20/2012. Collectively, 30 of the 199 pH readings made fell outside the acceptable range with all but one being greater than 8.5.

Specific conductance readings taken from the Attoyac Bayou when it was flowing ranged from 64 to 263 μS/cm and remained well below the allowable maximum of 307.7 μS/cm. Similarly, specific conductance readings in tributaries ranged from 68 to 289 μS/cm.

Ammonia-N

Ammonia-N levels were analyzed as part of the bi-weekly water samples taken to ANRA. The screening level that the Attoyac Bayou should not exceed is 0.33 mg/L. During the course of the study, 206 water samples were analyzed for ammonia-N. Of these, only 13 water samples exceeded this screening level with the maximum reading being 1.3 mg/L. This level of exceedance is well below the 20% threshold that indicates a recurring problem. Similarly, of the 213 samples collected from watershed tributaries and analyzed for ammonia-N, only 10 were above 0.33 mg/L with 0.96 being the highest recorded value. Ammonia-N values recorded at stations 16083 and 20842 exceeded the screening level 28 and 28.5% of the time; however, each of these sites were plagued by low flow, had a much smaller data set than other sites, and also experienced beaver activity as well.

Minimum, maximum and average values for each site are presented in Table 4 while Figure 5 graphically illustrates the distribution and tendencies of the data at each monitoring station across the watershed.

Table 4. Ammonia-N levels throughout the study; minimum, maximum and mean from 7/26/2011-8/20/2012.

Site	Minimum (mg/L)	Maximum (mg/L)	Mean (mg/L)
10636	0.04	0.33	0.11
15253	0.04	0.47	0.13
20841	0.04	0.40	0.12
16076	0.10	1.30	0.24
20842	0.10	1.02	0.29
20844	0.04	0.68	0.12
16084	0.04	0.96	0.17
20845	0.04	0.18	0.11
16083	0.04	0.76	0.24
20843	0.04	0.24	0.12

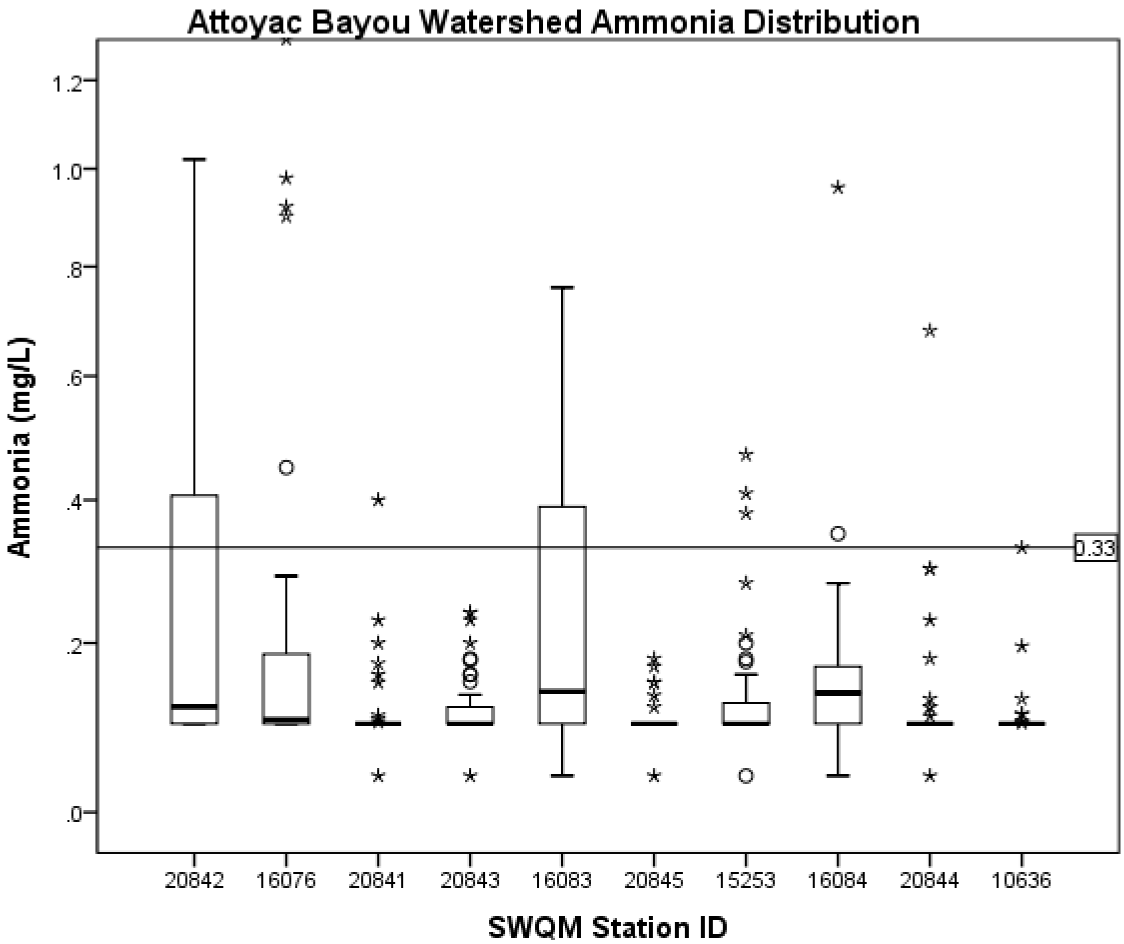

Figure 5. Ammonia-N data summary for the Attoyac Bayou and its tributaries. (Data are presented in an upstream to downstream manner)

Other Nutrient Parameters

Several other water quality parameters were monitored throughout the course of this project as well and included dissolved orthophosphorus, nitrate-nitrite nitrogen, and total phosphorus. Results from this monitoring were compared to the state's established screening levels for each parameter and illustrate that no concerns for elevated levels of these parameters exist in the Attoyac Bayou or its tributaries.

Dissolved orthophosphorus readings ranged from 0.04 to 0.28 mg/L and did not exceed the 0.37 mg/L screening level at all. Total phosphorus levels recorded ranged from 0.06 to 4.0 mg/L. This 4.0 mg/L reading was only recorded once at station 16076 and occurred when total suspended solids and *E. coli* numbers were markedly higher than normal suggesting that it was associated with a recent sediment disturbance event. All other total phosphorus readings taken across the watershed were below the 0.69 mg/L screening level. Nitrate-Nitrite Nitrogen levels recorded in the watershed ranged from 0.04 to 1.8 mg/L which is below the screening level of 1.95 mg/L.

E. coli

Water samples collected from flowing water illustrated that *E. coli* counts recorded in the watershed can vary widely. Counts recorded per 100 mL of water across the watershed ranged from 4 to more than 3,900 cfu/100 mL. Overall, the geometric mean of all *E. coli* data collected was 173.7 cfu/100 mL which exceeds the primary contact recreation standard of 126 cfu/100 mL that is universally applied across the watershed. However, TCEQ assess water bodies either individually or by assessment unit. Using this approach, none of the tributaries or assessment units of the Attoyac Bayou were within the applied water quality standard. Table 5 below illustrates the number of samples, as well as the minimum, maximum, and geometric mean for each sampling site and assessment unit (AU). Figures 6 – 8 also highlight the data's distribution as well.

Table 5. Summary of *E. coli* data available at each sampling site and by each assessment unit

Site	Number of Samples	Minimum (cfu/100 mL)	Maximum (cfu/100 mL)	Geometric Mean (cfu/100 mL)	Assessment Unit (AU)	AU Geometric Mean (cfu/100 mL)
10636	64	13	2400	241.1	0612_01	241.1
15253	50	13	2400	173.4	0612_02	244.7
20841	40	75	2400	376.5	0612_02	
16076	38	12	2400	208.6	0612_03	162.3
20842	14	4	820	82.1	0612_03	
20844	56	49	3900	454.3	NA	NA
16084	43	9	2400	194.3	NA	NA
20845	43	38	2400	346.6	NA	NA
16083	25	40	2400	201.9	NA	NA
20843	46	15	2400	189.5	NA	NA

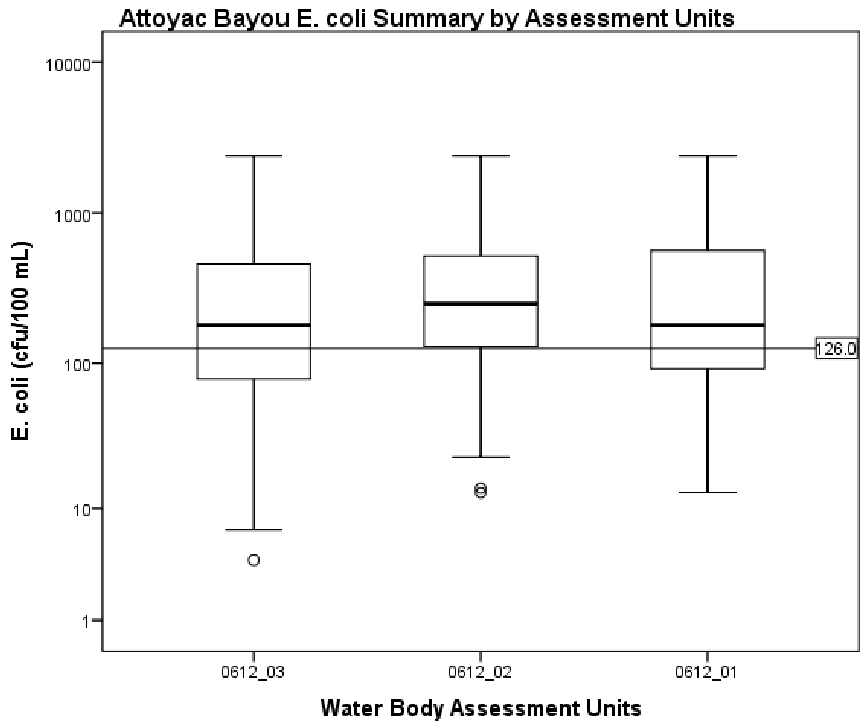

Figure 6. *E. coli* data summary for the Attoyac Bayou by assessment units: upstream to downstream

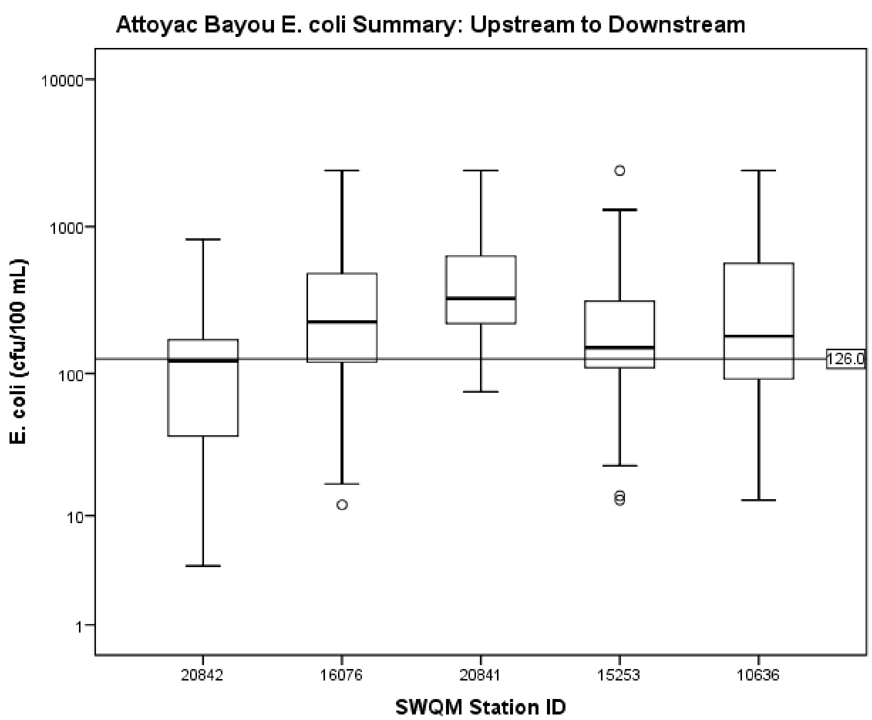

Figure 7. *E. coli* data summary for the Attoyac Bayou by station: upstream to downstream

While there are variations in the dataset as seen in Figures 6 – 8, overall geometric mean values were not significantly different among monitoring sites. A comparative analysis of the geometric means using the non-parametric Kruskal-Wallis test indicated that no significant difference among sites exists (p = 0.437; α = 0.05).

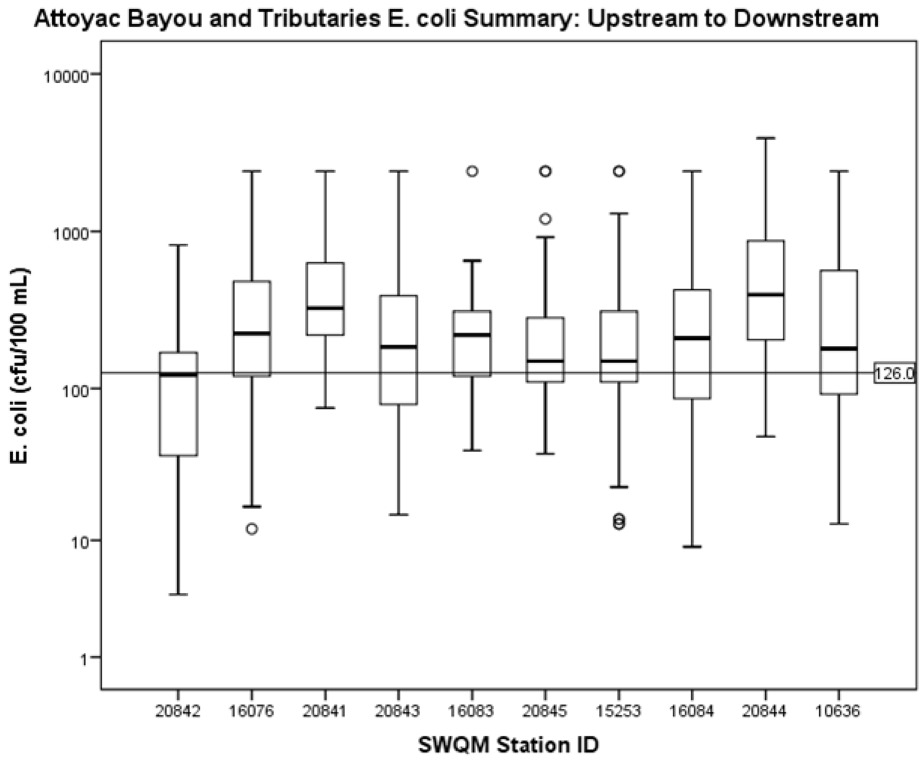

Figure 8. ***E. coli*** **data summary for the Attoyac Bayou and its tributaries by station: upstream to downstream (tributary sites are situated to mimic the relative location that they empty into the Attoyac Bayou)**

Conclusions

This monitoring program focused on collecting water quality data from across the Attoyac Bayou watershed at more locations and at a higher frequency than prior monitoring efforts had employed. The goal of the monitoring was to determine the validity of the Attoyac Bayou's current impaired status for elevated *E. coli* levels and its inability to support its designated primary contact recreation standard. TCEQ also noted a concern for elevated levels of ammonia in the waterbody as well, thus collecting data to further explore ammonia levels was also a goal.

Once completed and assessed, data collected throughout the Attoyac Bayou watershed over the two year monitoring period indicated that the elevated levels of bacteria do exist throughout the watershed. With the exception of station 20842, the geometric mean of *E. coli* recorded at each site exceeded the currently applied primary contact recreation standard of 126 cfu set by TCEQ. Geometric means observed were comparable to geometric means commonly found in other East Texas streams and did not significantly differ amongst sampling sites.

Other water quality parameters were similarly distributed among the sampling sites as well with only isolated instances of elevated concentrations as compared to the applicable water quality standard or nutrient screening level being observed. Based on data collected, the concern for elevated ammonia concentrations in the water body appear diminished. Only two sites exhibited ammonia levels above the screening level more than 20% of the time and they were both impacted by adverse flow conditions.

The presence of exceptional drought during the monitoring lowered observed stream flow conditions from what would have been under more normal precipitation conditions. The lower flows and higher temperatures resulted in lower dissolved oxygen concentrations. Direct effects from the drought were less discernable for other water quality parameters.

Water quality standards for recreation are currently being evaluated to determine if primary contact recreation is appropriate for the Attoyac Bayou and its tributaries. Should the state determine that a water quality standard other than primary contact recreation be appropriate, then that recommendation will have to be reviewed and approved by the U.S. Environmental Protection Agency before it would take effect. If enacted, newly applied standards could result in the Attoyac Bayou being removed from the *Texas Integrated Report* as an impaired water body as early as 2016.

References

TAC §307. 2013. *Texas Administrative Code: Chapter 307 – Texas Surface Water Quality Standards.* Available online, accessed October 14, 2013 at: info.sos.state.tx.us/pls/pub/readtac$ext.viewtac

TCEQ. 2004. *Atlas of Texas Surface Waters.* GI-316. Austin: Texas Commission on Environmental Quality. Also available online at: tceq.texas.gov/publications/gi/gi-316

TCEQ. 2010. *2010 Guidance for Assessing and Reporting Surface Water Quality in Texas.* Available online, accessed June 14, 2013 at: tceq.texas.gov/assets/public/compliance/monops/water/10twqi/2010_guidance.pdf.

TCEQ. 2012. *2012 Texas Integrated Report for Clean Water Act Sections 305(b) and 303(d).* Available online, accessed May 19, 2013 at: tceq.texas.gov/waterquality/assessment/waterquality/assessment/12twqi/twqi12

Appendix A:

Field Data Sheet

Surface Water Quality Monitoring
Field Data Sheet

Stephen F. Austin State University
P.O. Box 6109, SFA Station
Nacogdoches, TX 75962-6109
(936) 468-2469

Sample Location: ______________________________

Station ID: ____________ **Date Collected:** ____________

Sample Matrix: Water / Fecal **Time Collected:** ____________

Collector(s) Name/Signature: ______________________________

Sample Type: Routine / Storm **Sample Depth:** ____________

Field Tests and Measurements:			Parameters Collected:			
	pH (standard units)	00400		E. coli (IDEXX)		Total N
	water temperature °C	00010		E. coli (mTEC)		NNN
	Dissolved Oxygen (mg/L)	00300		TSS		Total P
	Specific Conductance (µS/cm)	00094		Diss. Ortho-P		
	Instant. Stream Flow (cfs)	00061		Ammonia-N		Field Split

Field Observations		
	01351 - Flow Severity (1 - no flow, 2 - low, 3 - normal, 4 - flood, 5 - high, 6 - dry)	
	89835 - Flow measurement method (1-gage, 2-electric, 3-mechanical, 4-weir/flume, 5-doppler)	
	72053 - Days since last significant rainfall	
	89966 - Present weather (1 - clear, 2 - partly cloudy, 3 - cloudy, 4 - rain, 5 - other)	
	74069 - Stream flow estimate (cfs) *Required measurements to calculate flow estimates	
	Stream width (feet)*	Note: Instantaneous stream flow is preferable to a stream flow estimate
	Averagae depth of stream (feet)*	
	Distance object travels (feet)*	
	Time for object to travel distance (seconds)*	

Comments:

Appendix B:

Chain of Custody Forms

Chain of Custody Record

Project:	Collecting Entity:
Development of a Watershed Protection Plan for Attoyac Bayou TSSWCB Project #09-10	**Stephen F. Austin State University** **P.O. Box 6109, SFA Station** **Nacogdoches, TX 75962-6109** Contact: Matthew McBroom: 936.468.2469
Name and signature of collector:	Receiving Entity:
	Angelina Neches River Authority **P.O. Box 387** **Lufkin, TX 75901** Contact: Brian Sims: 936.633.7527

Container Type					
S	H	H	H	H	H
Preservative					
Requested Analysis					

Container Types:
H: Precleaned High Density Polyethelyene
SP: Sterile Polyethelyene container

Preservatives:
1: ice 2: H2SO4 3: Sodium Thiosulfate

Sample Receipt Notes:
OK: all samples 100% correct (labels, COCs, shipping)
1: not on ice 2: incorrectly labeled 3: COC incorecct
4: bottle leaking 5: other (note in comments section)

Station ID	Sample ID	Media Code	Sample Type (Routine / Storm)	Number of Containers	Collection Date	Time	E. coli (IDEXX)	Total Suspended Solids	Ammonia - N, Total	Nitrate/Nitrite - N	Dissolved Ortho - P	Total P	Sample Receipt Notes: (Report any issues here: ie. Not on ice, improper label, damaged bottle, leaky bottle, etc.) 1	2	3
		water													
		water													
		water													
		water													
		water													
		water													
		water													
		water													
		water													
		water													
		water													
		water													
		water													
		water													
		water													

Relinquished by: (print name)	Date:	Time:	Received by: (print name)	Date:	Time:
1					
2					
3					

Special Comments:

Laboratory Comments:

Chain of Custody Record

Project:	Collecting Entity:
Development of a Watershed Protection Plan for Attoyac Bayou *TSSWCB Project #09-10*	**Stephen F. Austin State University** **P.O. Box 6109, SFA Station** **Nacogdoches, TX 75962-6109** Contact: Matthew McBroom: 936.468.2469
Name and signature of collector:	Receiving Entity:
	Stephen F. Austin State University **P.O. Box 6109, SFA Station** **Nacogdoches, TX 75962-6109** Contact: Leon Young: 936.468.4500

Container Type

SSB	SSB	SC	PD		

Preservative

Requested Analysis

Media Required:

water	supor filter	feces	mTec agar		
E. coli (mTec)	Bacteroidales	Fecal Specimen	E. coli water isolates		

Container Types:

SSB: sterile sample bag (whirl-pak)
SC: Sterile Container
PD: 50mm x 9 mm petri dish

Preservatives:

1: ice 2: GITC Buffer

Sample Receipt Notes:

OK: all samples 100% correct
1: not on ice 2: incorrectly labeled 3: COC incorecct
4: bottle leaking 5: other (note in comments section)

Station ID	Sample ID	Media Code	Sample Type (Routine / Storm)	Number of Containers	Collection Date	Time	E. coli (mTec)	Bacteroidales	Fecal Specimen	E. coli water isolates			Sample Receipt Notes: 1	2	3
		water													

Relinquished by: (print name)	Date:	Time:	Received by: (print name)	Date:	Time:	Laboratory Comments:
1						
2						
3						

Special Comments:

Appendix C:

Water Quality Graphics

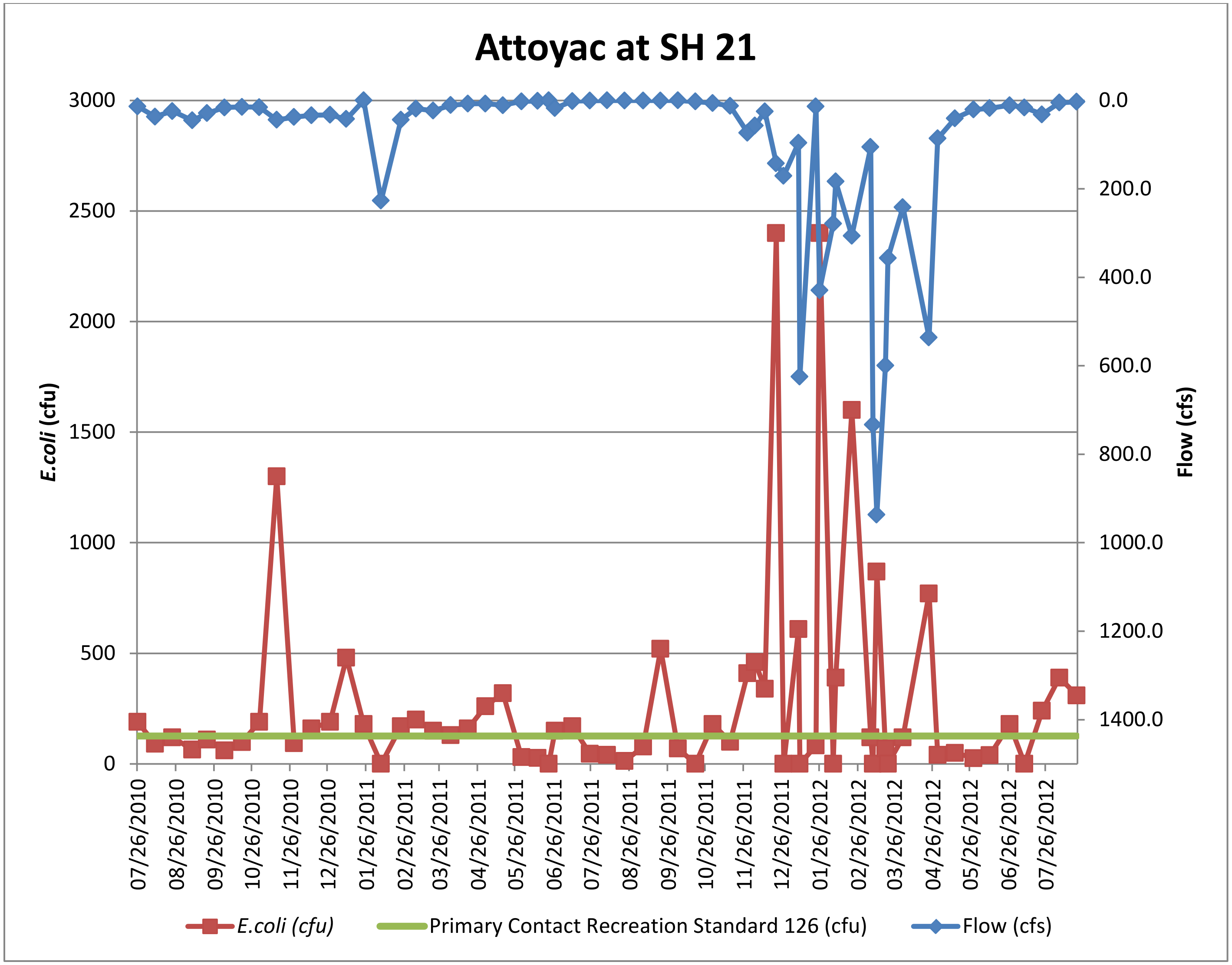

Figure C-1. Attoyac Bayou at State Highway 21 *E. coli* (cfu) vs. flow (cfs), from 7/26/2010 through 8/20/2012, compared to the standard for primary contact recreation 126 cfu. ** *E. coli* values reported as >2400 were entered as 2400.

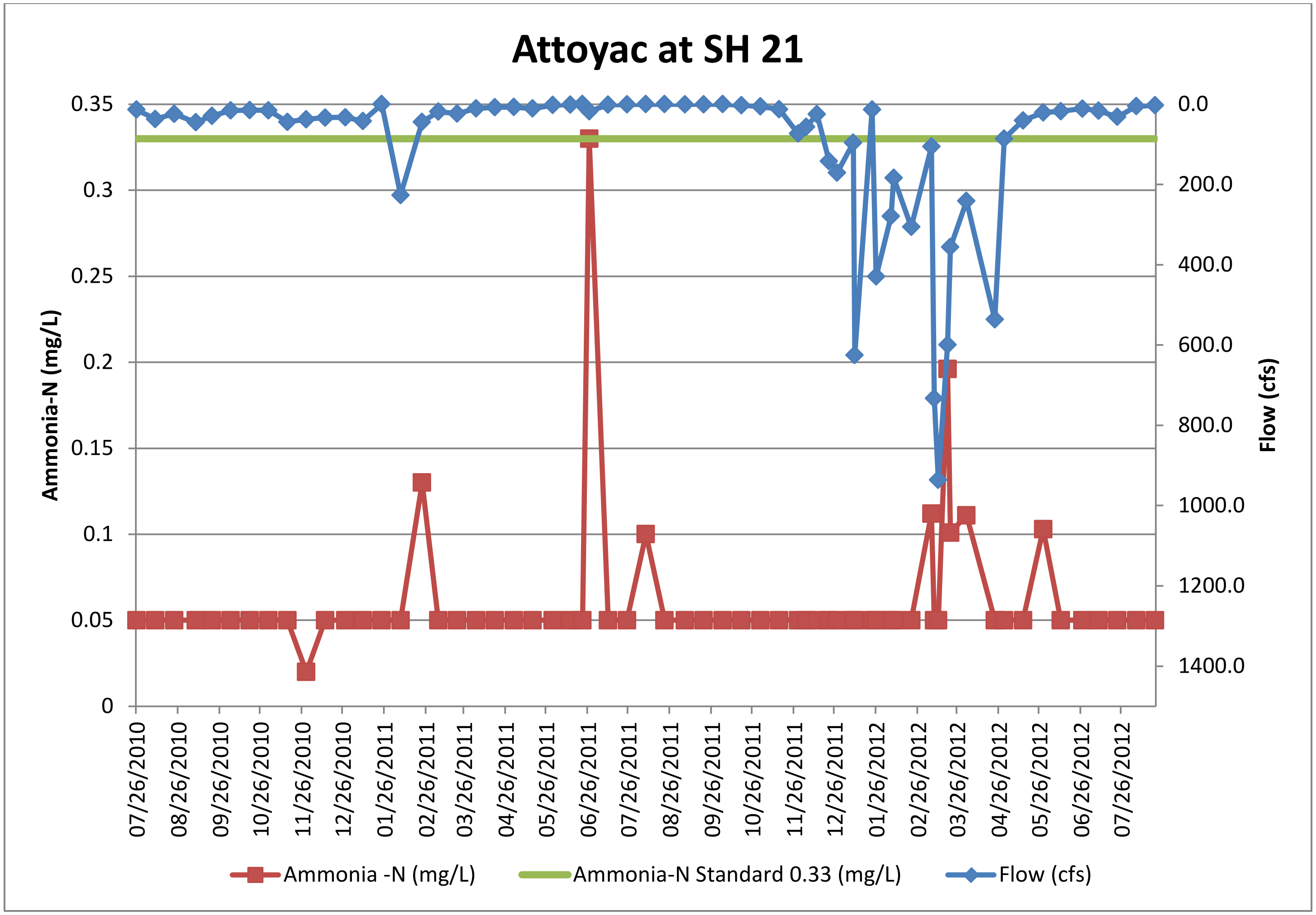

Figure C-2. Attoyac at State Highway 21 ammonia-n (mg/L) vs. flow (cfs) from 7/26/2012 through 8/20/2012, compared to the ammonia screening level of 0.33 mg/L. * Ammonia levels reported at <0.1 were entered as 0.05 mg/L.**

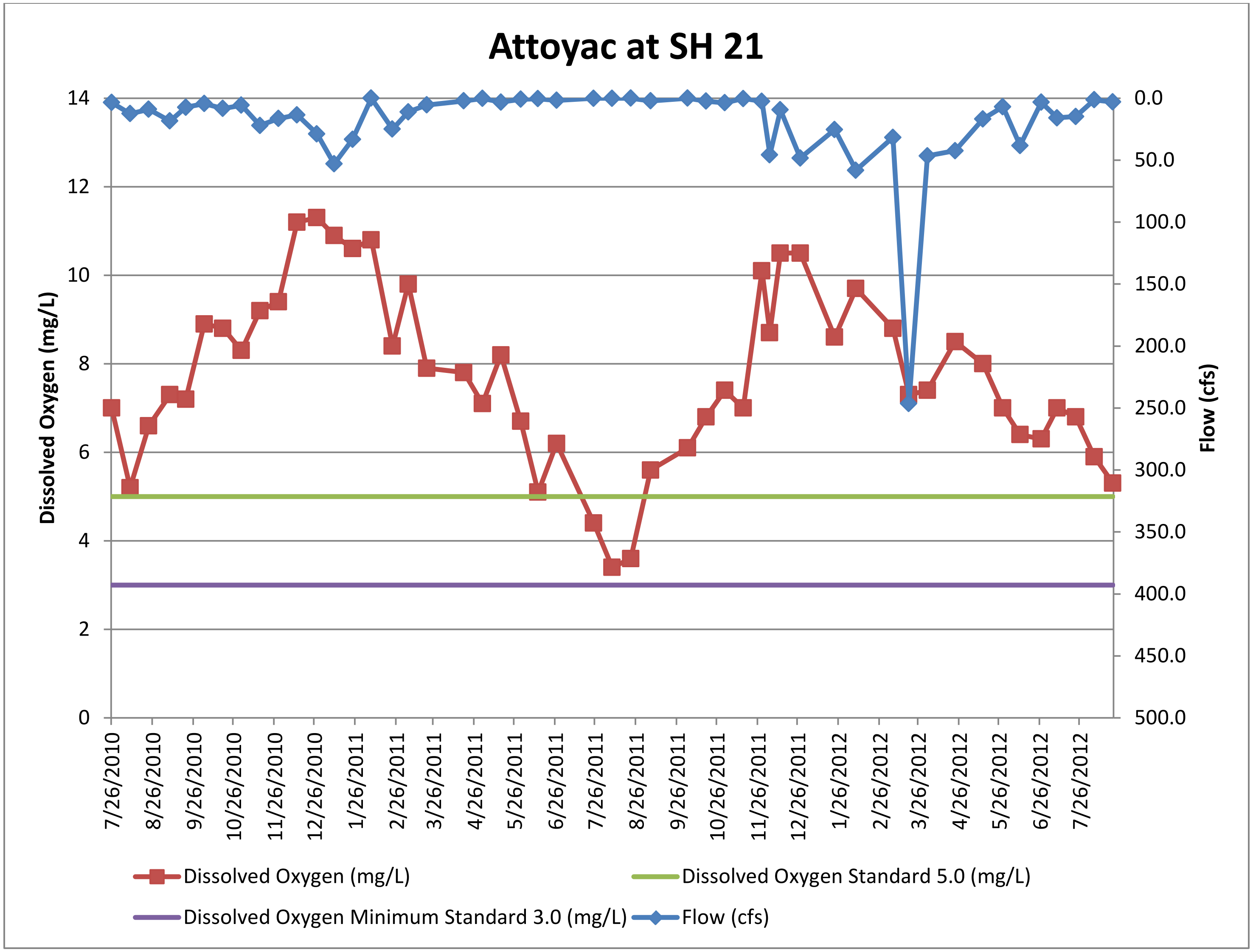

Figure C-3. Attoyac Bayou at State Highway 21 dissolved oxygen (mg/L) vs. flow (cfs) from 7/26/2010 through 8/20/2012, compared to the grab sample screening level of 5.0 mg/L.

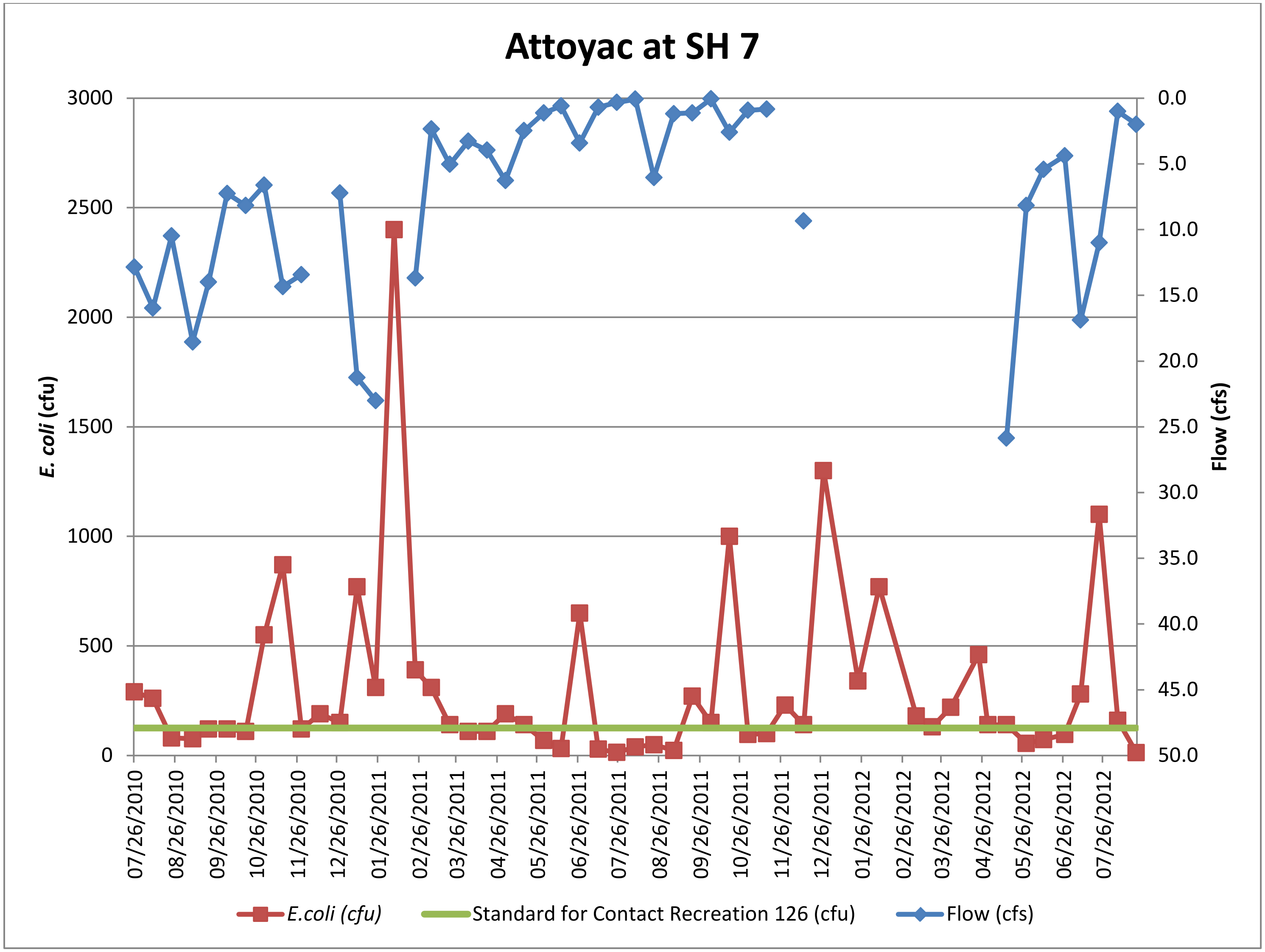

Figure C-4. Attoyac Bayou at State Highway 7 *E. coli* (cfu) vs. flow (cfs) from 7/26/2010 through 8/20/2012, compared to the standard of 126 cfu. * *E. coli* values reported as >2400 were entered as 2400.**

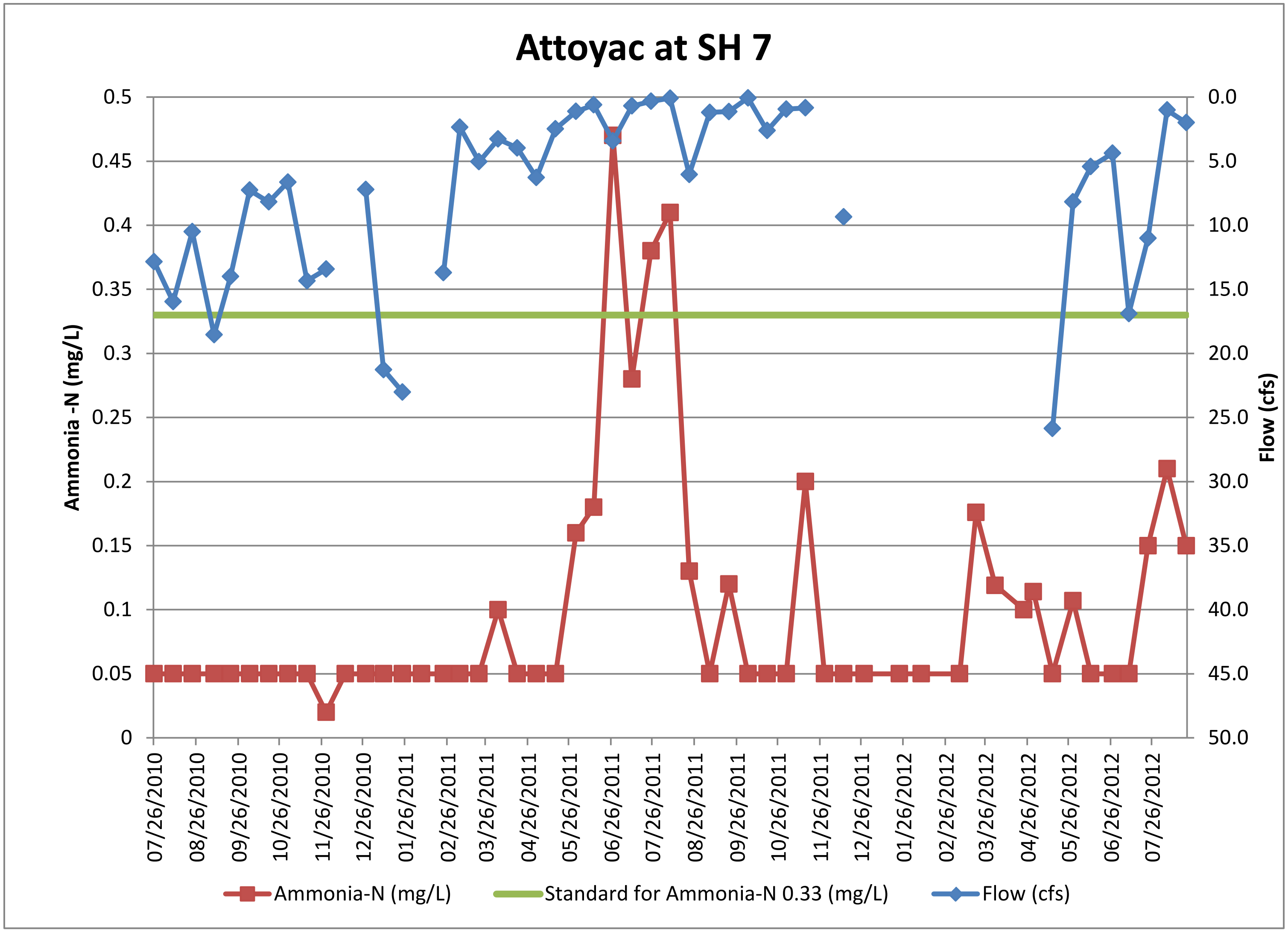

Figure C-5. Attoyac Bayou at State Highway 7 ammonia-n (mg/L) vs. flow (cfs), from 7/26/2010 through 8/20/12, compared to the standard of 0.1 (mg/L). * Ammonia levels reported at <0.1 were entered as 0.05 mg/L.**

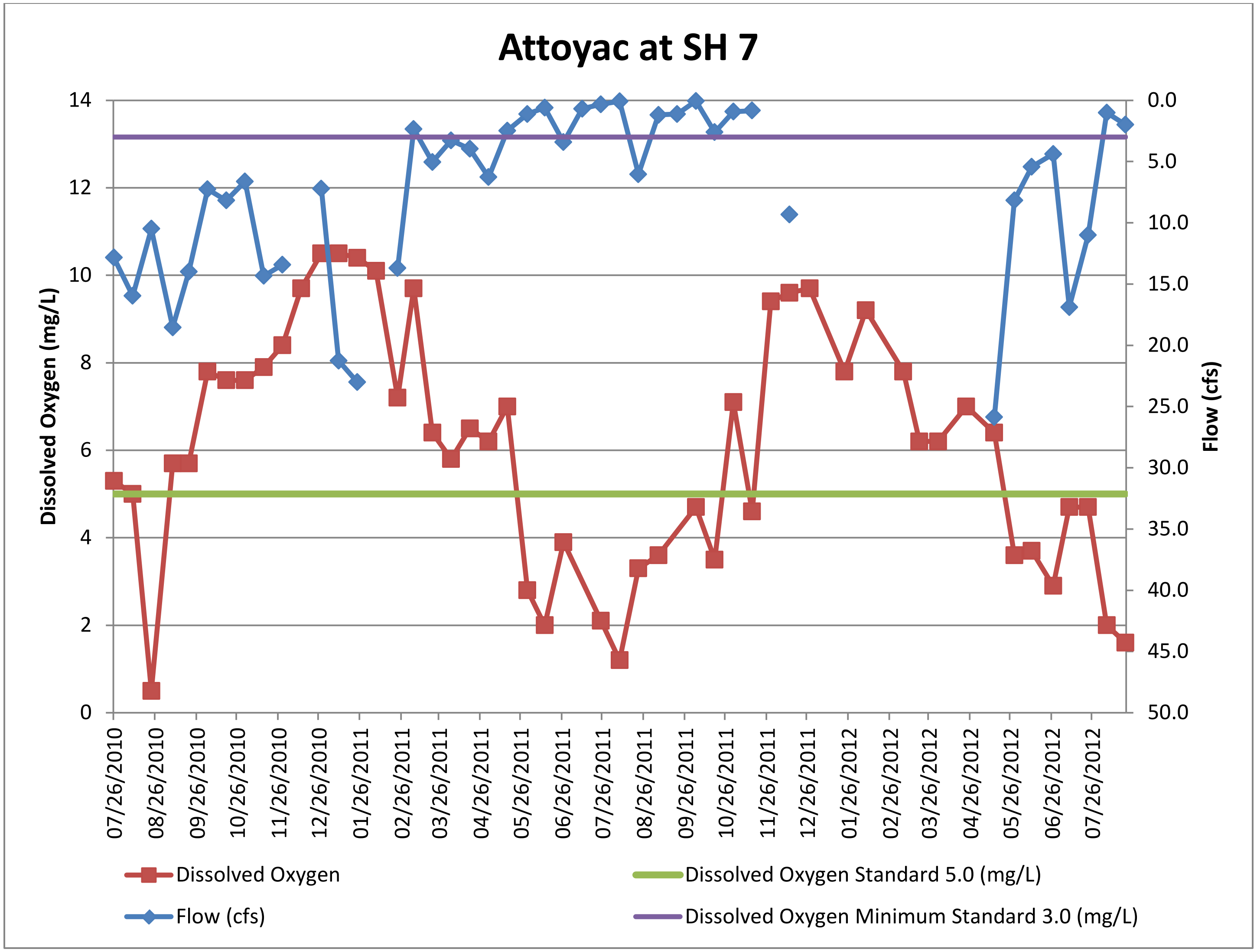

Figure C-6. Attoyac Bayou at State Highway 7 Dissolved Oxygen (mg/L) vs. flow (cfs), from 7/26/2010 through 8/20/2012, compared to the standard of 5.0 mg/L.

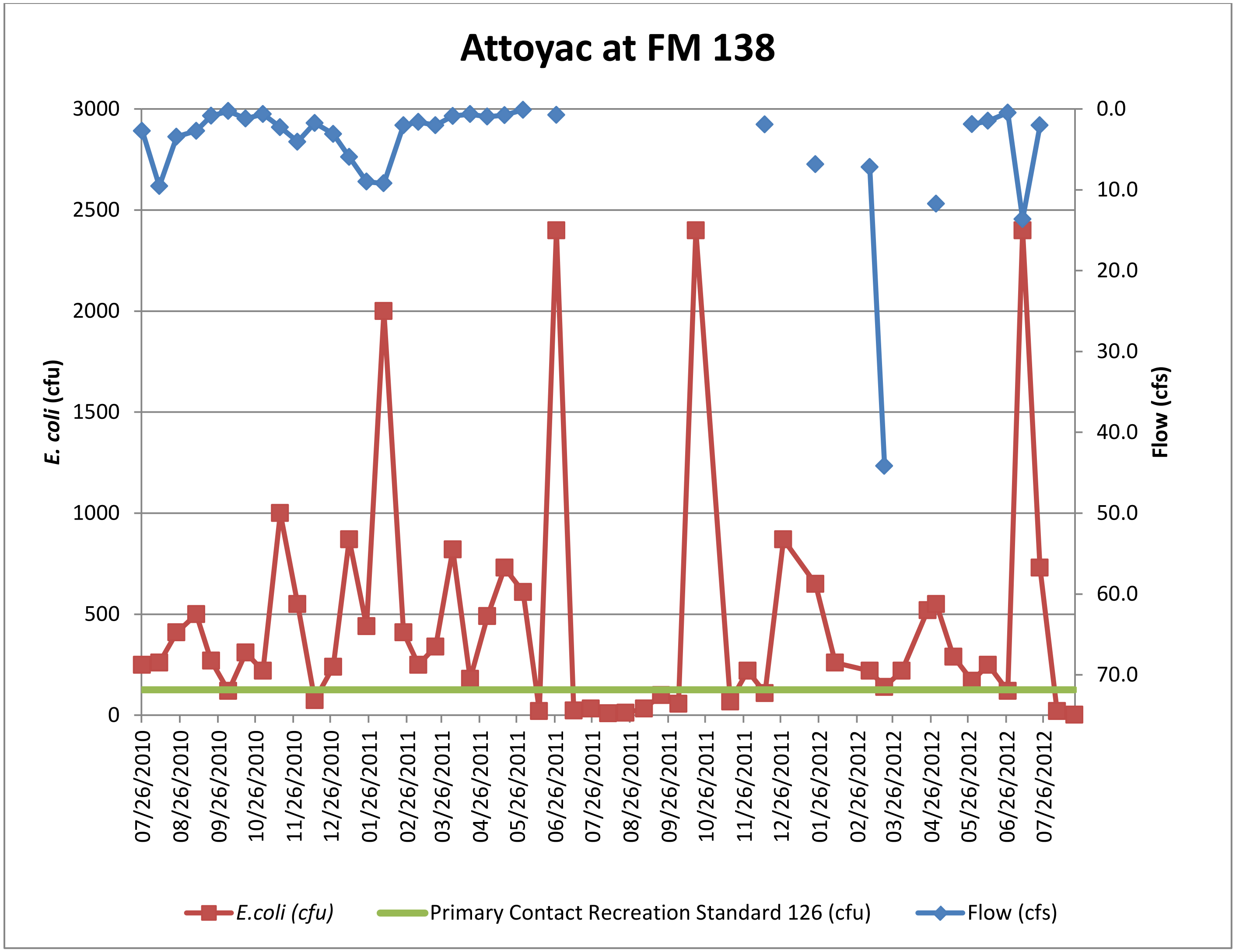

Figure C-7. Attoyac Bayou at FM 138 *E. coli* (cfu) vs. flow (cfs), from 7/26/ through 8/20/2012, compared to the standard of 126 cfu for primary contact recreation. * *E. coli* values reported as >2400 were entered as 2400.**

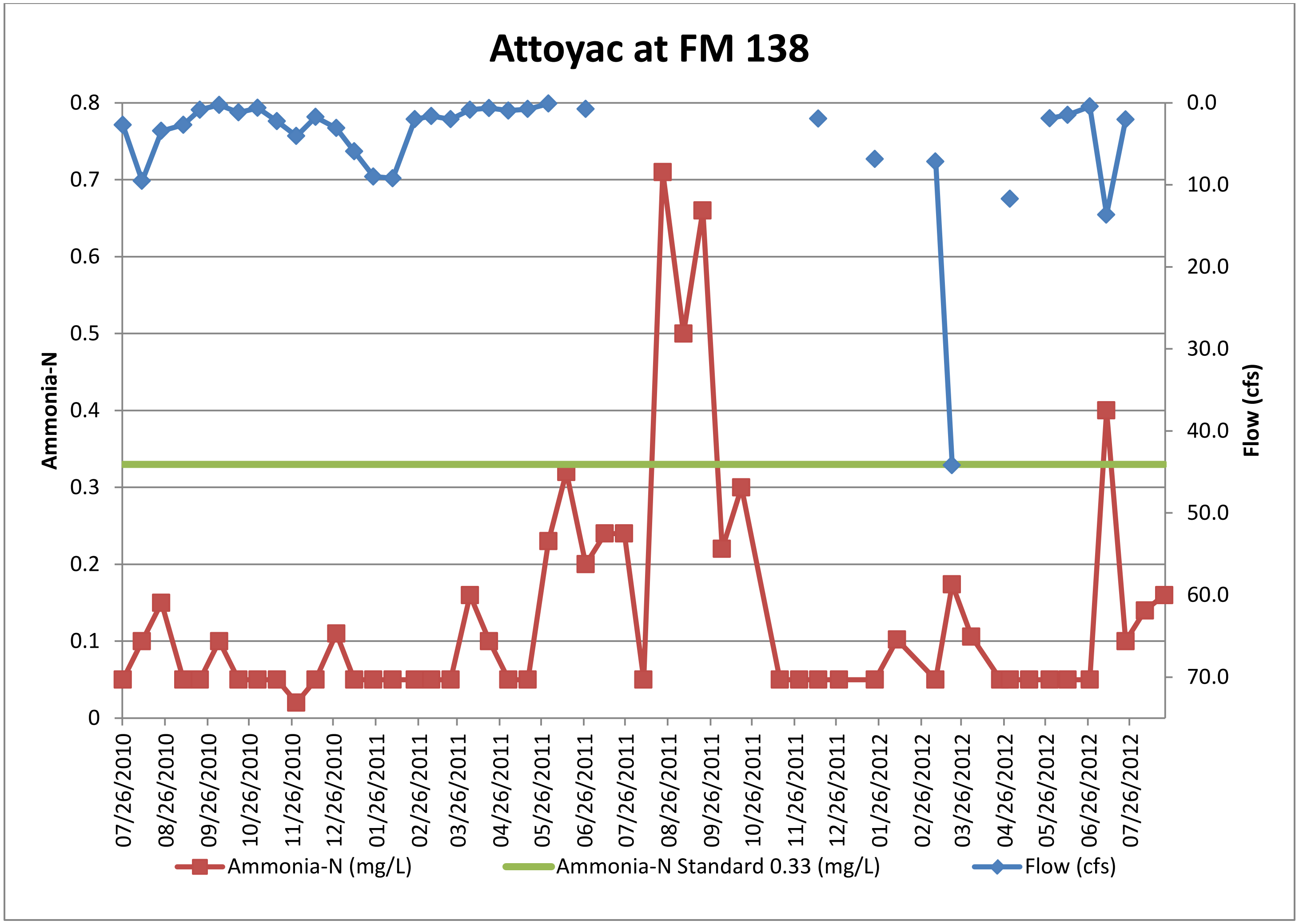

Figure C-8. Attoyac Bayou at FM 138 ammonia-n (mg/L) vs. flow (cfs), from 7/26/2010 through 8/20/12, compared to the standard of 0.1 (mg/L). * Ammonia levels reported at <0.1 were entered as 0.05 mg/L.**

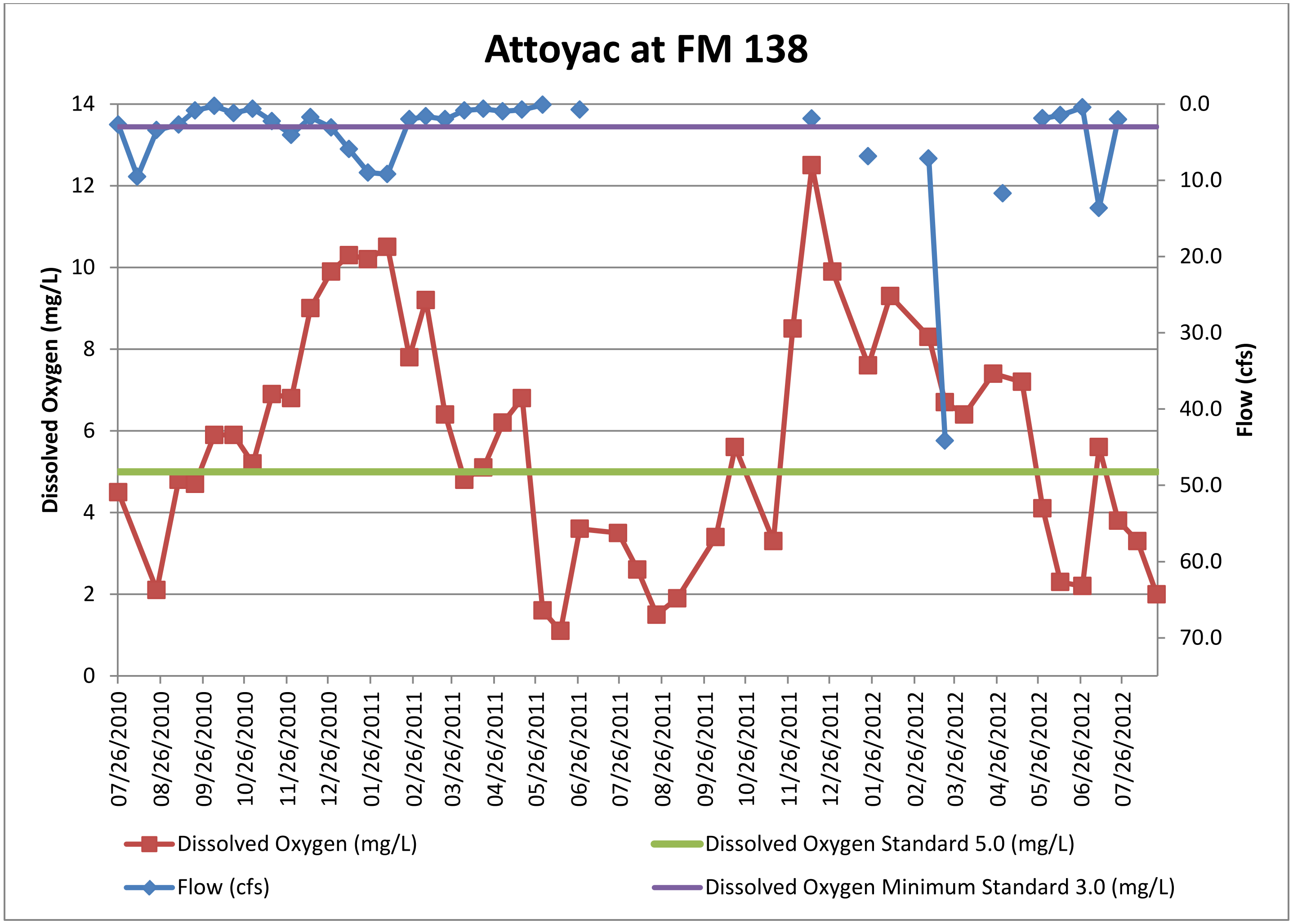

Figure C-9. Attoyac at FM 138 Dissolved Oxygen (mg/L) vs. flow (cfs), from 7/26/2010 through 8/20/2012, compared to the standard of 5.0 mg/L.

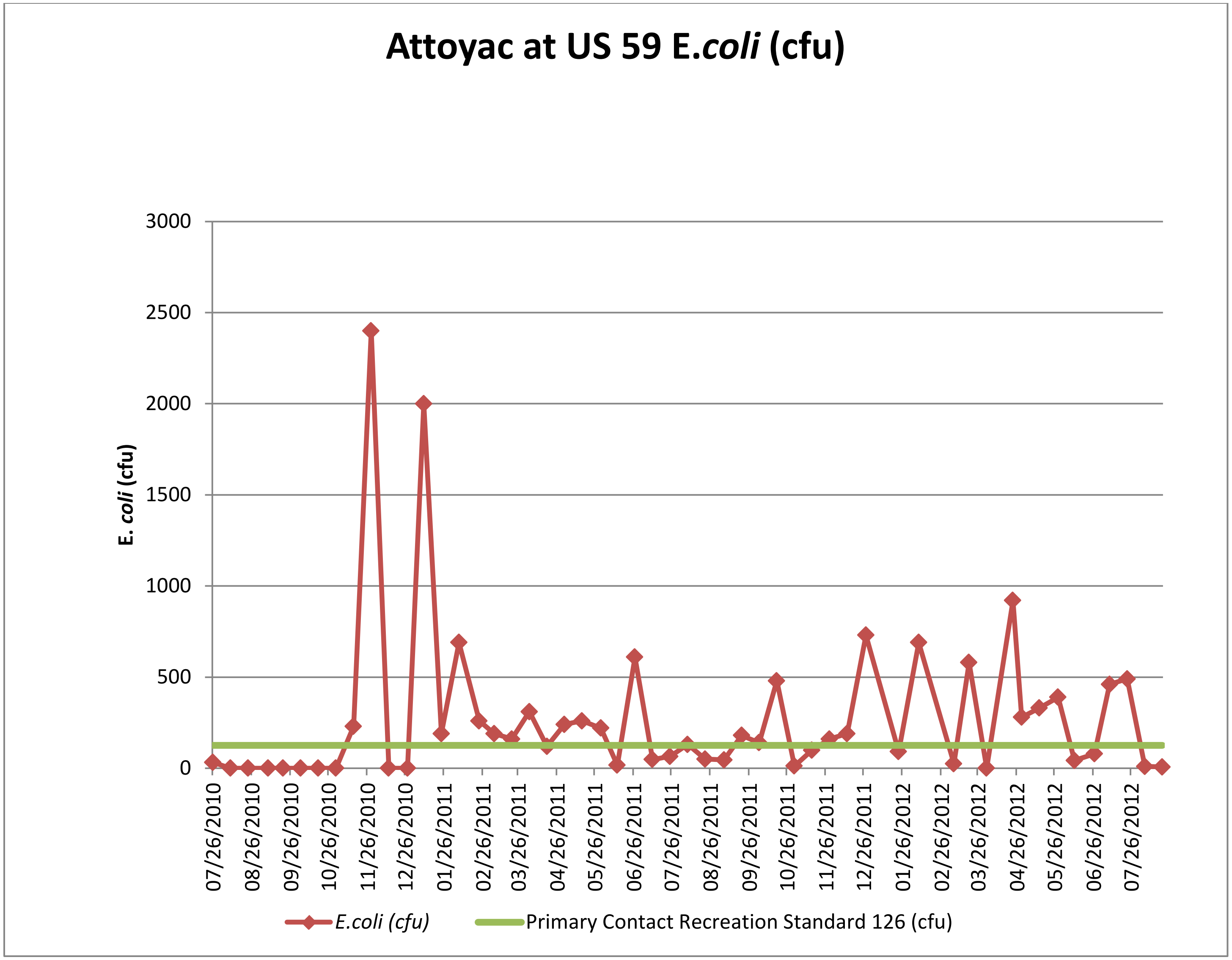

Figure C-10. Attoyac at US 59 *E. coli* (cfu) samples from 7/26/2010 through 8/20/2012. * *E. coli* values reported as >2400 were entered as 2400.**

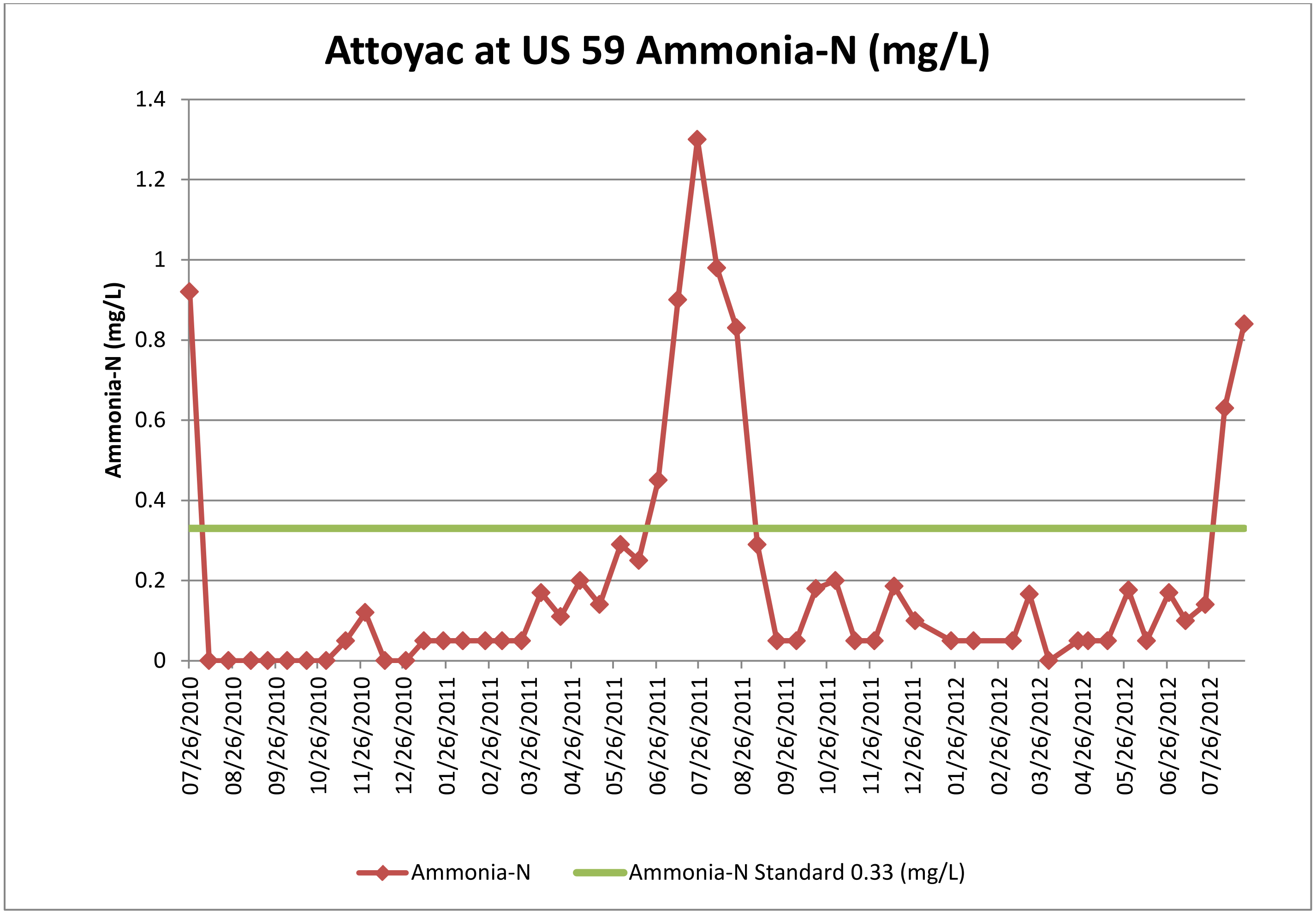

Figure C-11. Attoyac at US 59 Ammonia –N (mg/L) concentrations from 7/26/2010 through 8/20/2012. * Ammonia levels reported at <0.1 were entered as 0.05 mg/L.**

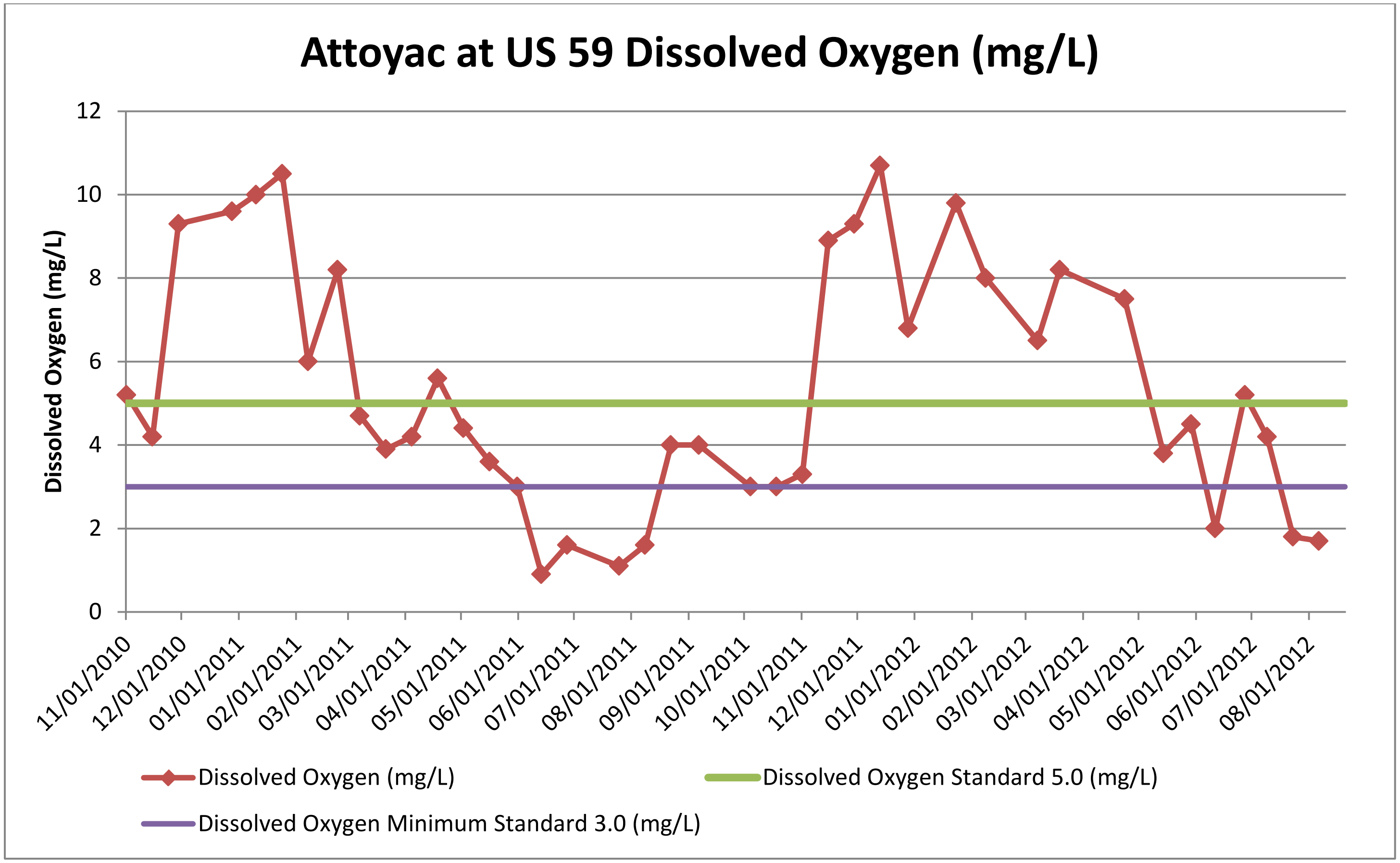

Figure C-12. Attoyac at US 59 Dissolved Oxygen (mg/L) measurements from 7/26/2010 through 8/20/2012.

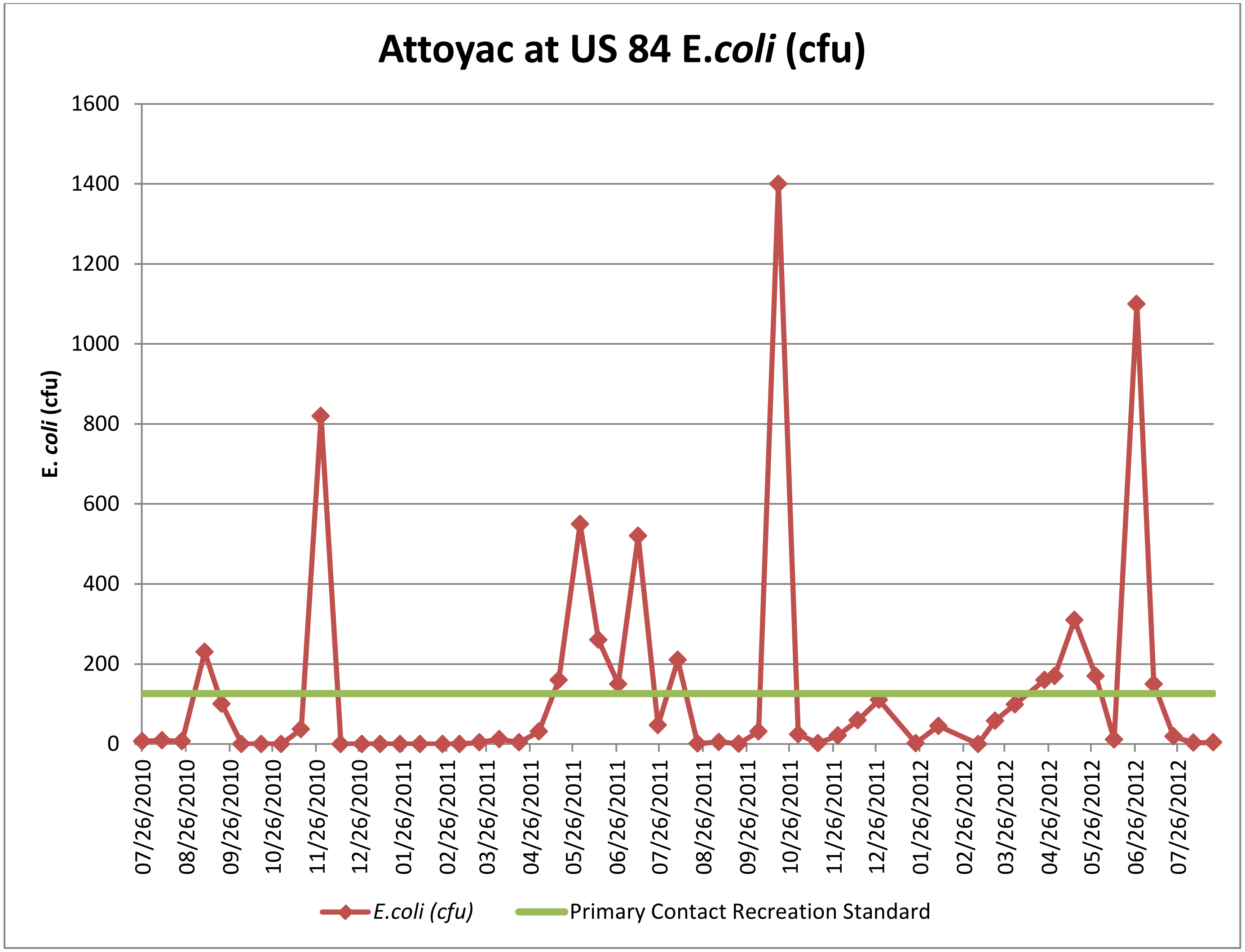

Figure C-13. Attoyac Bayou at US 84 *E. coli* cfu samples from 7/26/2010 through 8/20/2012 compared to the standard for primary contact recreation of 126 cfu. * *E. coli* values reported as >2400 were entered as 2400.**

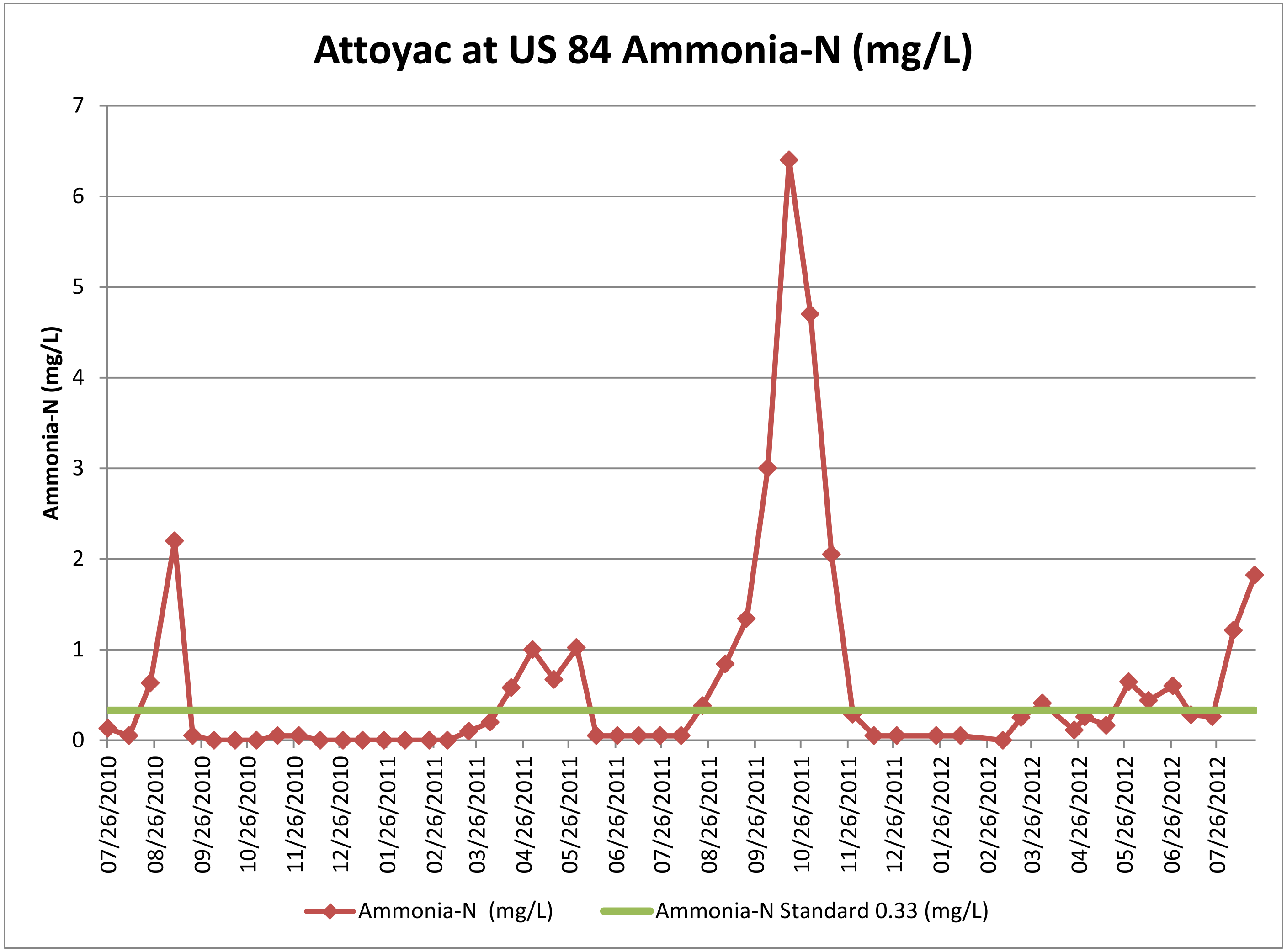

Figure C-14. Attoyac at US 84 Ammonia-A concentrations from 7/26/2010 through 8/20/2010 compared to the standard of 0.1 mg/L. * Ammonia levels reported at <0.1 were entered as 0.05 mg/L.**

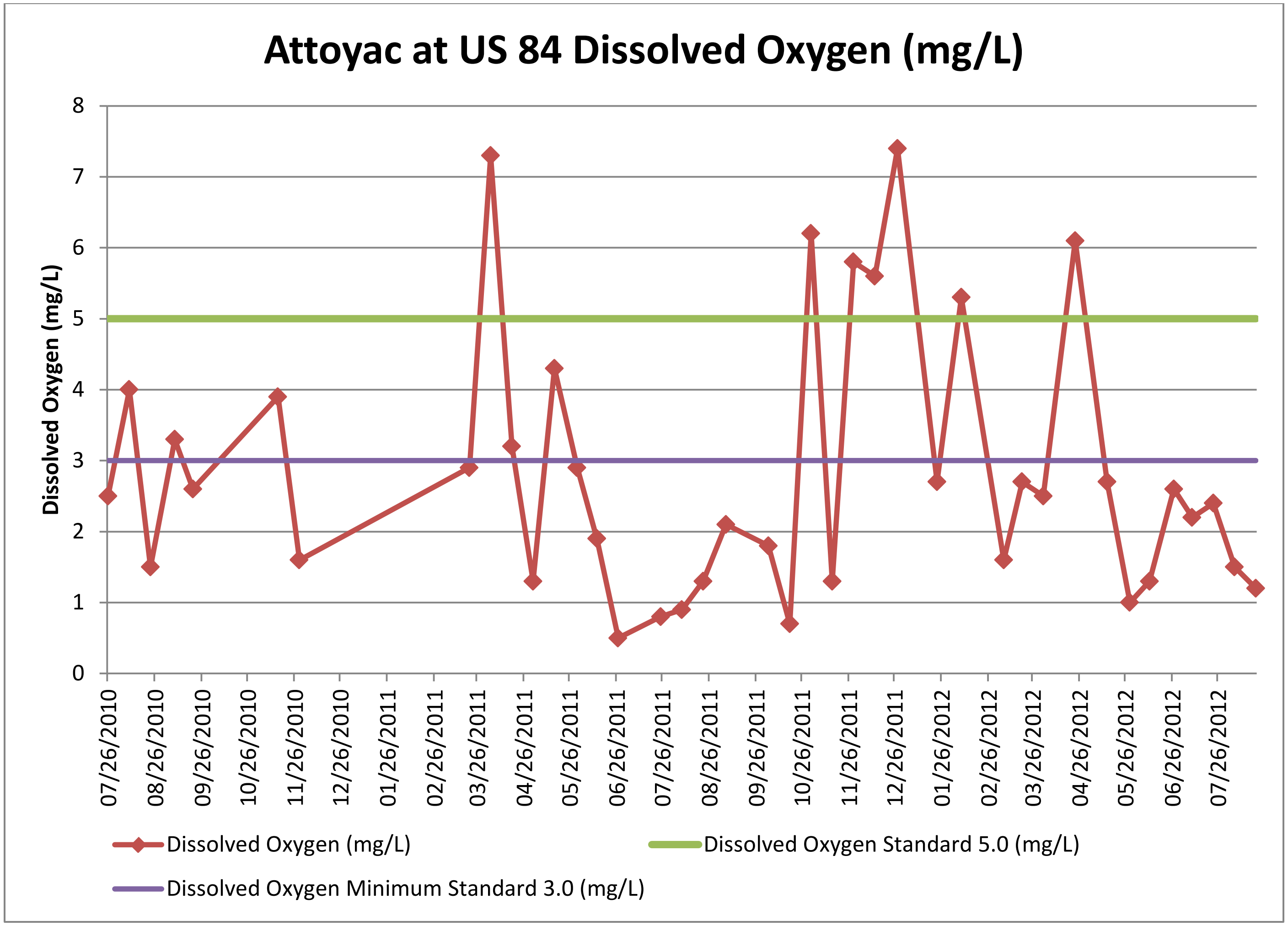

Figure C-15. Attoyac Bayou at US 84 Dissolved Oxygen (mg/L) measurements from 7/26/2010 through 8/20/2012, compared to the grab sample screening level of 5.0 mg/L.

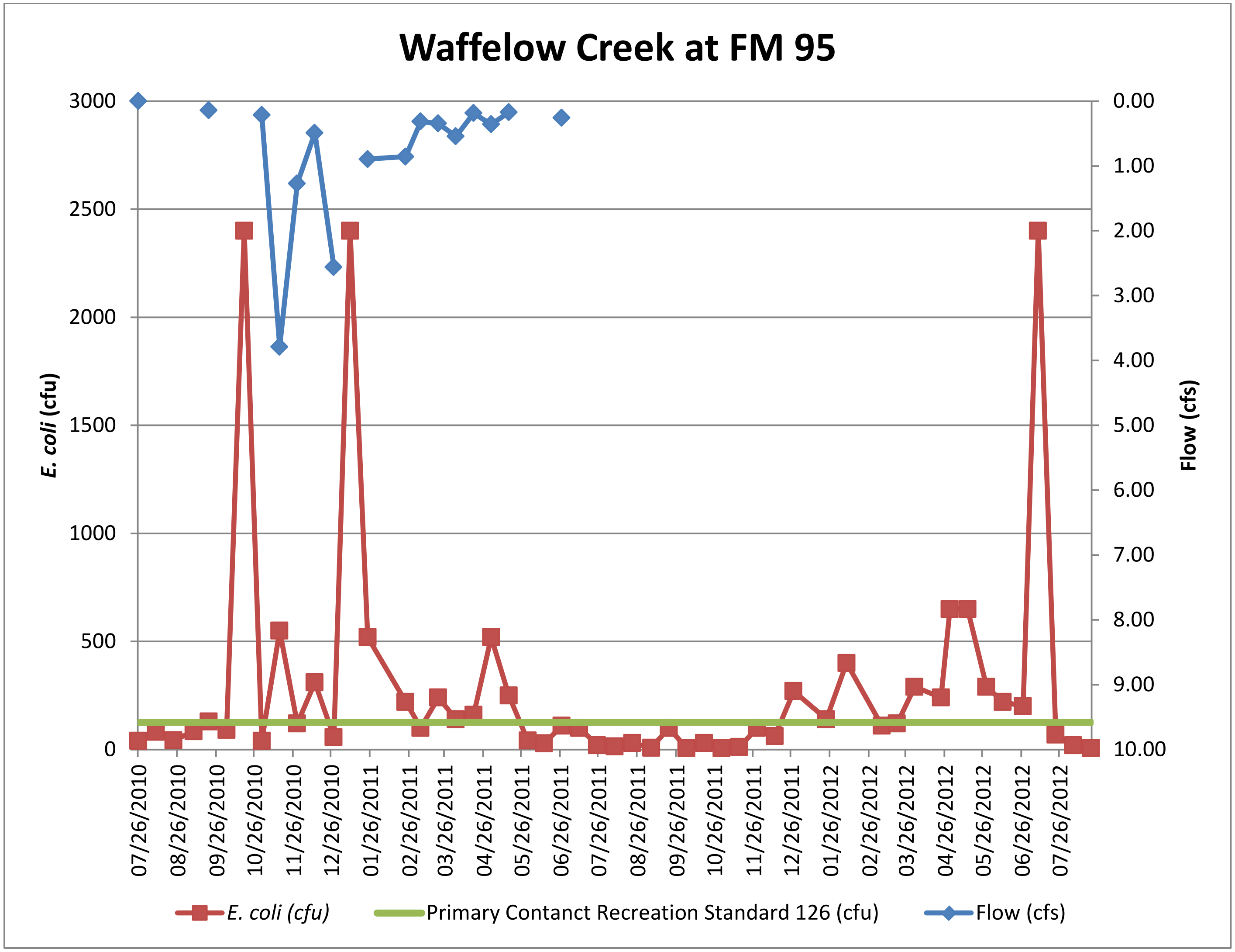

Figure C-16. Waffelow Creek at FM 95 *E. coli* (cfu) vs. flow (cfs), from 7/26/2010 through 8/20/2012, compared to the standard for primary contact recreation of 126 cfu. * *E. coli* values reported as >2400 were entered as 2400.**

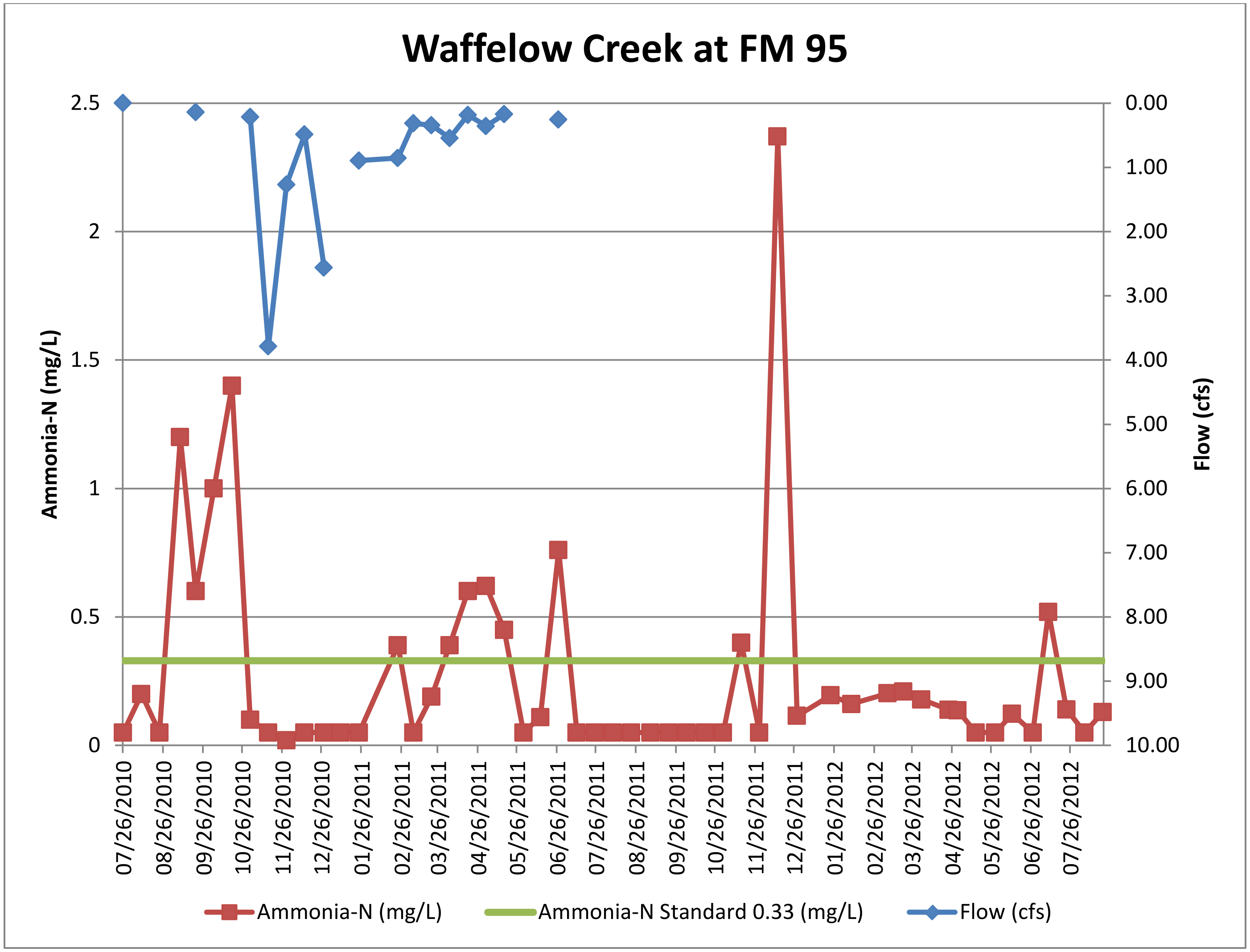

Figure C-17. Waffelow Creek at FM 95 Ammonia-N (mg/L) vs. Flow (cfs), from 7/26/2010 through 8/20/2012, compared to the standard of 0.1 mg/l. ** Ammonia levels reported at <0.1 were entered as 0.05 mg/L.

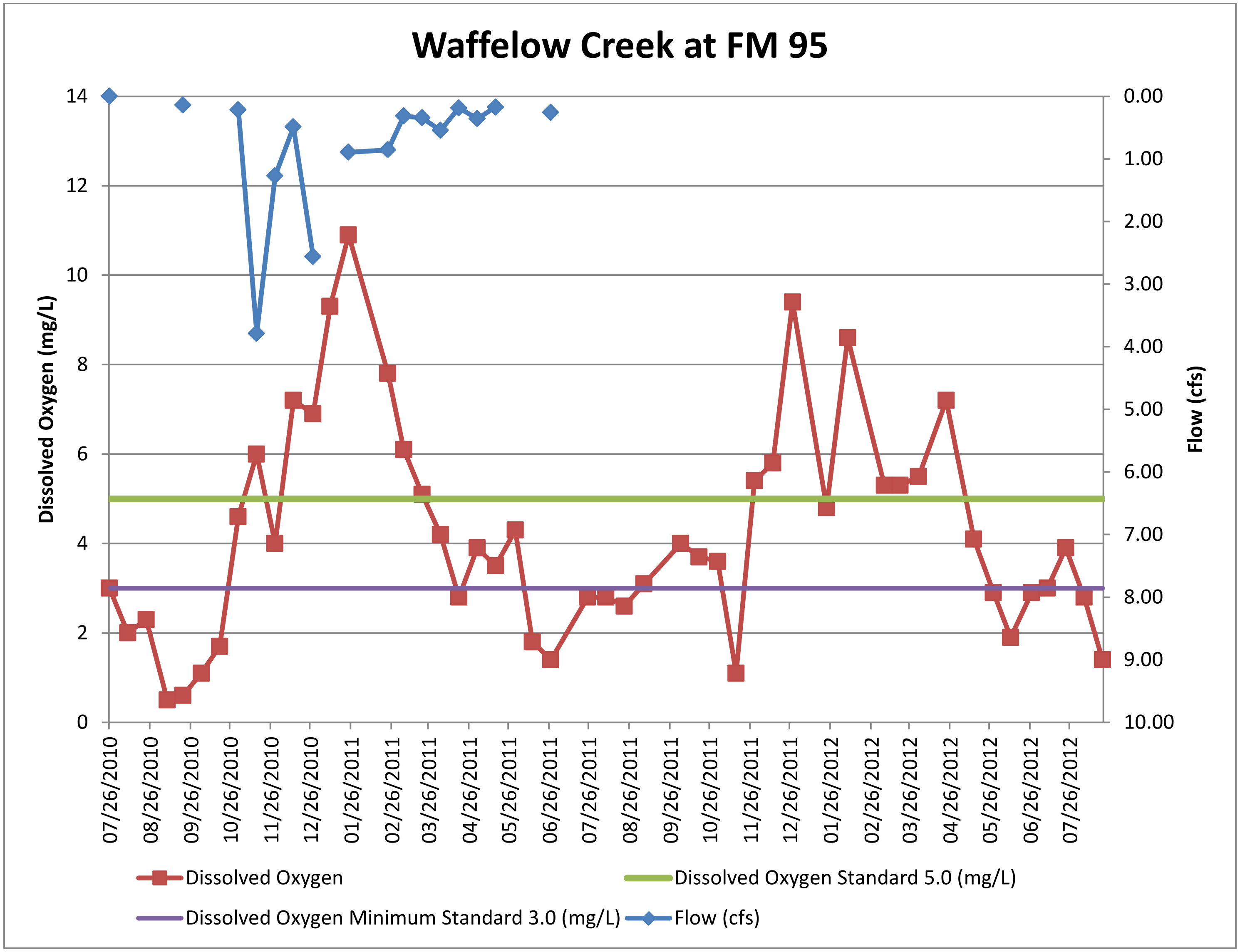

Figure C-18. Waffelow Creek at FM 95 dissolved oxygen (mg/L) vs. flow (cfs), from 7/26/2010 through 8/20/2012 compared to the standard of 5.0 mg/L.

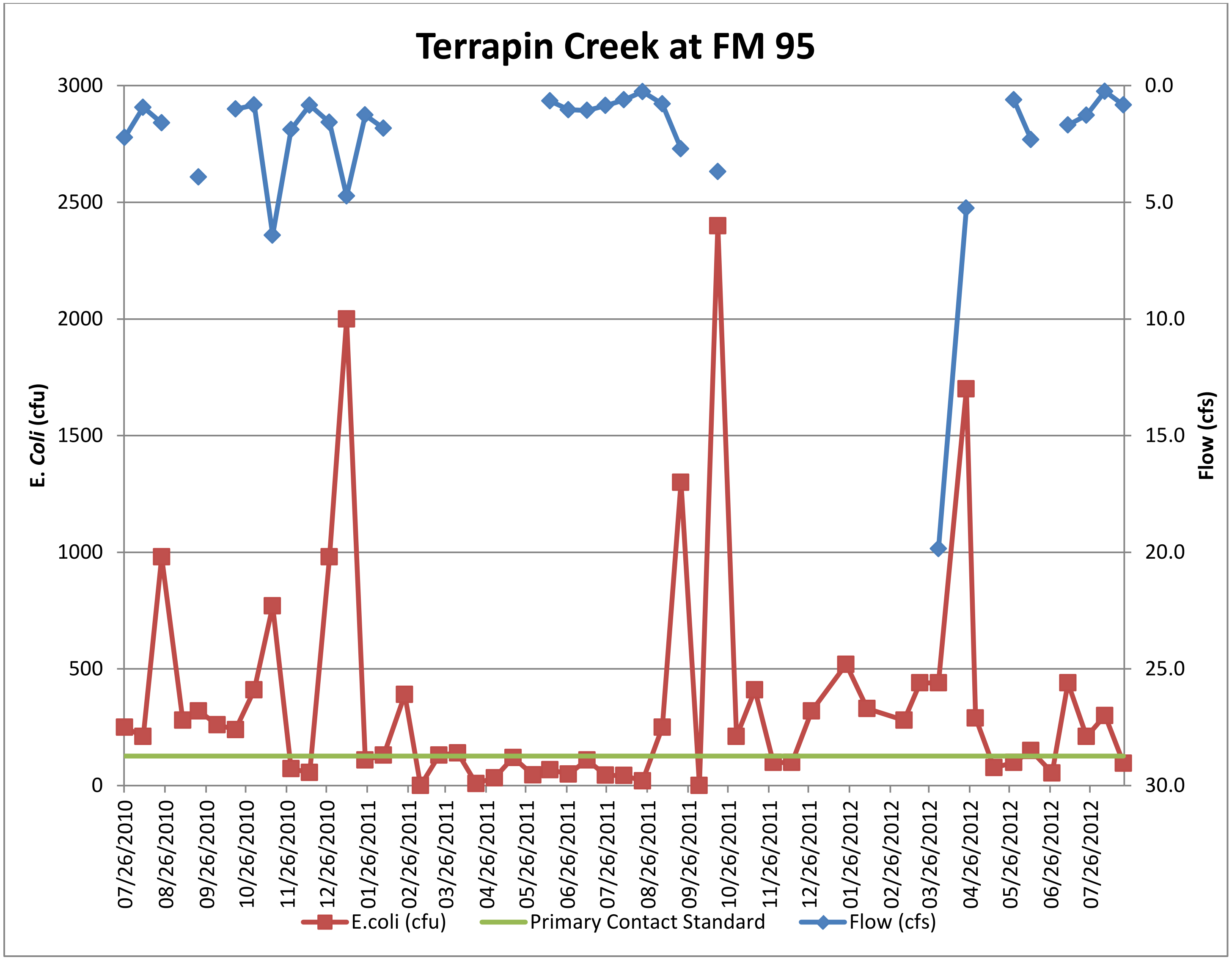

Figure C-19. Terrapin Creek at FM 95 *E. coli* (cfu) vs. flow (cfs), from 7/26/2012 through 8/20/2012, compared to the standard for primary contact recreation 126 cfu. * *E. coli* values reported as >2400 were entered as 2400.**

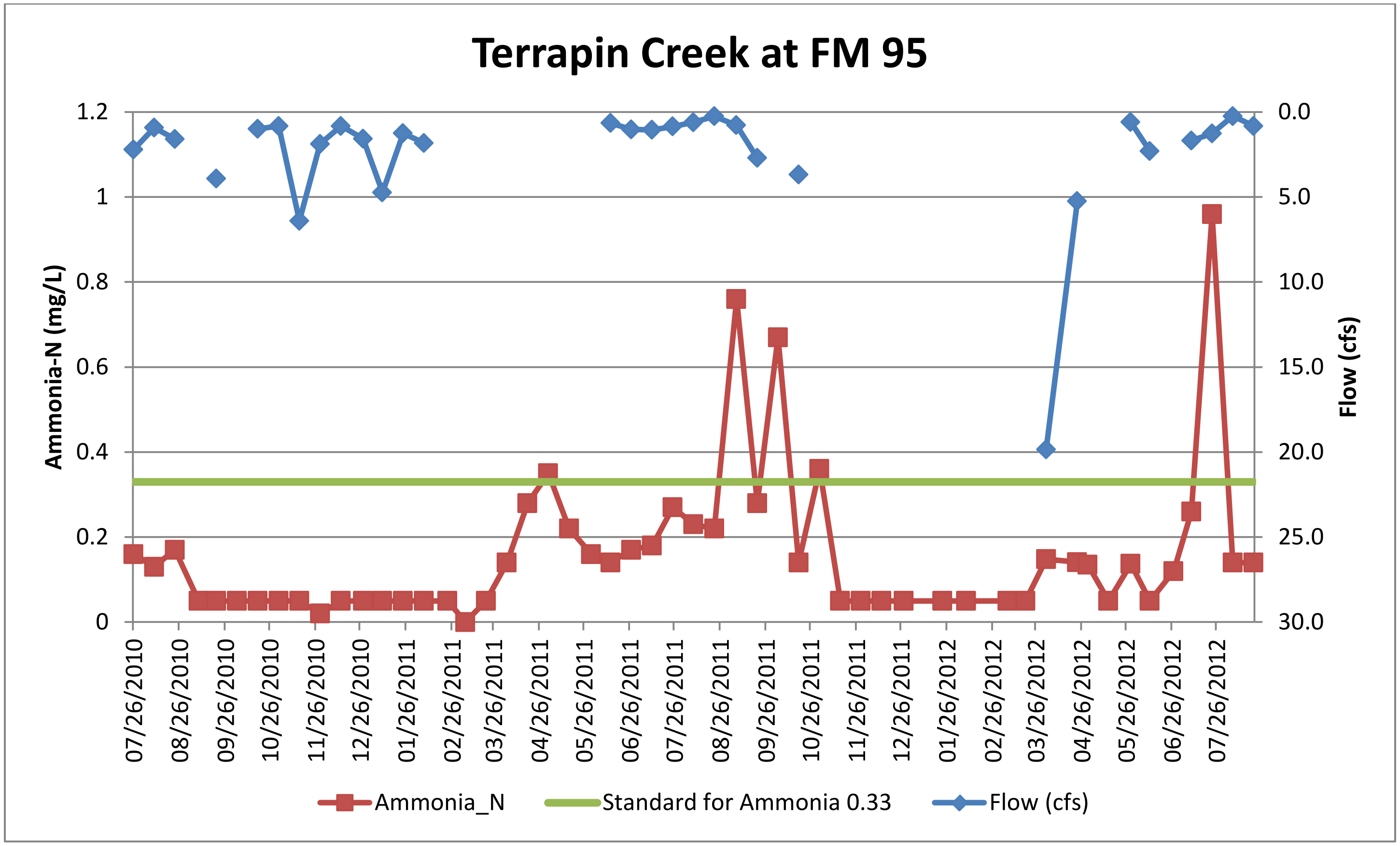

Figure C-20. Terrapin Creek at FM 95 Ammonia-N (mg/L) vs. flow (cfs), from 7/26/2012 through 8/20/2012, compared to the standard of 0.1 mg/L. * Ammonia levels reported at <0.1 were entered as 0.05 mg/L.**

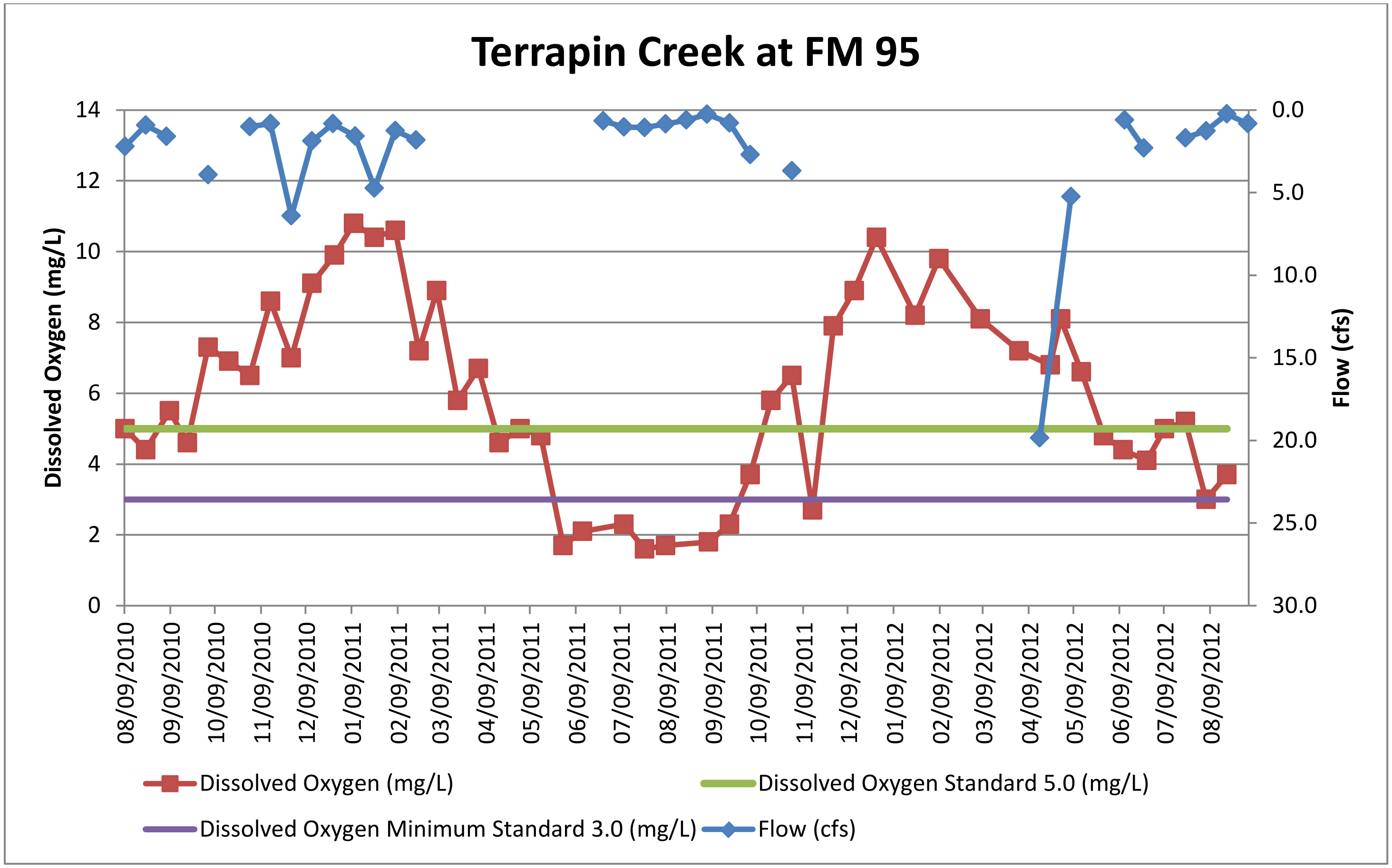

Figure C-21. Terrapin Creek at FM 95 Dissolved oxygen (mg/L) vs. flow (cfs), from 7/26/2012 through 8/20/2012, compared to the standard of 5.0 mg/L.

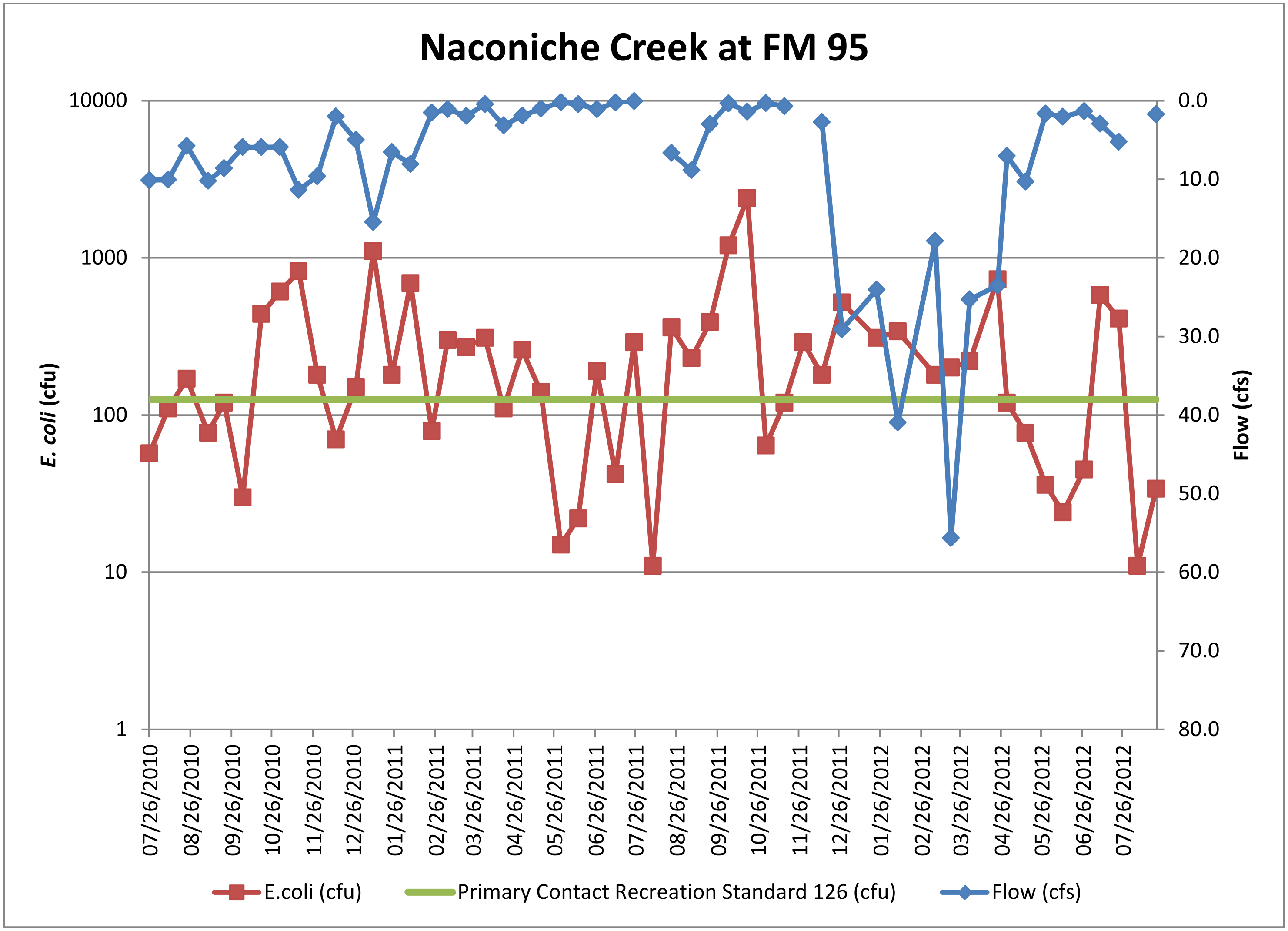

Figure C-22. Naconiche Creek at FM 95 *E. coli* (cfu) vs. flow (cfs), from 7/26/2010 through 8/20/2012, compared to the standard for primary contact recreation 126 cfu. * *E. coli* values reported as >2400 were entered as 2400.**

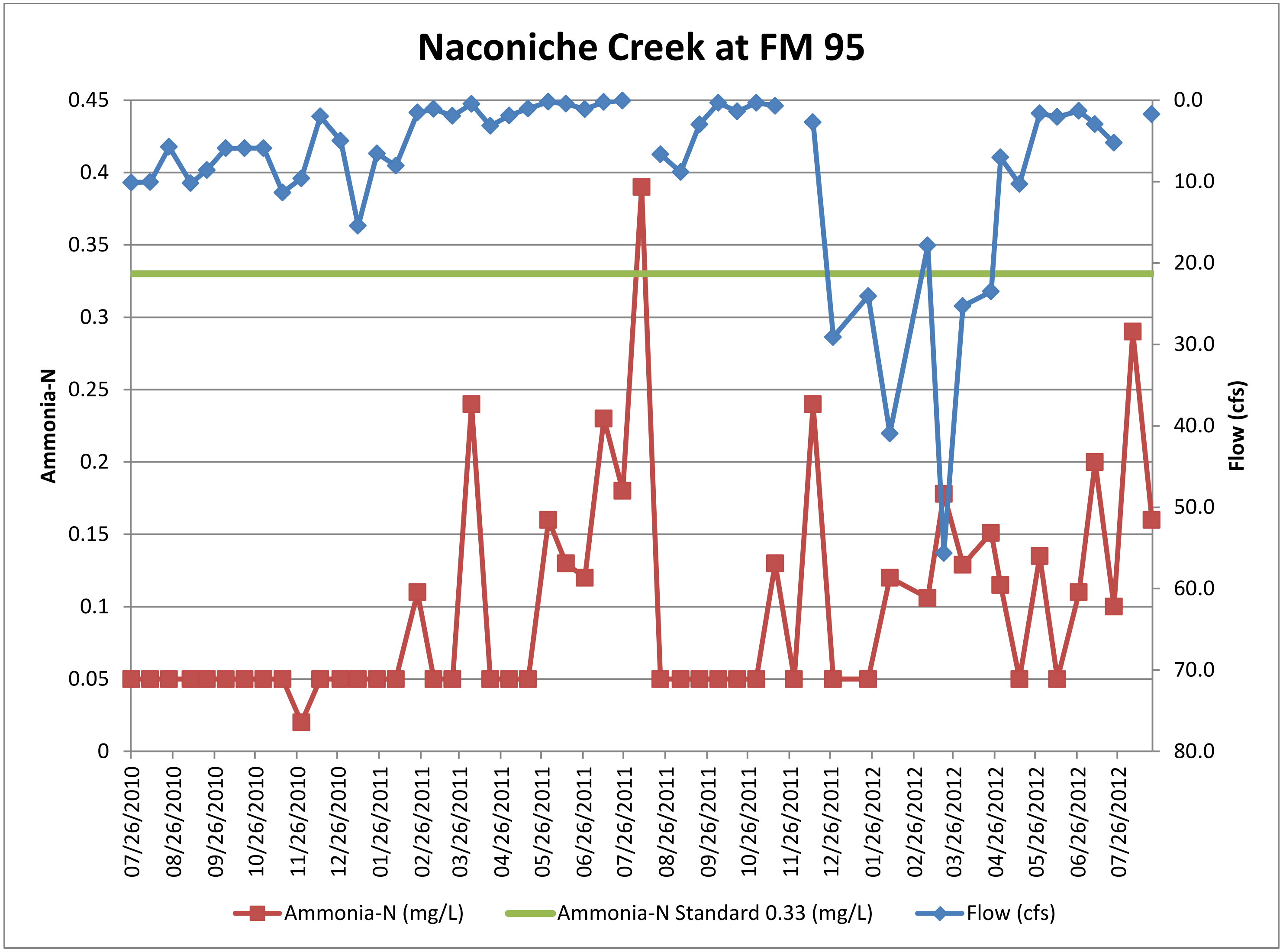

Figure C-23. Naconiche Creek at FM 95 Ammonia-N (mg/L) vs. flow (cfs), from 7/26/2010 through 8/20/2012, compared to the standard of 0.1 mg/L. * Ammonia levels reported at <0.1 were entered as 0.05 mg/L.**

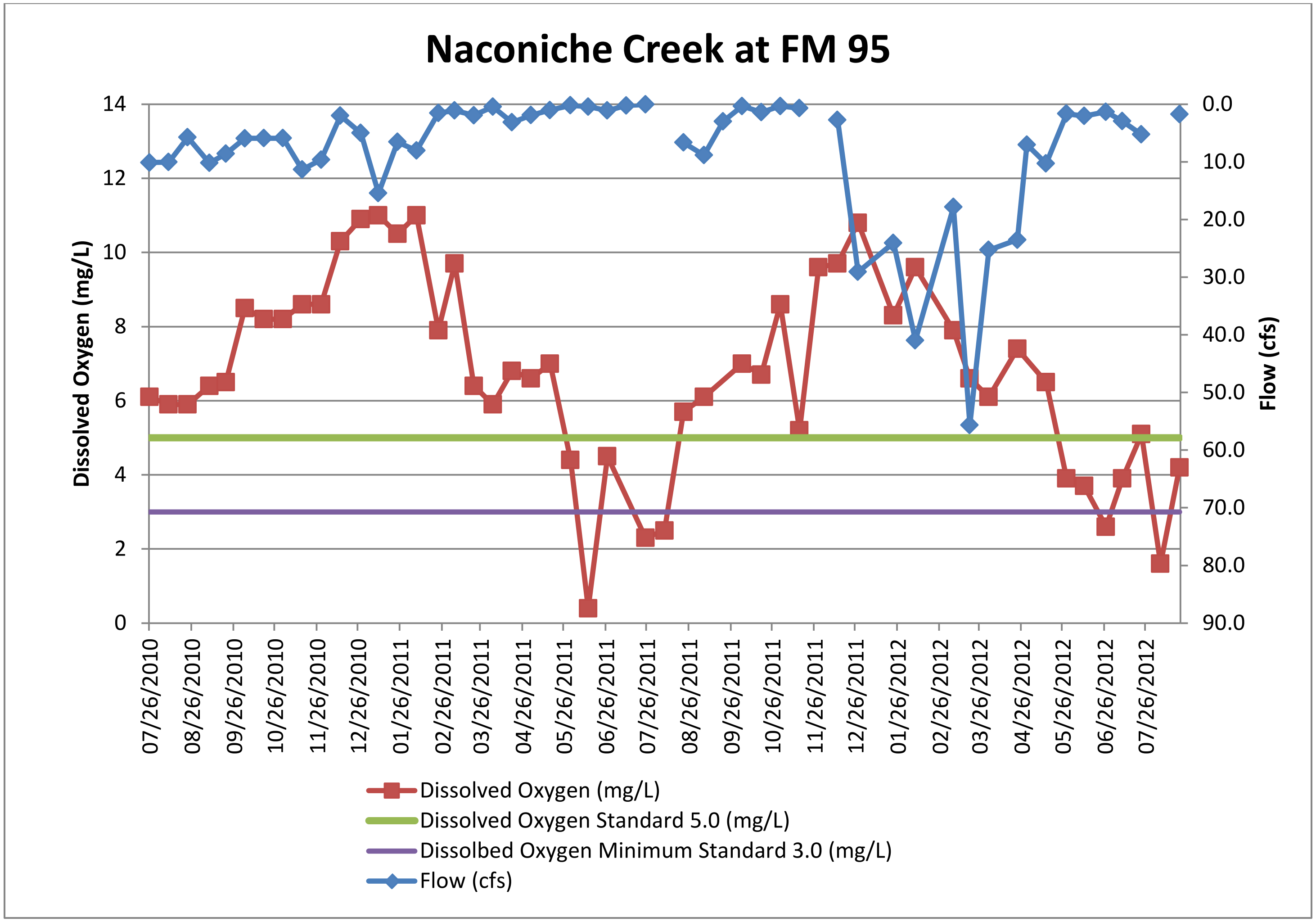

Figure C-24. Naconiche Creek at FM 95 Dissolved oxygen (mg/L) vs. flow (cfs), from 7/26/2010 through 8/20/2012, compared to the standard of 5.0 mg/L.

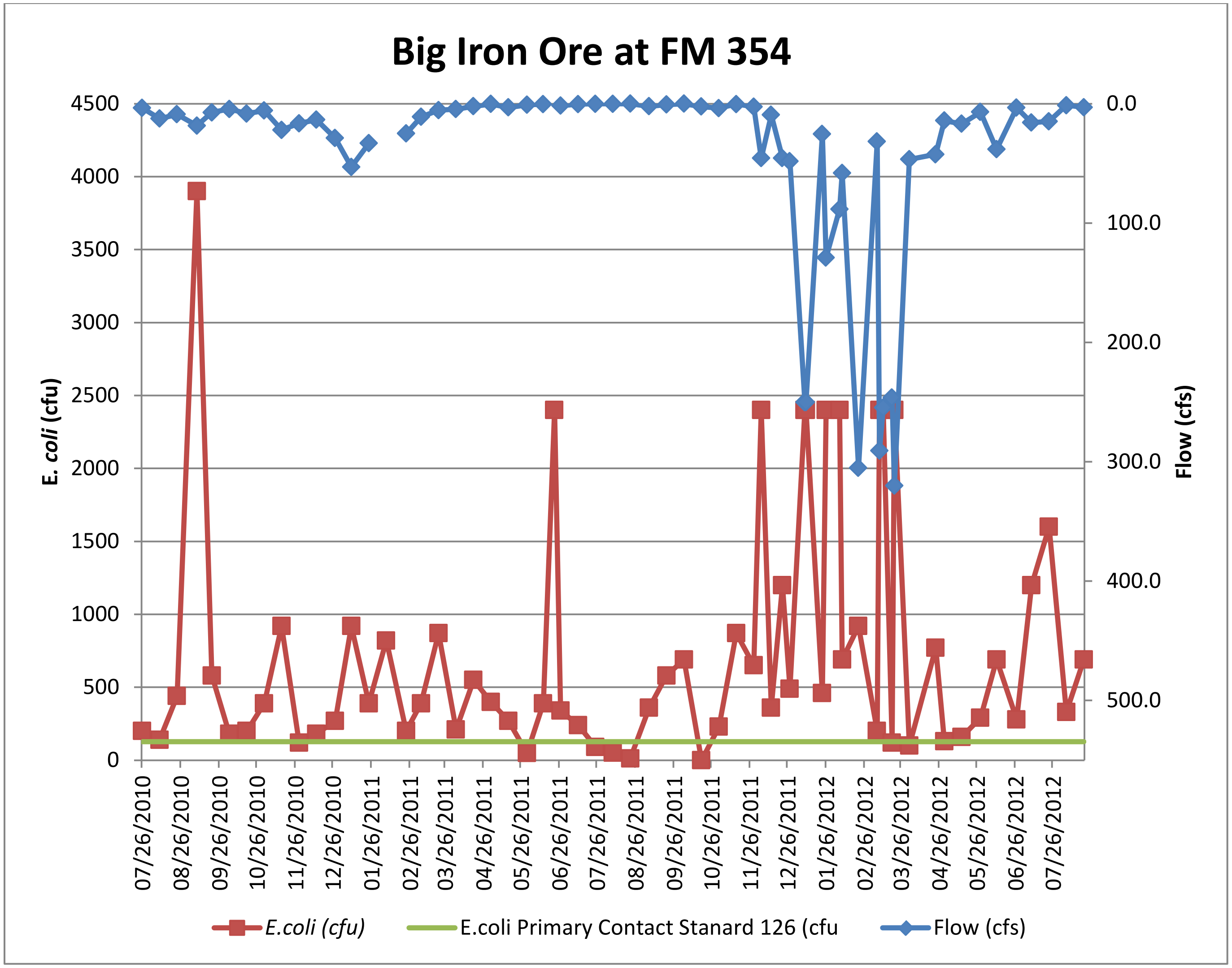

Figure C-25. Big Iron Ore Creek at FM 354 *E. coli* (cfu) vs. flow (cfs) from 7/26/2010 through 8/20/2012, compared to the standard for primary contact recreation 126 cfu. * *E. coli* values reported as >2400 were entered as 2400.**

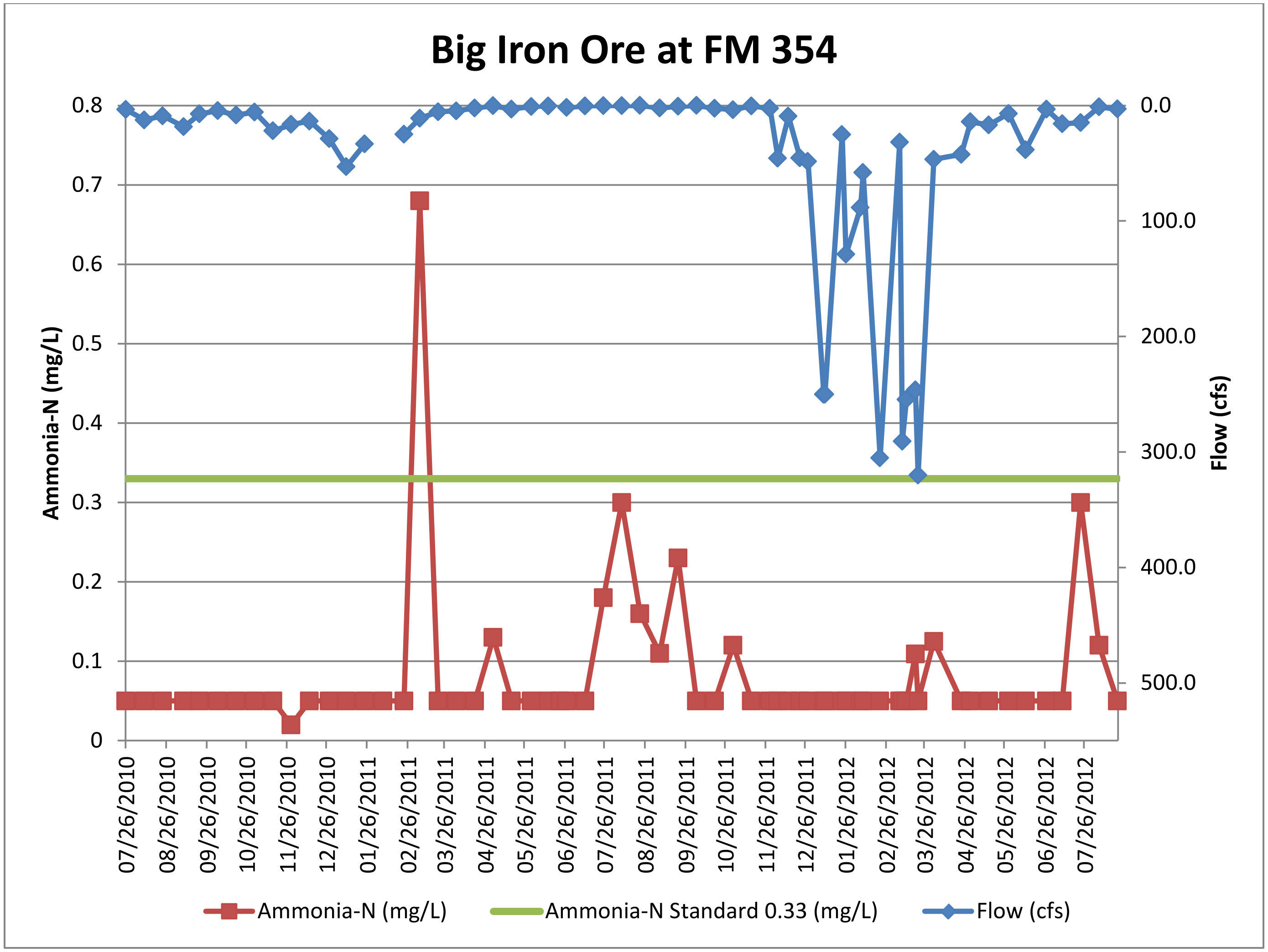

Figure C-26. Big Iron Ore Creek at FM 354 Ammonia-N (mg/L) vs. flow (cfs), from 7/26/2010 through 8/20/2012, compared to the standard of 0.1 mg/L. * Ammonia levels reported at <0.1 were entered as 0.05 mg/L.**

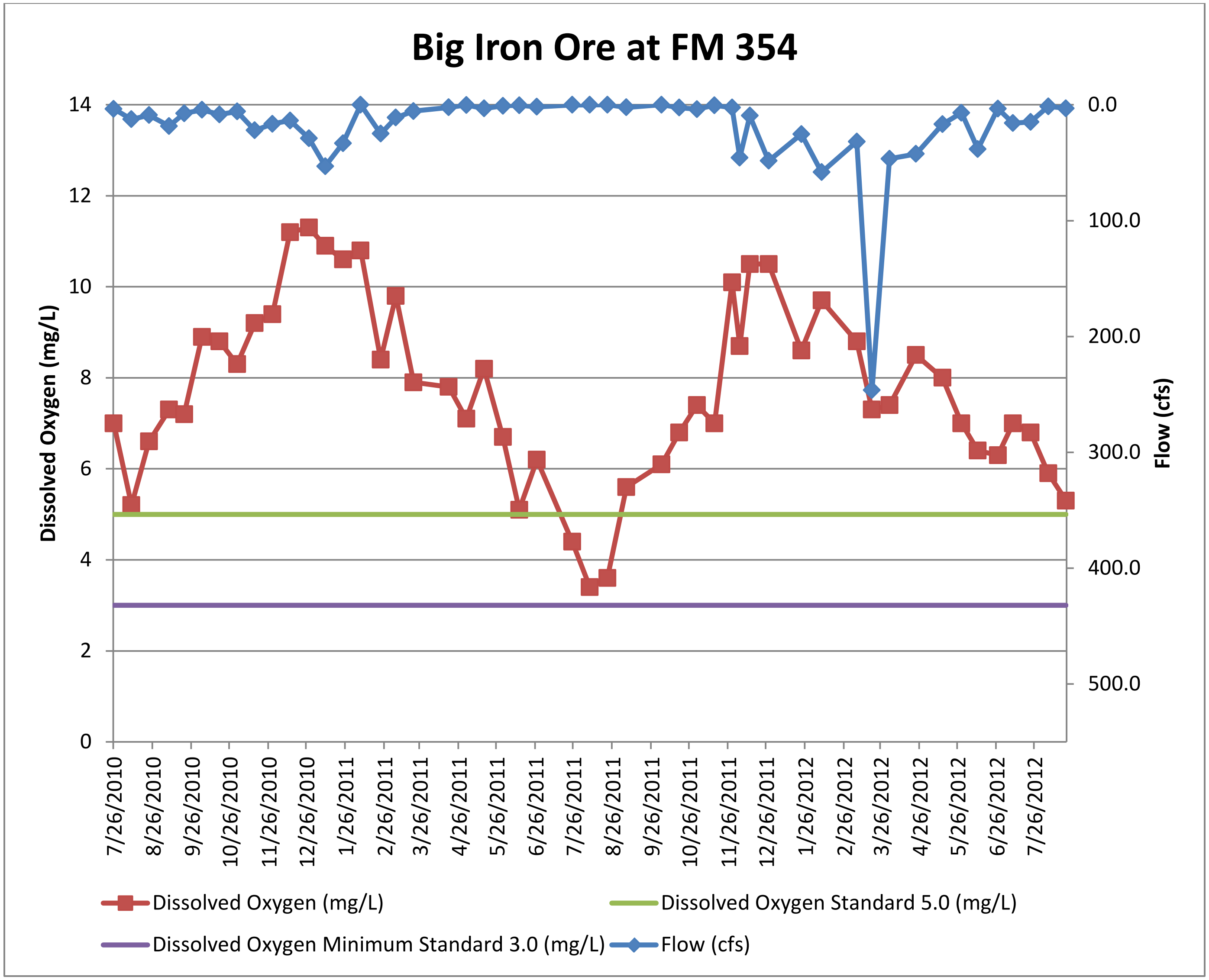

Figure C-27. Big Iron Ore Creek at FM 354 Dissolved oxygen (mg/L) vs. flow (cfs), from 7/26/2010 through 8/20/2012, compared to the standard of 5.0 mg/L.

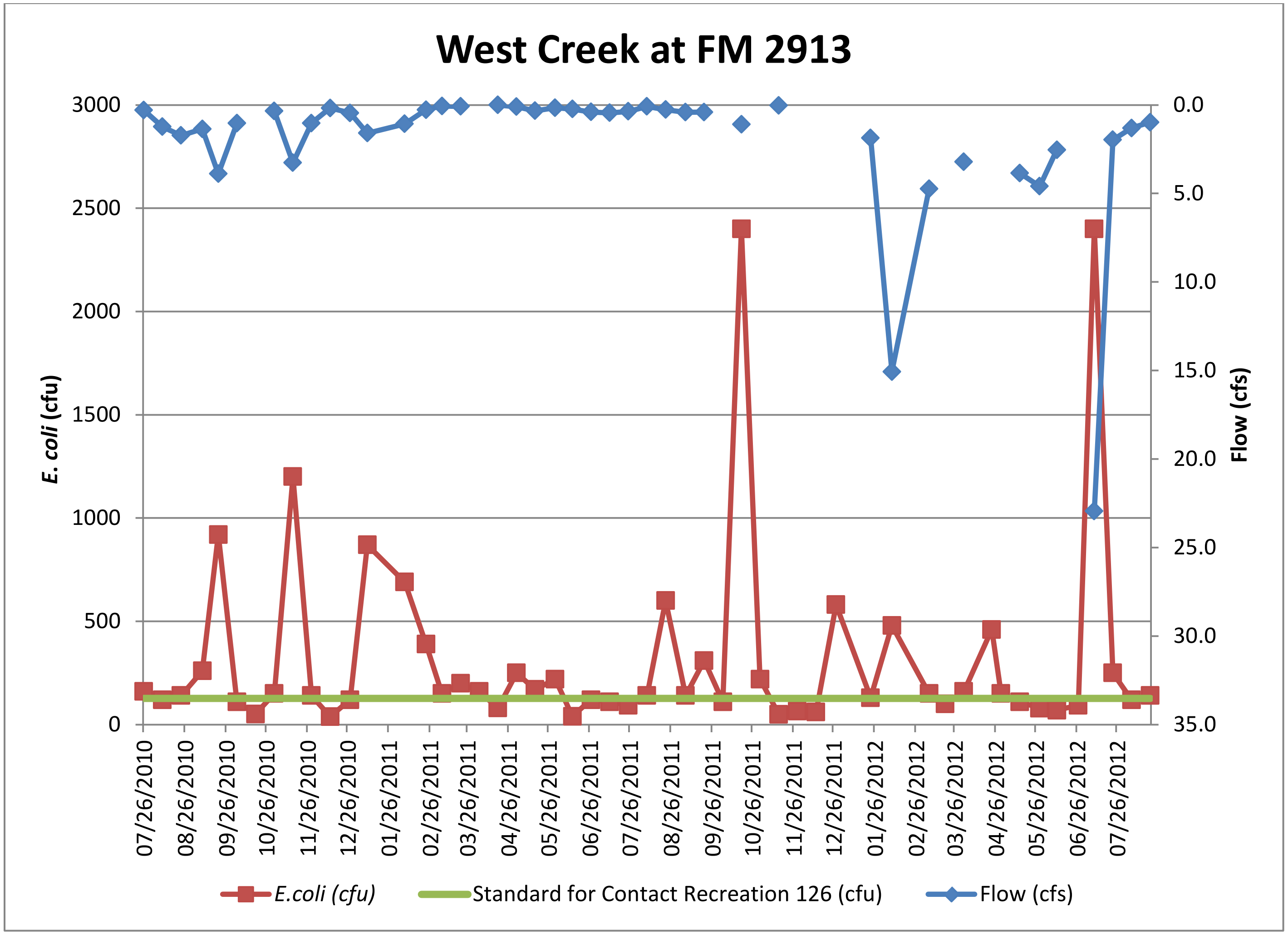

Figure C-28. West Creek at FM 2913 *E. coli* (cfu) vs. flow (cfs), from 7/26/2010 through 8/20/2012, compared to the standard for primary contact recreation 126 cfu. * *E. coli* values reported as >2400 were entered as 2400.**

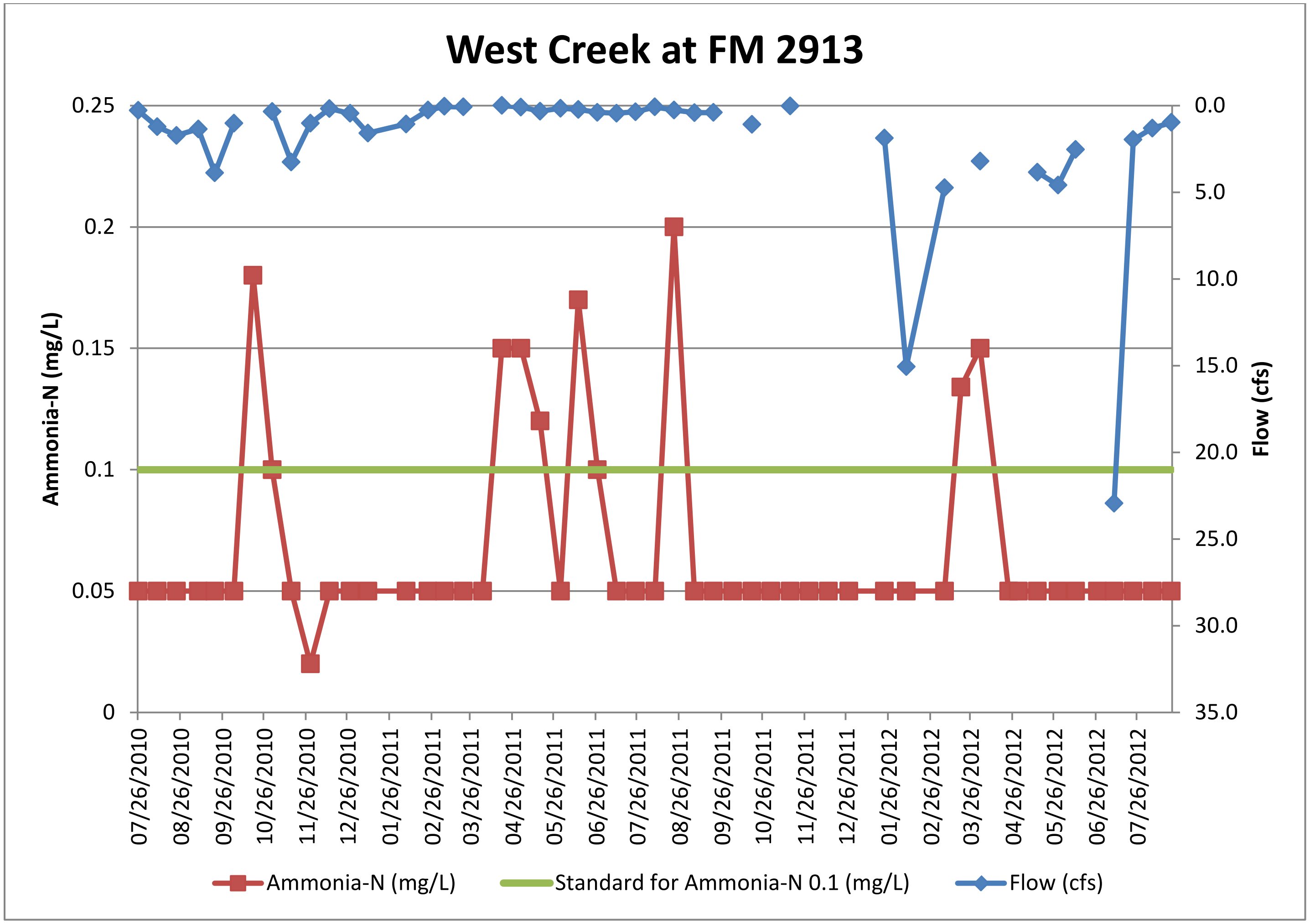

Figure C-29. West Creek at 2913 Ammonia-N (mg/L) vs. flow (cfs), from 7/26/2010 through 8/20/2012, compared to the standard of 0.1 mg/L. * Ammonia levels reported at <0.1 were entered as 0.05 mg/L. if was >0.04 was entered as 0.02**

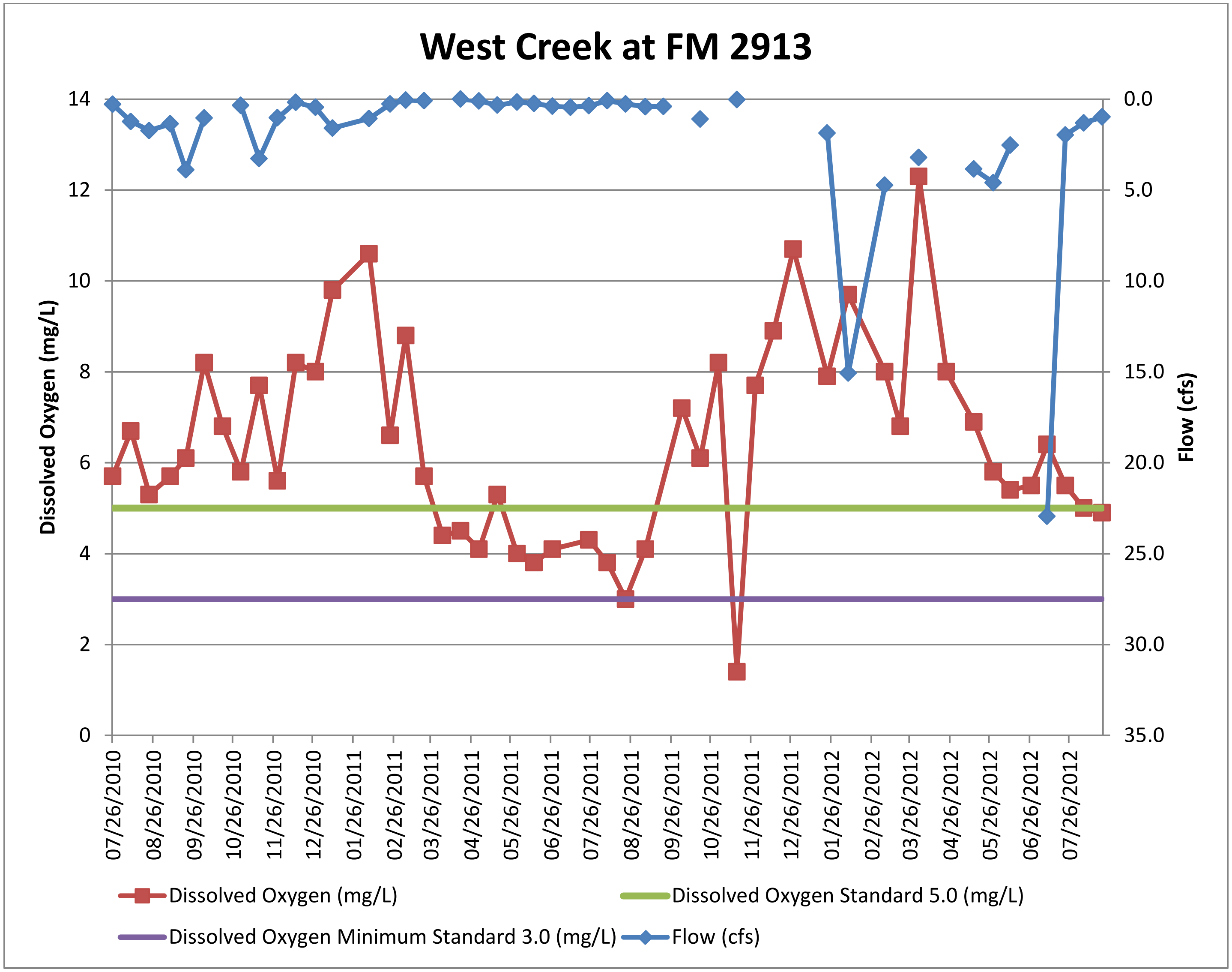

Figure C-30. Dissolved oxygen (mg/L) vs. flow (cfs), from 7/26/2010 through 8/20/2012, compared to the standard of 5.0 mg/L.