



Gulf Coast Network Water Quality Report

Status of Water Quality of Big Thicket National Preserve

Natural Resource Technical Report NPS/GULN/NRTR—2012/523



ON THE COVER

Village Creek at McNeely Road Bridge, May 19, 2010

Photograph by Joe Meiman

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Acronyms and Abbreviations

°C	degrees Celsius
BITH	Big Thicket National Preserve (the Preserve)
BSVC	Big Sandy Creek at Farm to Market Road 176
CaCO ₃	calcium carbonate
cfs	cubic feet per second
CO ₂	carbon dioxide
CRP	Clean Rivers Program
DO	dissolved oxygen
DSHS	Texas Department of State Health Services
FM	Farm to Market Road
GULN	Gulf Coast Network
km	kilometer
LDL	lower detection limit
LNVA	Lower Neches (River) Valley Authority
LPIB	Little Pine Island Bayou at Farm to Market Road 770
MCMC	Menard Creek at State Highway 146
mg/l	milligrams per liter
ml	milliliter
mm	millimeter
MPN	most-probable number
MRVC	Village Creek at McNeely Road Bridge
MS	Mississippi
n	number of measurements
NECH	Neches River at Lakeview
NELAP	National Environmental Laboratory Accreditation Program
NH ₃	ammonia
NH ₃ -N	ammonia-nitrogen
NPS	National Park Service
NPStoret	NPS's water quality depository
NTU	nephelometric turbidity unit
ppt	parts per thousand
QC	Quality Control
SH	State Highway
SM	Standard methods for the examination of water and wastewater
SOP	standard operating procedure

Acronyms and Abbreviations, cont'd

SpC	specific conductance
STORET	national water quality database
SU	standard unit (pH)
TCEQ	Texas Commission on Environmental Quality
TCTC	Turkey Creek at Gore Store Road
TDS	Total Dissolved Solids
TMDL	Total Daily Maximum Load
TPWD	Texas Parks and Wildlife Department
TSS	Total Suspended Solids
U.S.C.	United States Code
UDL	Upper Detection Limit
USACE	United States Army Corps of Engineers
µS/cm	microSiemens per centimeter
USEPA	United States Environmental Protection Agency
USGS	United States Geological Survey
VCVC	Village Creek at Mouth

Gulf Coast Network Long-Term Water Quality Monitoring

Water quality ranked among the top vital signs and was selected for long-term monitoring in the eight parks that make up the National Park Service's (NPS) Gulf Coast Network (GULN). Water quality monitoring program protocols and standard operating procedures (SOPs) are described in the GULN Vital Signs Monitoring Plan (Segura et al. 2007). The report that follows is a park-specific document that describes the status of water quality knowledge, a description of the monitoring program, sites, parameters tested, results in graphic form (when available), a brief interpretation of the results, and recommendations of parameters, locations and frequencies to be measured for the long-term.

Sampling sites were chosen following site visits by GULN hydrologist Joe Meiman and in consultation with park staff. Some sites were chosen to coincide with past inventories and monitoring efforts. In most cases, sites were chosen at the downstream end of a watershed (or as a stream enters or leaves a park) to serve as an integrator of the basin, which should yield characteristics of, and contributions from, the entire watershed. Other near-shore and estuarine sites were chosen with respect to other key park resources (e.g., seagrass beds).

The NPS's Water Resources Division requires each network water quality program to monitor four core field parameters: water temperature, pH, specific conductance, and dissolved oxygen (DO). While these key parameters are essential, additional parameters, tailored to specific parks, were chosen to reflect particular water quality issues.

Non-conditional synoptic sampling, where samples are taken, regardless of flow and weather conditions on fixed calendar dates, is central to this effort. Basic fixed sampling locations include integrator sites (locations commonly at tributary confluences or springs that are representative of water quality issues for individual sub-basins) and indicator sites (locations downstream from either suspected or documented water quality threats, or pristine conditions). It is recognized that in order to best fit with other GULN monitoring activities, some flexibility in site selection is likely. This strategy, over the long-term, has proven to yield statistically valid data for tracking trends in water quality.

Specific management objectives, past water quality history, biological significance, recreational use, enabling legislation, and field logistics were considered separately for each GULN park in the design of a long-term program. While parameter lists may differ from park to park, and sampling frequency can be dictated by extant programs or resource importance, there are several fundamental constants to the GULN program. Namely, all measurements are made in accordance with SOPs, which are adapted from agencies such as the U.S. Geological Survey (USGS) or the Texas Commission on Environmental Quality (TCEQ). All contract laboratories are accredited by the National Environmental Laboratory Accreditation Program (NELAP). All in-house analyses are performed according to Standard Methods (SM) for the Examination of Water and Wastewater (American Public Health Association 2005).

Measureable Objectives

This is a long-term monitoring program. It is not designed to respond to catastrophic or singular water quality events. It is designed to form a comparative database to detect changes in a variety

of water quality parameters over time within an individual park or stream. Parks within a particular ranking category may be cross-comparable, but charting changes in water quality within a particular park is the primary statistical objective for the long-term data. Through a series of Vital Signs Workshops and other meetings with park managers, the water quality monitoring program was devised to meet the management objectives of the GULN parks. These measurable objectives are as follows:

- Provide a backdrop to compare changes in the aquatic biologic community.
- Compare water quality to Texas water quality standards.
- Identify stressors such as land uses and land use change within the watershed.
- Determine potential pollutant sources (non-point source contaminants versus point-sources).
- Ascertain impacts to water quality by in-park activities within selected watersheds.
- Determine regional effects of atmospheric contaminants (e.g., acid precipitation).

Brief Hydrologic Introduction to Big Thicket National Preserve

It would be difficult to overstate the importance of fresh water at Big Thicket National Preserve (the Preserve). Sprawled across an area comprising 9,000 square kilometers (km²) (2.2 million acres), the NPS manages 390 km² (or 96,000 acres), including 300 km (186 miles) of stream corridor. These streams, ranging from first-order headwater tributaries to the Neches River, play a vital role in the ecologic function of the Preserve. Draining the southwestern portion of the Lower Neches, these streams originate in the gently rolling sandy terrain with the adjoining Trinity River to the west and cross the vast Coastal Prairie of southeast Texas. Adjacent riparian forests depend on regular flooding to replenish nutrients and support wetland plants.

With the exception of Menard Creek, all streams within the Preserve drain into the Neches River. Included in the Preserve are three main streams that are in some part managed by the NPS: the Neches River, Village Creek, and Pine Island Bayou. Menard Creek, although adjacent to the headwaters of Village Creek, enters the Trinity River near the community of Romayor, Texas.

Neches River

The Preserve manages the Neches River corridor from the B.A. Steinhagen Reservoir (managed by the U.S. Army Corps of Engineers [USACE]) to the Saltwater Barrier immediately downstream of the confluence with Pine Island Bayou on the northern edge of Beaumont, Texas. The Neches below the reservoir can be divided from north to south into the Upper Neches River Corridor, the Neches Bottom and Jack Gore Baygall Unit, and the Lower Neches River Corridor Unit.

The NPS manages approximately 130 km (81 miles) of this meandering river corridor. It should be noted that the NPS does not actually own the Neches, or its bed. According to the Texas Parks and Wildlife Department (TPWD) (2011), *“The navigation of Texas’s inland and coastal waters is one of several “public rights and duties” specifically recognized by the Texas Constitution. A form of the right to travel, the navigation right is part of the liberty and the freedom of movement enjoyed by our society. Texas’s laws on navigation have evolved under different governments during Texas’s history.”* Furthermore: *“Under Texas state law, the beds of navigable streams are generally owned by the state, in trust for the public. Most of the land alongside navigable streams is privately owned. The beds of non navigable streams are usually privately owned, and public use of the stream may be forbidden by the private landowner. However, the state owns the beds of perennial streams, regardless of navigability, where the original land grant was made under the civil law prior to December 14, 1837.”*

Water management of the Lower Neches River is in coordination with the Lower Neches River Valley Authority (LNVA). This quasi-governmental entity was created by the State of Texas in 1933, primarily to serve the ever-increasing need for freshwater in the Lower Neches River Valley. The LNVA is in the business of providing (selling) water. At the turn of the century, land use was dominated by agricultural activities with potatoes, cotton, oats, and hay as the principal crops in the rolling hills of the northern counties and rice to the south. To ensure an ample water supply, the LNVA relies on the operation of two USACE projects: the Sam Rayburn and B.A. Steinhagen reservoirs. The LNVA has secured rights from the state for adequate water well into the twenty-first century. The LNVA delivers water to its customers via canals cut into the

Neches River and Pine Island Bayou. A potential daily volume of 3.8 million cubic meters (1 billion gallons) per day can be delivered to a variety of cities, water districts, industries, and farms.

Throughout the entire Neches Valley, oil and gas exploration is a prevalent industry. In order to increase shipping capabilities at the Port of Beaumont, the Neches downstream to Port Arthur was dredged – wider, deeper, and straighter than natural. This channel modification allowed saltwater from the Gulf of Mexico to encroach upstream to Beaumont under low-flow conditions, thus threatening the LNVA's freshwater resources. In response, saltwater barriers, for years a series of sheet-pile barriers, were constructed across the Neches River near Beaumont. Beginning in 2000, the USACE began a 3-year project to construct a permanent structure immediately downstream of the confluence of Pine Island Bayou. Completed in 2003, the Saltwater Barrier is operated by the LNVA through a Federal cost-share agreement (Figure 1).



Figure 1. The Saltwater Barrier of the Neches River during above-normal flow conditions. Photograph by Joe Meiman, May 14, 2009. Note open gates to accommodate high discharge of the Neches River and elevated turbidity at this time; maximum flow was 4,450 cfs on this date.

Of increasing concern for park and estuary managers is the regulation of freshwater inflows. The Neches is a highly modified river from large reservoirs throughout the watershed to the dredged lower 40 km (25 miles) of its route to the Sabine Lake estuary. The Neches River portion of the Preserve is precariously in the balance between continued reduction in freshwater inflow and the ever-enlarging shipping channel, both modifications synergistically increasing the periodicity and magnitude of high salinity events. On May 14, 2011, a combination of historically low

freshwater in-flows and the “improved” river channel created surface salinity of 13 parts per thousand (ppt) in the Neches River adjacent to the Preserve’s Beaumont Unit (river mile 23 from Sabine Lake). Surface salinity reached 11 ppt at river mile 29 and people caught redfish and flounder on the downstream side of the Saltwater Barrier.

Village Creek

Village Creek is the largest of the NPS-managed stream corridors and the largest tributary of the Lower Neches River. It is fed by Big Sandy Creek, heading beyond the Alabama-Coushatta Indian Reservation and the Preserve’s Big Sandy Creek Unit, and Hickory and Turkey creeks, which enter Village Creek in the Turkey Creek Unit. The NPS manages over 90 percent of the main stem of Village Creek, which also passes through the Roy E. Larsen Sandyland Bird Sanctuary and Village Creek State Park.

The NPS does not manage the Hickory Creek watershed, with exception of a couple of hectares near its confluence with Village Creek. The Hickory Creek Savannah Unit is a few kilometers removed from the stream corridor. The NPS manages approximately 12 km (7.5 miles) of the lower segment of Turkey Creek. Its upper watershed is privately owned and contains several small lakes near Ivanhoe, Texas.

Beech Creek is located southwest of the B.A. Steinhagen Reservoir. The Preserve manages most of these headwaters. A proposed acquisition may one day include all headwaters of Beech Creek. Beech Creek flows southward to join Village Creek downstream of the Turkey Creek Unit.

Pine Island Bayou

Pine Island Bayou, the second largest tributary of the Lower Neches River, is mostly contained within the Coastal Prairie. Little of this watershed extends northward where the topography transitions from flat to rolling terrain. Pine Island Bayou comprises three tributaries: the northern and southern branches of Pine Island Bayou and Little Pine Island Bayou. The Preserve manages the stream corridor in the lower half of Little Pine Island Bayou, including the Lance Rosier Unit. The Preserve also contains the stream corridor of Pine Island Bayou from its confluence with Little Pine to its mouth at the Neches River.

Menard Creek

The only stream corridor managed by the Preserve that is not within the Neches watershed is Menard Creek. This stream, in the gently rolling hills of the north, parallels the headwaters of Village Creek and comes within a few kilometers of Village Creek in the Big Sandy Unit. It then turns southwestward and flows into the Trinity River. The NPS manages the Menard Creek Corridor Unit, which merges into the Big Sandy Creek Unit, along this stream.

Threats to Water Quality

Threats to water quality of the Lower Neches generally range from a broad list of point and non-point source contaminants as well as habitat alteration. It is important to remind the reader of scale. The Neches River drains approximately 25,353 km² (6.3 million acres) (Aragon Long et al. 2004). Conversely, on a local scale, the two main tributaries of the Lower Neches River within the Preserve are Village Creek (2,230 km² [550,000 acres]), and Pine Island Bayou (1,640 km² [410,000 acres]). Within any of these three watersheds, the NPS owns, and thus controls, a very small portion. The Big Thicket National Preserve totals 390 km² (96,000 acres) (exclusive of Menard Creek), but makes up only 1.5 percent of the entire Neches watershed.

Land uses define non-point source threats to water quality. Within the Neches are thousands of hectares of agricultural and silvicultural activities, all of which are potential threats to water quality. According to the NPS's *Baseline Water Quality Data Inventory and Analysis, Big Thicket National Preserve* (1995), there are 14 permitted industrial discharges within the Preserve's watershed. Many of these are a result of oil and gas production and their associated point source threats to water quality.

Under section 303(d) of the Federal Pollution Control Act (33 U.S.C. 1251 et seq., commonly known as the Clean Water Act), states, territories and authorized tribes are required to develop lists of impaired waters. Impairment is defined as failure to meet water quality standards as per a water body's state-defined designated use. The law requires that these jurisdictions establish priority rankings for waters on the section 303(d) list (non-attainment list) and evaluate the need to develop Total Maximum Daily Loads (TMDL) for these waters. A TMDL describes the maximum amount of a pollutant that a body of water can receive and still meet its water quality standards. The TCEQ 2010 draft biannual report to Congress lists the following streams within (red) or draining into (black) BITH as non-attainment (Table 1) (TCEQ 2010a). "Category" denotes administrative status; 5b means that a review of water quality standards will be conducted before a TMDL is scheduled, where 5c indicates additional data will be collected before a TMDL is scheduled. "First listed" refers to the first year in which the water body was identified on the 303(d) list as having a possible water quality concern.

Table 1. 2010 draft section 303(d) listing for water bodies in and around BITH.

<i>Stream</i>	Segment	Problem	Category	First Listed
Neches River	Between Saltwater Barrier and B.A. Steinhagen Reservoir and all tributaries	Mercury (Hg) in fish	5c	2010
Pine Island Bayou	Mouth to mile 12.1	Low dissolved oxygen (DO)	5b	2000
Pine Island Bayou	Mile 12.1 to mile 35.4	Low DO bacteria	5b	2000
Little Pine Island Bayou	Lower 25 miles	Low DO bacteria	5b 5c	2000 2006
Village Creek	FM 418 to Lake Kimball	Low pH	5b	2000
Village Creek	Entire stream	Hg in fish	5c	2010
Beech Creek	Lower 20 miles	Bacteria	5c	2006
Big Sandy Creek	Lower 30 miles downstream from US 190	Bacteria	5c	2000
Turkey Creek	Lower 25 miles	Bacteria	5c	2000
Cypress Creek	Entire water body	Low DO bacteria	5b 5c	2000 2006
Mill Creek	Entire water body	Low DO	5c	2006
Boggy Creek	Entire creek	Low DO	5b	2000
Willow Creek	Entire Creek	Low DO	5b	2000
Lake Kimball	Entire lake	Hg in fish	5c	2000

In March 2010 the Texas Department of State Health Services (DSHS) posted a fish-consumption advisory for the Neches River and all contiguous waters in Angelina, Hardin, Houston, Jasper, Polk, Trinity, and Tyler counties. This advisory, which includes all Preserve waters except those downstream of the Saltwater Barrier, is based on elevated levels of mercury in tissue samples of flathead catfish, freshwater drum, gar, largemouth bass, spotted bass and white bass. The state identified non-point source pollution from an atmospheric source as the likely source of mercury contamination (TCEQ 2010b).

Recreational Use and Aquatic Life

Within the Preserve, human use generally consists of primary and secondary recreational contact on the Neches and its tributaries. The river is the focus of hundreds of visitors each summer weekend engaged in fishing, boating, wading, and swimming. Recreationalists are provided river access at numerous points along the river, including the Saltwater Barrier (operated by the LNVA), confluence of the Neches River and Pine Island Bayou, Lakeview Sandbar, and Evadale.

Boating and fishing activities on the tributaries are largely limited (due to stream size) to the lower portions of the watersheds. Boat ramp locations include the Town Bluff Dam, U.S. Highway 96 (US 96) near Evadale, the US 69 bridge at Pine Island Bayou, and at the confluence of the Neches River and Pine Island Bayou. Canoe launching is provided on Village Creek at the US 96 bridge and in the Village Creek State Park. Fishing access is gained at Franklin Lake, the pond at the highway beginning of the Woodland Trail, bridges along the southern edge of the Big Sandy Unit, and the bridge at the end of Teel House Road in the Lance Rosier Unit.

While there are no federally listed aquatic species at the Preserve, several are listed as threatened by the State of Texas. Threatened fish include blue sucker (*Cycleptus elongatus*), bluehead shiner (*Pteronotropis hubbsi*), creek chubsucker (*Erimyzon oblongus*), and paddlefish (*Polyodon spathula*). The alligator snapping turtle (*Macrochelys temminckii*) is also listed as threatened by the state. Five species of state-listed mussels are listed as possibly occurring in the area. These species include the Louisiana pigtoe (*Pleurobema riddellii*), sandbank pocketbook (*Lampsilis satura*), southern hickory nut (*Obovaria jacksoniana*), Texas heelsplitter (*Potamilus amphichaenus*), and Texas pigtoe (*Fusconaia askewi*).

The Preserve has been a favorite sampling location of aquatic biologists for decades and numerous biological inventories have been conducted. Parks and Cory (1954) conducted a general biological survey that assessed mammals, birds, reptiles, amphibians, fish, spiders, insects, crayfish, and shellfish in the Big Thicket area. They concluded that this vast area of unique biotic assemblages must be protected and such an effort would require Federal assistance. Parks and Cory (1954) also noted effects of land use change as timber was cut and land was put into agrarian uses.

McCullough (1974) compiled exiting surveys of invertebrate fauna of the proposed preserve. He reported that 51 species of mollusca had been found, which included 14 species of Helicidae (snails) and 37 species of Unionidae (mussels).

Suttkus and Clemmer (1979) were contracted by the NPS to complete an inventory of the fishes of the Preserve. They made 15 survey trips to the Preserve in the late 1970s and collected 98,871 specimens (an additional 53,128 specimens were used from previous collections) from 79 sites.

They found a total of 85 species of fish from the Neches River watershed within the Preserve area. They compared their results to that of a 1971 survey and noted the decline of three species, silvery minnow (*Hybognathus nuchalis*), speckled chub (*Hybopsis aestivalis*), and the suckermouth minnow (*Phenacobius mirabilis*). They noted habitat loss and intermittent flow (caused by impoundments) to be the cause of population declines.

Howells (1997) reported on the status of freshwater mussels of the greater Big Thicket region. He found that the Neches River immediately downstream from the Town Bluff Dam (B.A. Steinhagen Reservoir) supports one of the most abundant and diverse unionid assemblages remaining in Texas. However, he also reported that downstream of Silsbee/Evadale, few living mussels remain. While eight species were found in Village Creek, few mussels were found in the historically polluted Pine Island Bayou.

Moring (2003) provides an excellent baseline summary of community structures and stream habitat of mussels, benthic macroinvertebrates, and fish of the Preserve. He concludes that fish communities were dominated by minnows (Cyprinidae) and sunfishes (Centrarchidae). Reaches with smaller channel sizes had higher species richness than larger reaches of the Neches River and Pine Island Bayou. Riffle beetles (Elmidae) and midges (Chironomidae) dominated aquatic insects. The EPT index (Ephemeroptera-Plecoptera-Trichoptera) was the lowest in Little Pine Island Bayou, a stream with a long history of water quality issues. Moring (2003) also concludes that the percentage of urban land use was negatively correlated to reach structure index, which indicates less stable habitat for aquatic biota as urban land use increases.

Existing Water Quality Information

Just as the Preserve has been the focus of numerous biological inventories, several water quality investigations have been completed. In a series of NPS-funded annual reports, Lamar University's Dr. Richard Harrel et al. (Harrel 1977, Harrel and Bass 1979, Harrel and Commander 1980, Harrel and Darville 1978, and Harrel and Newberry 1981) describe the water quality of several streams in the newly established Preserve. Water quality issues documented in these studies, such as elevated specific conductance in Little Pine Island Bayou and Menard Creek caused by the improper disposal of oilfield brine, have been mitigated. Other violations of water quality standards, including depressed dissolved oxygen in Big Sandy Creek and Little Pine Island Bayou near Saratoga, remain. Dr. Harrel's dataset has been entered into the NPS water quality depository (NPStoret) and uploaded into the national water quality database (STORET).

The USGS published a summary of statistical and trend analysis of water quality data collected near the Preserve in 1985 (Wells and Bourdon 1985). Limited to three sites — the Neches River at Evadale, Village Creek at Farm to Market Road 418 (FM 418), and Pine Island Bayou upstream from its confluence with Little Pine Island Bayou — this report also shows depressed dissolved oxygen in the tributaries to the Neches River.

The NPS's 1995 *Baseline Water Quality Data Inventory and Analysis, Big Thicket National Preserve*, summarizes all STORET data in and around the Preserve. This report notes over 40,000 observations at 41 stations (17 within the Preserve), but only seven stations with a long-term record (one within the Preserve). The most common water quality concerns were depressed dissolved oxygen and low pH.

The LNVA has sampled 31 stations outside of the Preserve since 1997 as part of routine monitoring under the Texas Clean Rivers Program (CRP). Thirteen sites are of particular interest to the NPS as they are immediately upstream of the Preserve. Monitoring occurs on a quarterly basis and includes a variety of field and laboratory measures. Diurnal continuous recording of field parameters also occurs on an annual site rotation.

Sampling Sites

During quarterly sampling, water quality sampling sites shown on Figure 2 (and described on the following pages) were visited. An additional Quality Control (QC) sample was collected from each site. Quarterly sampling commenced in October 2007 and is expected to continue in the future. Placement of GULN sites (yellow highlighting) were co-located with LNVA sites (pink). Both GULN and LNVA sites are monitored under the same schedule, parameters, and protocols.

As shown on Figure 2, sites underlined and depicted with irregular borders are sampled under the GULN program through a contract with the LNVA. Sites with rectangular outlines are sampled by the LNVA under the TCEQ Clean Rivers Program. Colors correspond to the following graphs and appendix.

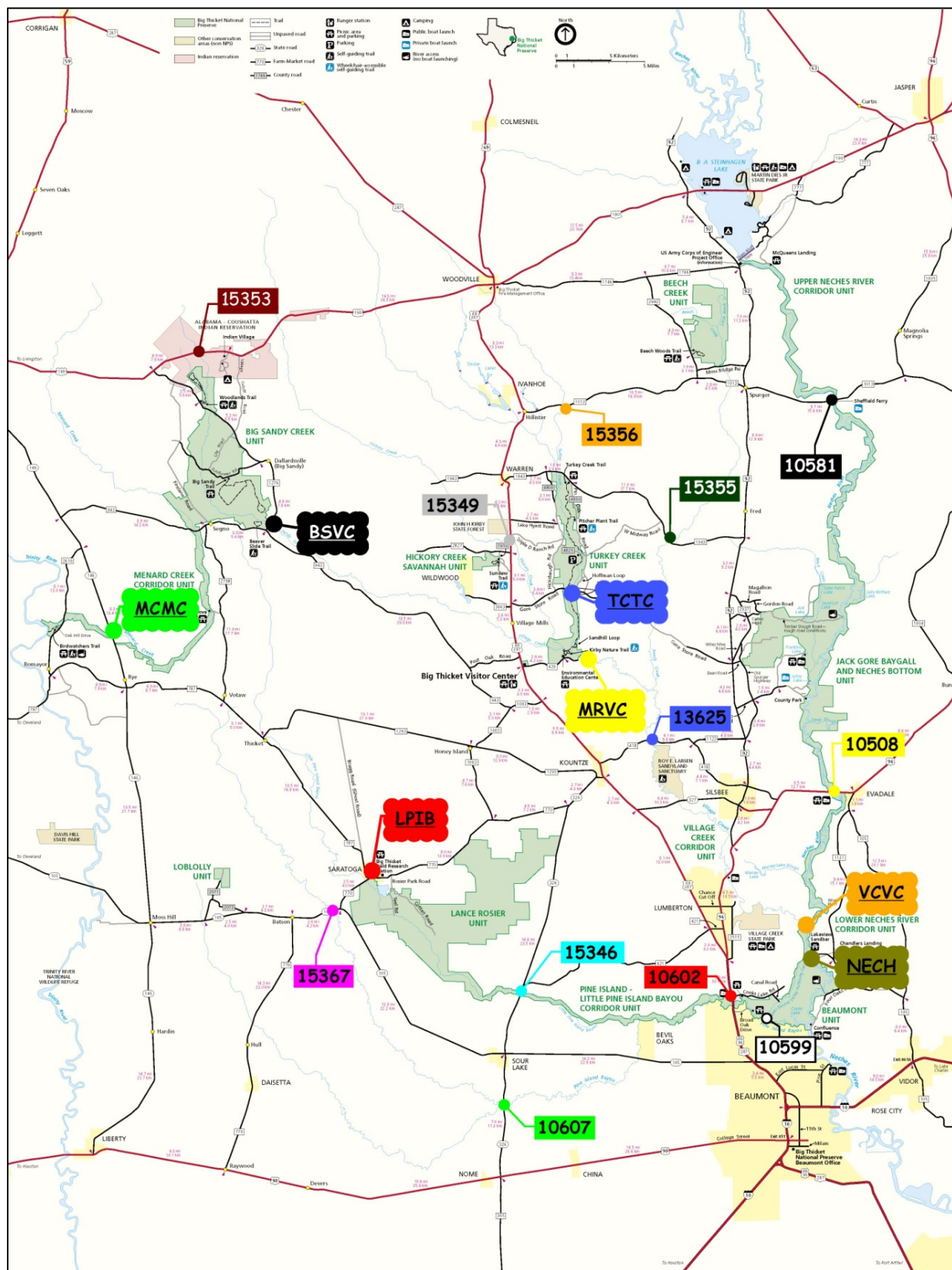


Figure 2. Map of water quality sampling sites at BITH.

Menard Creek (MCMC): Menard Creek is the only stream in the Preserve that does not contribute flow to the Neches, but instead flows into the Trinity River. It is sampled at the crossing of Texas State Highway 146 (SH 146) (Figure 3). The NPS controls a narrow corridor of the lower half of this stream. The upper portion of the Menard Creek Corridor Unit connects to the Big Sandy Creek Unit. Access to the sampling site is gained via unpaved roadway adjacent to the northwestern approach to the SH 146 bridge over Menard Creek. This station is co-located with the USGS (08066300) real-time monitoring station (stage and discharge).



Figure 3. The Menard Creek site, facing upstream. Photograph by Joe Meiman, April 12, 2007. USGS reported mean daily flow of 83 cfs. The 12-year mean daily flow is approximately 70 cfs for this date. Discharge was reported at 19 cfs at the time of the photograph.

Big Sandy Creek (BSVC): This stream, which changes names to Village Creek downstream of this point, is sampled at its crossing under the FM 1276 bridge, at the downstream end of the Big Sandy Creek Unit (Figure 4). This site represents a headwater site within the Village Creek watershed. Two additional sites are sampled at the approximate mid- and end-points of Village Creek. Upstream of the Big Sandy Creek is the Alabama-Coushatta Indian Reservation (location of a TCEQ CRP sampling site). Access is gained from the approach to the FM 1276 bridge.



Figure 4. Big Sandy Creek from the FM 1276 bridge, facing downstream. Photograph by Joe Meiman, August 22, 2006. An oil pipeline crosses the stream in foreground and is visible during low flows. A pole-mounted electrical transformer was found in the creek during this visit.

Village Creek at McNeely Road Bridge (MRVC): Near its midpoint, Village Creek is sampled at the McNeely Road Bridge a few kilometers east of the BITH Visitor Center (Figure 5). This site is downstream of the confluence of Hickory and Turkey creeks, the former a significant tributary to Village Creek but without much federally managed land. This is a popular recreational site for fishing, swimming, and canoeing.



Figure 5. Village Creek at McNeely Road Bridge, facing upstream. Photograph by Joe Meiman, May 19, 2010.

Turkey Creek (TCTC): Turkey Creek, another significant tributary to Village Creek, is sampled at the Gore Store Road Bridge (Figure 6). Unlike the adjacent Hickory Creek, the Preserve manages a considerable part of the lower portion of this watershed, the Turkey Creek Unit. The headwaters of this basin are privately owned and contain several small reservoirs near Ivanhoe.

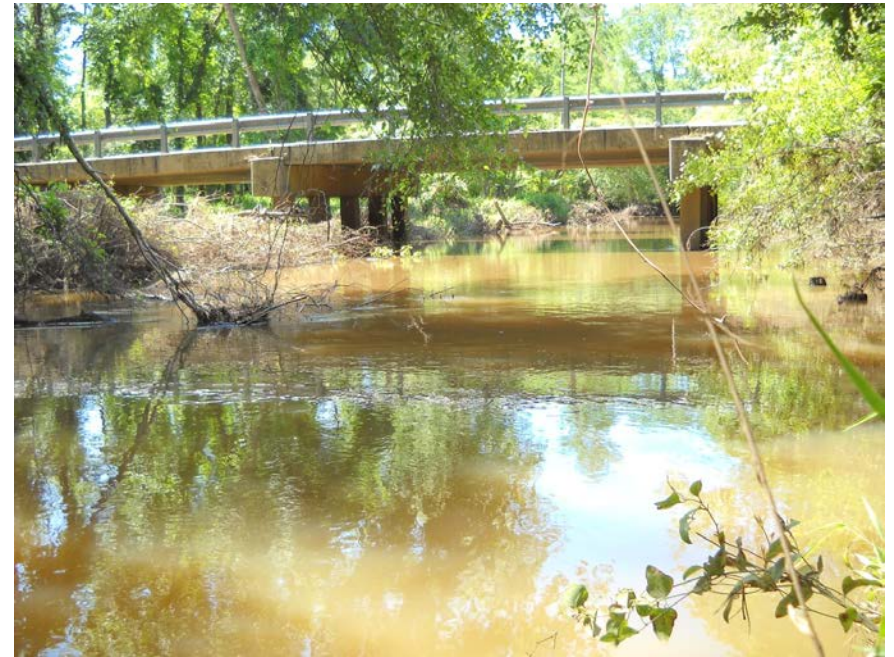


Figure 6. Turkey Creek at Gore Store Road Bridge, facing downstream. Photograph by Joe Meiman, May 18, 2009. Flow is above normal due to recent rains.

Little Pine Island Bayou (LPIB): Little Pine Island Bayou is a wide, low-gradient stream entering the Preserve at the upstream end of the Lance Rosier Unit (Figure 7). The NPS does not own any of the watershed upstream of this site. Little Pine Island Bayou is sampled at the FM 770 bridge as it flows into the Lance Rosier Unit of the Preserve. Flow typically diminishes to a trickle during the drier summer months with isolated pools left during drought.



Figure 7. Little Pine Island Bayou, facing upstream during normal flow conditions.
Photograph by Joe Meiman, May 18, 2009.

Village Creek at Neches River (VCVC): This site represents the third and most-downstream sampling location along Village Creek (Figure 8). At this point, Village Creek has grown from the shallow headwater streams of Big Sandy, Hickory, Turkey, and Beech creeks to a navigable waterway. The site is accessed by boat via the Neches River.



Figure 8. Mouth of Village Creek during above-normal flow.
Photograph by Joe Meiman, August 23, 2006. The turbid waters (right) of the Neches River mix with the tannin-stained waters of Village Creek (left).

Neches River at Lakeview (NECH): This location has been included in the routine LNVA sampling effort since 1997 (LNVA site 15353). This site is an integrator of the Neches River as related to the Preserve, with the exception of Pine Island Bayou, which enters the Neches River just above the Saltwater Barrier (Figure 9). The GULN program does not monitor this site.



Figure 9. Neches River at Lakeview, facing downstream.
Photograph by Joe Meiman, August 23, 2006. This section of the river, and Lakeview in particular, is heavily used for full-contact recreation during warmer months.

Stream Designated Uses and Water Quality Standards

Pursuant to the Clean Water Act, states must classify their waters into specific categories, or designated uses. A designated use reflects the highest use or activity for that segment (i.e., drinking water supply, recreation, or fish and wildlife use) (Table 2). The U.S. Environmental Protection Agency (USEPA), in addition to mandating these rankings, directs the states to develop water quality criteria that support each designated use. Not all BITH waters have site-specific water quality criteria and designated uses. State law states that unclassified waters are designated for the specific uses that *are attainable or characteristic of those waters* (italics by author). Water quality trends can be evaluated within the parks, states, regions, or watersheds by comparing them to established water quality criteria. Table 3 includes all routine monitoring parameters measured in the GULN and CRP programs. As shown, the state does not have criteria for some of these parameters.

For more information on Texas water quality standards, please see Texas Administrative Code Chapter 307: Texas Surface Water Quality Standards §§ 307.1–307.10

Table 2. Designated stream uses by site at BITH.

Site	Site Name	State	Designated Use ²
MCMC	Menard Creek	TX	SCR, H
BSVC	Big Sandy Creek	TX	SCR, H
MRVC	Village Creek, McNeely Road ¹	TX	PCR, H, PS
TCTC	Turkey Creek ¹	TX	SCR, H
LPIB	Little Pine Island Bayou	TX	SCR, H
VCVC	Village Creek at Neches River ¹	TX	PCR, H, PS
NECH*	Neches River at Lakeview ¹	TX	PCR, H, PS

¹ Streams with site-specific designated uses and water quality criteria.

² PCR – Primary Contact Recreation (high likelihood of ingesting water), SCR – Secondary Contact Recreation (lower likelihood of ingesting water), H – High Aquatic Life Use, PS – Public Water Supply.

Table 3. Water quality criteria for parameters measured at BITH.
Water quality standards tied to specific stream segments are noted.

Parameter	Water Quality Criteria
Alkalinity	No state standard
Ammonia as N	No state standard
Chloride	<150 mg/l (Village Creek), <50 mg/l (Neches River)
Specific conductance	No state standard
Dissolved oxygen	>3.0 mg/l (instantaneous value), >5.0 mg/l (24-hour average) Spring season: >4.5 mg/l (instantaneous value), >5.5 mg/l (24-hour average)
<i>E. coli</i>	<394 MPN/100 ml, single sample
Flow	No state standard
Hardness, total	No state standard
Nitrate+Nitrite as N	No state standard
pH	Between 6.0 and 8.5 SU
Phosphorous, total	No state standard
Secchi depth	No state standard
Sulfate	<75 mg/l (Village Creek), <50 mg/l (Neches River)
TDS	<300 mg/l (Village Creek), <200 mg/l (Neches River)
TSS	No state standard
Water temperature	<32.2 °C (Village Creek), <32.8 °C (Neches River)
Turbidity	No state standard

Parameters for Water Quality Monitoring

The LNVA and GULN use TCEQ protocols for all field measures, including sample collection and transport. These protocols can be found in TCEQ (2003) “Surface Water Quality Monitoring Procedures, Volume 1: Physical and Chemical Monitoring Methods for Water, Sediment, and Tissue”.

Field Measures

Specific Conductance

Electrical conductance (SpC) is a measure of the capacity of water (or other media) to conduct an electrical current (the inverse of resistance). SpC is a quick and reliable estimation of the dissolved solids in the water, but there is no universal linear relation between total dissolved substances and specific conductance. A dip-cell electrode sensor was used and SpC measured in microSiemens per centimeter ($\mu\text{S}/\text{cm}$).

Dissolved Oxygen

Accurate data on concentrations of dissolved oxygen (DO) in water are essential for documenting changes to the environment caused by natural phenomena and human activities. Sources of DO in water include atmospheric reaeration and photosynthetic activities of aquatic plants. Many chemical and biological reactions depend directly or indirectly on the amount of oxygen present. DO is necessary in aquatic systems for the survival and growth of many aquatic organisms. The GULN uses an amperometric method in which DO concentration is determined with a temperature-compensating, galvanic, membrane-type sensor and measured in milligrams per liter (mg/l).

Flow

Flow, or discharge, is either directly measured using a flow meter or estimated when flows are too high to permit a safe or accurate measurement. If near a USGS gauging station (such as Menard Creek), flow is adjusted according to a USGS rating curve. Flow is measured in cubic feet per second (cfs).

pH

The pH of an aqueous solution is controlled by interrelated chemical reactions that produce or consume hydrogen ions. Water pH is a useful index of the status of equilibrium reactions in which water participates. The pH of water directly affects physiological functions of plants and animals, and is therefore an important indicator of the health of a water system. The pH is measured using the electrometric measurement method via a hydrogen ion electrode and reported in standard units (SU).

Secchi Depth

Secchi depth is a measure of water clarity, or transparency, and is calculated by lowering a circular disk with alternating black and white quadrants into the water and recording the depth at which the disk is no longer visible. Secchi depth is reported in meters.

Water Temperature

Measurements of water and air temperatures at the field site are essential. Determinations of dissolved oxygen concentrations, specific conductance, pH, rate and equilibria of chemical

reactions, biological activity, and fluid properties rely on accurate temperature measurements. Accurate water and air temperature data are essential to document thermal alterations to the environment caused by natural phenomena and human activities. Water temperature was measured in degrees Celsius (°C) using a thermistor thermometer, which is an electrical device made of a solid semiconductor with a large temperature coefficient of resistivity. An electrical signal processor (meter) converts changes in resistance to a readout calibrated in temperature units.

Laboratory Measures

The GULN uses only laboratories that are certified by the National Laboratory Accreditation Conference. As required for any data generated through the TCEQ CRP, the LNVA's accredited laboratory was used for each of the following parameters:

Alkalinity

Alkalinity is a measure of carbonate (CO_2HCO_3) and bicarbonate (CO_3^{2-}) ions in water. These ions absorb excess H^+ from the addition of acids, and thus can be thought of as an acid neutralizer. In effect, alkalinity is a measure of the water's acid neutralizing capacity. Generally, water with an alkalinity of less than 20 mg/l CaCO_3 (calcium carbonate; alkalinity is expressed as CaCO_3 even though carbonate species may be derived from other salts) has a limited ability to buffer the addition of acids and is thus susceptible to acidification. Alkalinity was measured using SM 2320-B.

Ammonia-Nitrogen

Nitrogen in its reduced form (ammonia) can be toxic to fish. Ammonia (NH_3) may exist as unionized ammonia or ionized ammonia, largely dependent on pH. At higher pH (8 SU and above), the proportion of ammonia as un-ionized ammonia increases. Elevated levels of unionized ammonia may be toxic to aquatic life. At lower (acidic) pH levels, the proportion of ammonia as un-ionized NH_3 is lower. Ammonia was measured using USEPA method 350.1 Rev. 2.0.

Chloride

Chlorides naturally occur in the environment and surface water. Chlorides are typically very low in most east Texas streams; therefore, elevated chlorides can be an indication of brine disposal or leaks from oil fields common in the area. Chloride is a very conservative ion — it readily passes through the aquatic system with little biological interference or chemical alteration. Elevated chloride levels and high SpC values (the low ion-strength waters of BITH have naturally low SpC) may detect the presence of brines. Long-term exposures to concentrations greater than 400 mg/l may affect some freshwater aquatic life. Chloride was analyzed with SM 4500-Cl-B.

Escherichia coli

Escherichia coli (*E. coli*) is a naturally occurring bacteria found in the intestines and feces of warm-blooded animals. While not generally a human pathogen (a substance that causes harm to people), some strains of *E. coli*, 0157:H7 for example, have been linked to illness in contaminated foods. As *E. coli* may be associated with pathogens, they are considered an indicator species, and thus used as a measure of water quality. *E. coli* bacteria enters a stream or river by point source (direct contribution at specific points) and non-point source (runoff over a broad area). Point sources include failing septic systems, inadequate waste water treatment facilities, and confined livestock operations. Non-point sources include surface runoff from

livestock pastures, land application of manure, and wildlife. *E. coli* was measured using SM 9223-B, a most-probable number method.

Hardness, total

Total hardness is a measure of calcium and magnesium and expressed as mg/l CaCO₃. Its value is important when determining the toxicity of heavy metals on aquatic biota. Generally, the higher the hardness, the lower the toxicity. Total hardness was determined using SM 2340B or C.

Nitrate/Nitrite as N

The most common form of nitrogen is N₂, but it is not useable by most biota. Biota primarily utilize nitrogen as nitrate (NO₃), nitrite (NO₂), or ammonia (NH₃) in freshwaters, in large part depending on the amount of dissolved oxygen. While nitrate alone is not particularly toxic to aquatic life (except in extremely high concentrations), moderate levels of nitrogen can lead to eutrophication, habitat loss, and depressed dissolved oxygen. Nitrate and nitrite were analyzed to provide a total nitrogen value using SM 4500-NO₃-E.

Phosphorous, total

Phosphorous in the form of orthophosphates is found in natural waters and, in low concentrations, is essential for aquatic life. While not toxic to humans except in extremely high concentrations, excess phosphates can cause eutrophication, leading to excessive aquatic plant growth. Excessive aquatic plants can cause low DO via respiration or through decomposition after the plants die. Excessive DO depletion may cause fish kills. Phosphate was reported as total phosphorous-P by the LNVA lab using USEPA Method 365.3.

Sulfate

Sulfate is present in freshwaters from natural sources such as dissolved bedrock and decomposition of organic material. Allochthonous sulfate sources can also come from oilfield waste, which is often comingled with oil field brine. Sulfate was analyzed using USEPA Method 375.4.

Total Dissolved Solids

Total dissolved solids (TDS) represents the total dissolved ions and was estimated from specific conductance. TDS is estimated using the following equation: TDS (mg/l) = SpC (μS/cm) x 0.65 and expressed as mg/l.

Total Suspended Solids

Total suspended solids (TSS) is a direct gravimetric measurement of particles normally suspended in water and expressed as mg/l. In general terms, TSS contributes to turbidity, with higher TSS values sometimes representing higher turbidity values. TSS was measured using SM 2540D.

Turbidity

Turbidity measures the scattering effect that suspended solids have on light, with higher amounts of suspended solids resulting in greater turbidity measurements. Primary contributors to turbidity include clay, silt, finely divided organic and inorganic matter, soluble colored organic compounds, plankton, and microscopic organisms. The measurement cannot be correlated directly to milligrams per liter of TSS. Measurements were made in the laboratory with a nephelometer using SM 2130-B and reported in nephelometric turbidity units.

Water Quality Status

Water quality has been sampled through a combination of quarterly sampling of the above parameters and 4-week-long deployments of multiparameter datasondes that record water temperature, DO, SpC, pH, turbidity, and depth at 15-minute intervals per TCEQ (2003). While these data have not spanned the entire flow continuum (sampling has not been conducted during flood flow), a general picture of water quality status is beginning to emerge. In addition to quarterly sampling, data were collected upon deployment and retrieval of datasondes. It should be noted that in addition to basic field observations, weather, flow, air temperature, and precipitation during the week preceding sampling were also recorded. These data are important in interpreting water quality results.

The dataset for the Preserve is rich with a number of short-term investigations spread through the Lower Neches River Valley as well as populated with long-term records at a few key locations. This section focuses on data collected through the GULN Water Quality Monitoring Program (plus the LNVA site within the Preserve on the Neches River at Lakeview) and supplemented with important data from other sources for specific discussion.

TCEQ CRP routine monitoring data for 12 sites, monitored from 1997 through the present, are presented in the appendix. These sites are located either in or immediately upstream from the Preserve. As the Preserve has acquired new lands, some sites that were once outside the boundary are now within it. These data represent an additional 10 years preceding the GULN program and can provide valuable insight to the water quality within the Preserve as well as help interpret the recent results.

Quarterly Sample Results

The LNVA is contracted to collect and analyze water quality samples at BITH as part of their quarterly routine CRP monitoring. Sampling for the six sites at BITH is not synoptic as they are sampled as part of the entire Lower Neches River Valley station network. Notice that there are “missing” data points on some of the graphs presented below. These missing points are not included in final results as, although sampled and analyzed, their concentrations were below method detection limits. Table 4 is a brief statistical summary of quarterly results.

Sample populations (n) combined from all seven sites are typically below 100. With a small dataset, timing of sampling can greatly distort the water quality picture. Because of the small dataset, it is possible that over a period of 12 site visits, nearly every sample was taken at base flow, and thus water quality was reflective of those conditions. Other sampling events occurred during higher flows. Neither one may be a true representation of overall water quality. It will take several years for a clear assessment of water quality trends to be determined.

Alkalinity

All streams monitored at Big Thicket National Preserve have moderate to low levels of alkalinity, thus having a limited ability to buffer acids (Figure 10). Preserve streams are the recipients of several acids, including humic and fulvic acids of leaf decay, and carbonic, sulfuric, and nitric atmospheric precipitation (the latter two largely anthropogenic). The pH of BITH streams is predictably low. Low alkalinity is a natural condition and reflects the lack of carbonate strata available for dissolution in the watershed. There are no state numerical criteria for alkalinity.

Table 4. Statistical summary of BITH quarterly sample results, September 2007 through August 2010.

Parameter	Units	Count	Samples below detectable limits	Min	Max	Mean	Median	Std Dev
Alkalinity	mg/l CaCO ₃	79	10	10	31	19.96	16	4.67
Ammonia-nitrogen	mg/l as N	77	59	0.10	0.31	0.14	0.10	0.08
Chloride	mg/l	79	0	5.5	57.0	13.6	10.7	7.9
DO	mg/l	108	0	0.54	12.7	6.91	7.19	2.8
<i>E. coli</i>	MPN/100 ml	79	0	2	2,419	197	50	529
NO ₃ +NO ₂ -nitrogen	mg/l as N	78	24	0.05	0.33	0.01	0.08	0.06
pH	SU	108	0	5.05	8.1	6.55	6.60	0.64
Secchi	M	79	2	0.17	1.2	0.58	0.57	0.26
SpC	μS/cm	108	0	49.5	234	91	82.5	33
Sulfate	mg/l	79	68	8.6	25.7	17.9	19.4	5.2
TDS	mg/l	79	0	32	150	62	55	23
Discharge	cfs	70	7	0	2,493	257	95	485
Hardness	mg/l CaCO ₃	79	0	14	52	24	22	7
Total phosphorus	mg/l	83	51	0.06	0.27	0.09	0.09	0.04
TSS	mg/l	79	0	4	80	12	9	12
Turbidity	NTU	96	0	6.9	237	21	17	23
Temp	°C	108	0	5.6	31.5	21.1	22.3	6.2

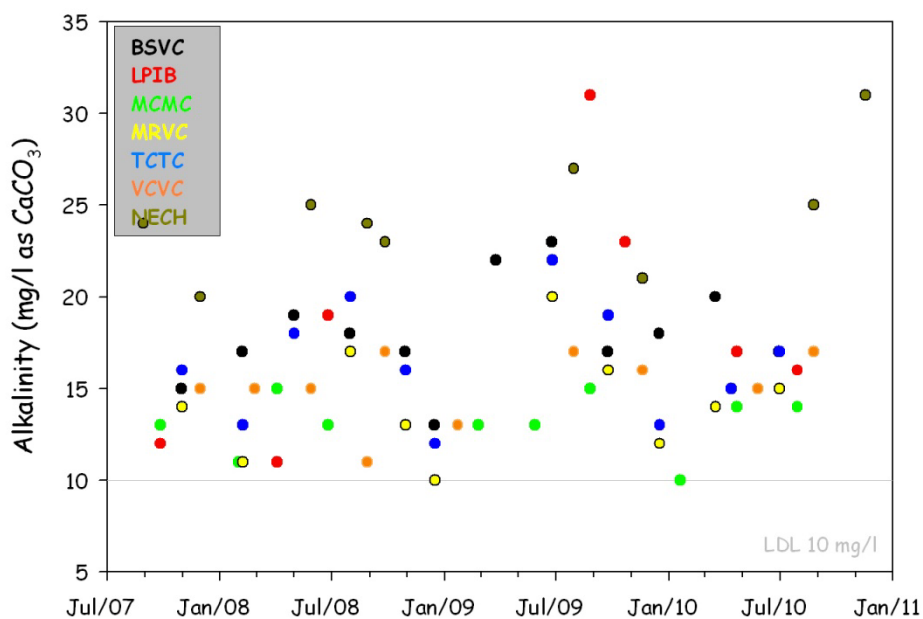


Figure 10. Alkalinity by station at BITH (n = 69).

Ammonia

As BITH waters are typically acidic, ammonia likely exists in its ionized form. The USEPA is currently revising ammonia standards and there are no state numerical criteria for ammonia. However, Texas has established a “screening level” for ammonia (as nitrogen) at 0.33 mg/l. On three occasions ammonia levels at Little Pine Island Bayou has approached this value (other sites monitored through the CRP have seen exceedences of the screening limit; see appendix).

The USEPA (2009) has focused the criteria on freshwaters with mussels and early life stages of fish with a pH of 8 SU and above — targeting the toxic un-ionized $\text{NH}_3\text{-N}$ form. Under these standards, acute ammonia limits are 2.9 mg/l at a pH of 8.0 and temperature of 25 °C with a chronic exposure limit of 0.26 mg/l, also at a pH of 8.0 and temperature of 25 °C. As will be shown later, only one pH sample thus far has exceeded 8 SU: BSVC, 8.10 SU (10-30-2007) (see Figure 19). Of all 12 ammonia samples taken at Big Sandy, only one has been as high as the 0.10 mg/l lower detection limit (Figure 11). Little Pine Island Bayou is the only site that commonly exceeds the detection limit (exceeding 0.26 mg/l on three occasions), while pH remained below 8 SU. These higher levels are associated with low flow of the summer months.

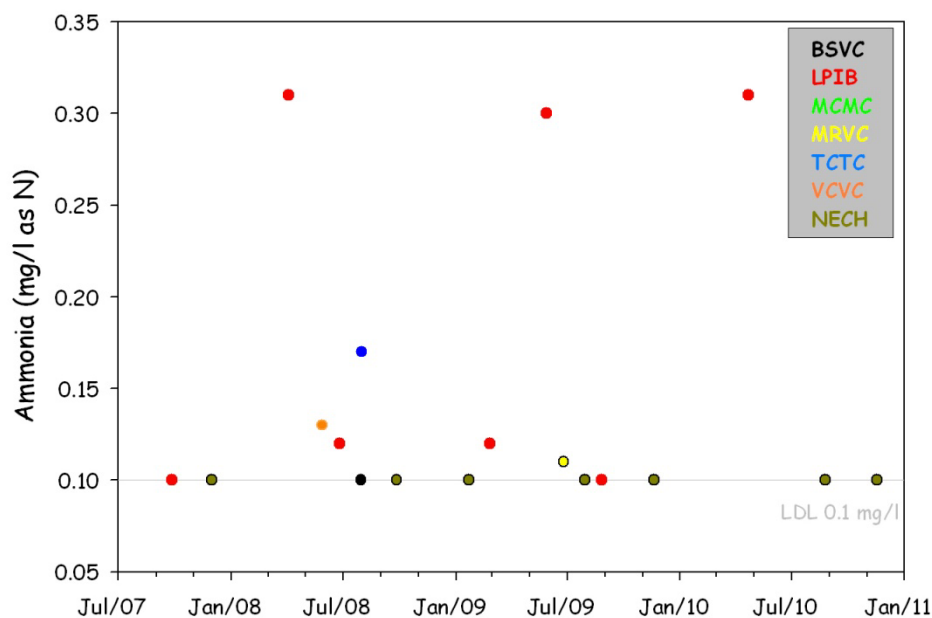


Figure 11. Ammonia-N by station at BITH (n = 18).

Chloride

Chloride, a fairly conservative ion in that it is not readily complexed or up taken through biological processes while in solution, enters the streams of the Preserve in very low concentrations in precipitation or in very high concentrations in oil field brines and saltwater intrusion. With the exception of the recently acquired Beaumont Unit, which is downstream of the Saltwater Barrier, BITH waters typically have low (<30 mg/l) chloride concentrations (Figure 12). These concentrations are below the chloride criterion of 50 mg/l for the Neches River.

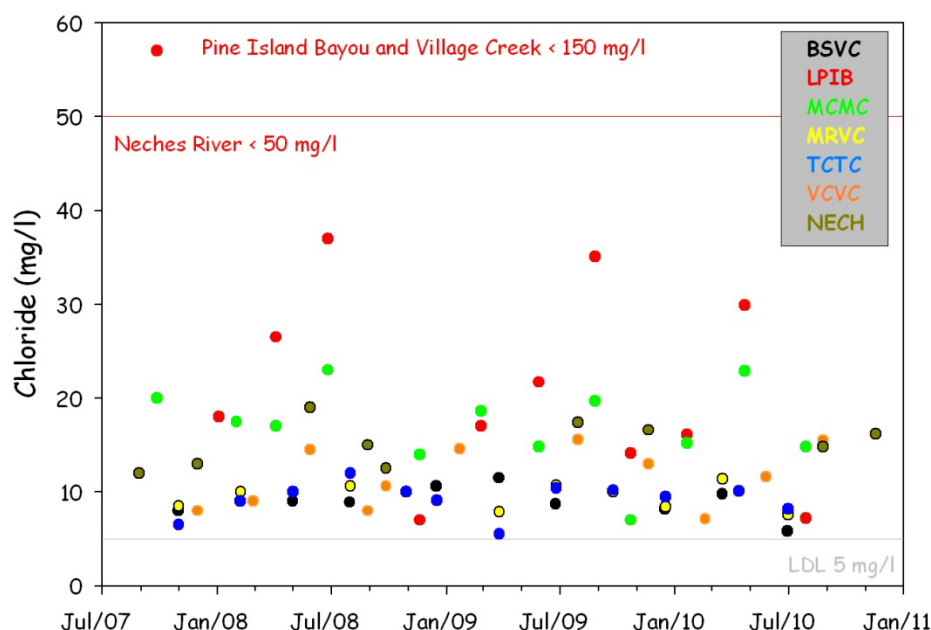


Figure 12. Chloride by station at BITH (n = 79).

Little Pine Island Bayou has a documented history of high chloride, as found by Harrel et al. (Harrel 1977, Harrel and Bass 1979, Harrel and Commander 1980, Harrel and Darville 1978, and Harrel and Newberry 1981) during water quality surveys in the late 1970s and early 1980s (Figure 13). Elevated chloride levels were found along Little Pine Island Bayou throughout the Lance Rosier Unit and were attributed to seepage of brine from the Saratoga Oil Field (Harrel 1977). While dwarfed by the exceptionally high concentrations in Little Pine Island Bayou, Harrel and Bass (1979) found elevated chloride in Menard Creek (see Figure 13). The authors hypothesized that the source is brine leakage from the Schwab Oil Field draining into Mill Creek, which enters Menard Creek 2 km (1.2 miles) upstream from the monitoring station. While chloride levels approaching those found by Harrel and Bass (1979) have not been recorded during current sampling events, residual effects of the brine in Little Pine Island Bayou and Menard Creek remain evident (see Figure 13). Chloride levels elsewhere in the Pine Island Bayou are occasionally elevated (see appendix).

Dissolved Oxygen

With the exceptions of Little Pine Island Bayou and Big Sandy Creek, DO levels are above state criteria (Figure 14). Low DO concentrations recorded are most likely due to natural processes. Depressed oxygen may be caused by a combination of natural conditions such as decaying vegetation, warm water, and low gradients. Reduced summer flows reduce physical aeration and the warmer the water the less oxygen can be dissolved. Time of day when samples were taken may also influence DO levels. However, low DO may also indicate eutrophication, the processes of a water body receiving excessive nutrients, and will be addressed through continued sampling.

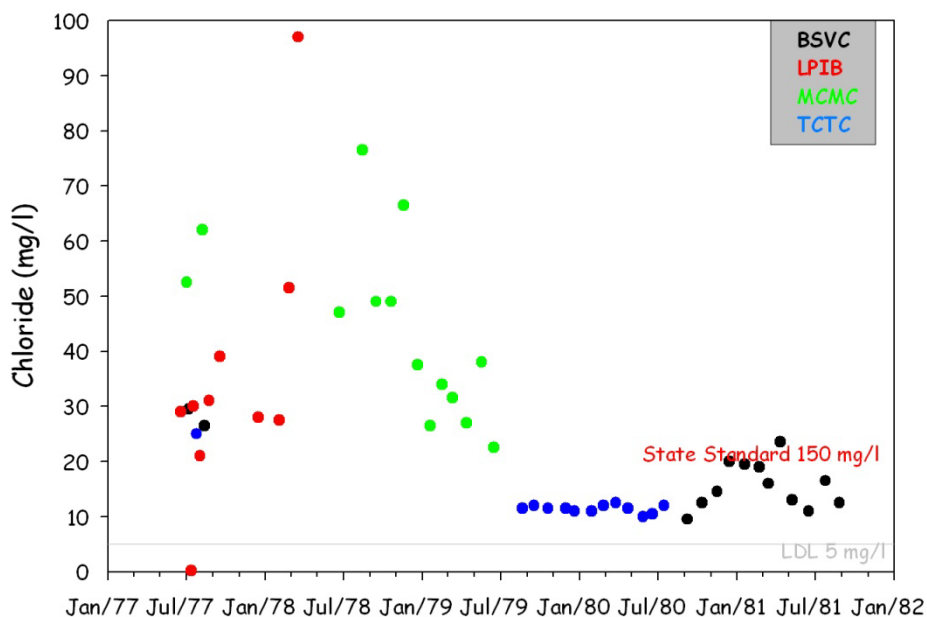


Figure 13. Chloride levels present at Big Sandy Creek, Little Pine Island Bayou, Menard Creek, and Turkey Creek stations as reported by Harrel et al. (Harrel 1977, Harrel and Bass 1979, Harrel and Commander 1980, Harrel and Darville 1978, and Harrel and Newberry 1981) (n = 55).

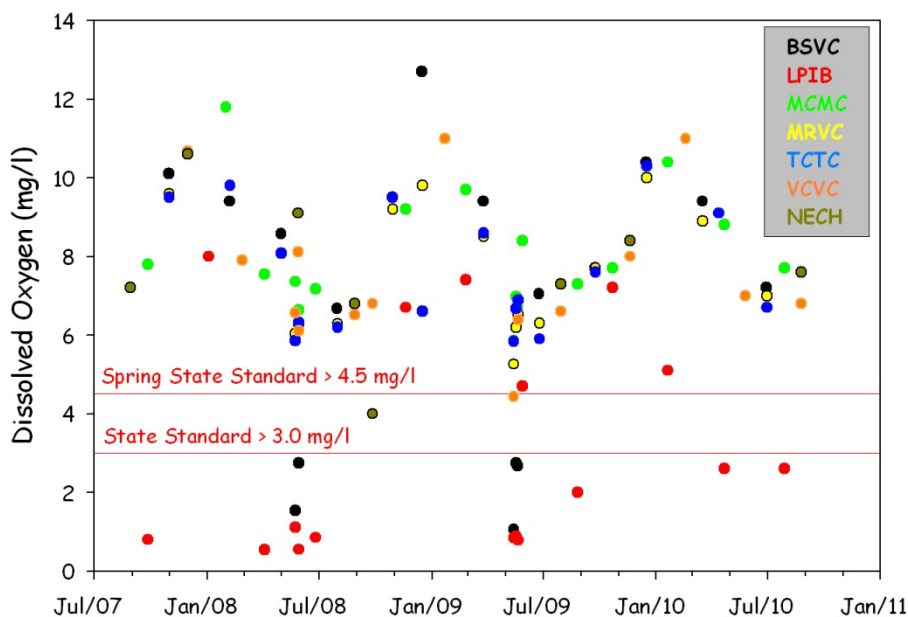


Figure 14. Dissolved oxygen concentrations by station at BITH (n = 108).

Low DO in Little Pine Island Bayou and Big Sandy Creek is not a recent phenomenon, as evident in Harrel (1977) and other earlier surveys (Figure 15). Higher DO levels are associated with higher flows during the winter and lower DO levels occur under low-flow conditions. When discharge is low, these streams stagnate and decaying vegetation increases oxygen demand. Low DO levels are common throughout the Pine Island Bayou watershed, including the tributary of Little Pine Island (see appendix).

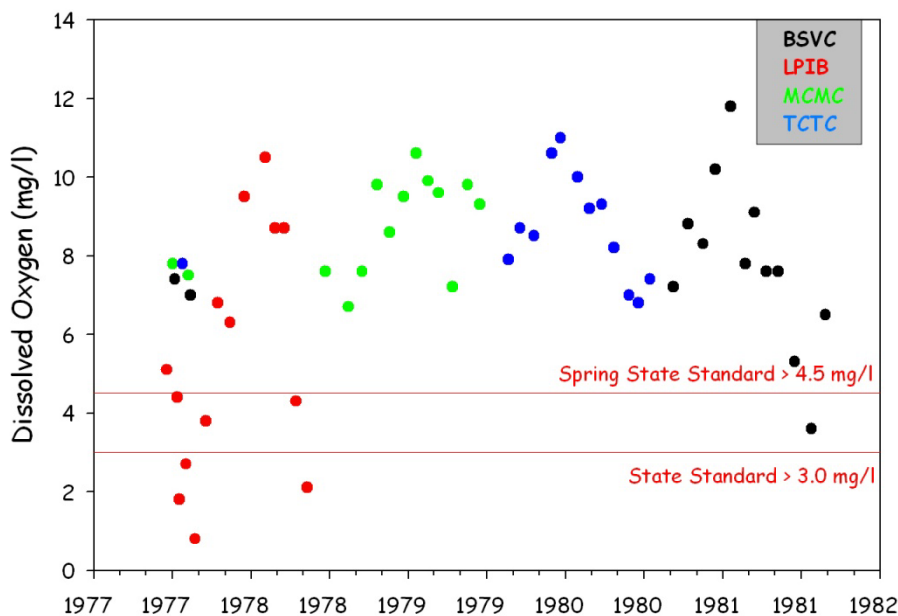


Figure 15. Dissolved oxygen concentrations at Big Sandy Creek, Little Pine Island Bayou, Menard Creek, and Turkey Creek stations as reported by Harrel et al. (Harrel 1977, Harrel and Bass 1979, Harrel and Commander 1980, Harrel and Darville 1978, and Harrel and Newberry 1981) (n = 55).

E. coli

Waters sampled at BITH were found to be generally under the state's single-sample, full recreational contact *E. coli* standard of 394 MPN/100 ml. MPN is a statistically derived bacterial count of "most-probable number" (Figure 16). *E. coli* levels at BITH generally correlate to discharge, where higher bacterial counts occur with higher discharge (Figure 17). This relationship is indicative of non-point sources of the bacteria as they are washed into the streams during rainfall events. While this dataset is still fairly small, the relationship between discharge and flow is evident. The highest flows recorded thus far in each case coincided with the highest *E. coli* levels. The exception is Little Pine Island Bayou. Three measurements were not used in the analysis because discharge could not be taken, however the highest bacteria measured coincided with flow too low to measure. It is too early to suggest that a point source is affecting bacteria in Little Pine Island Bayou thus far due to the small dataset. Occasional high *E. coli* values are found throughout the Lower Neches River Valley (see appendix).

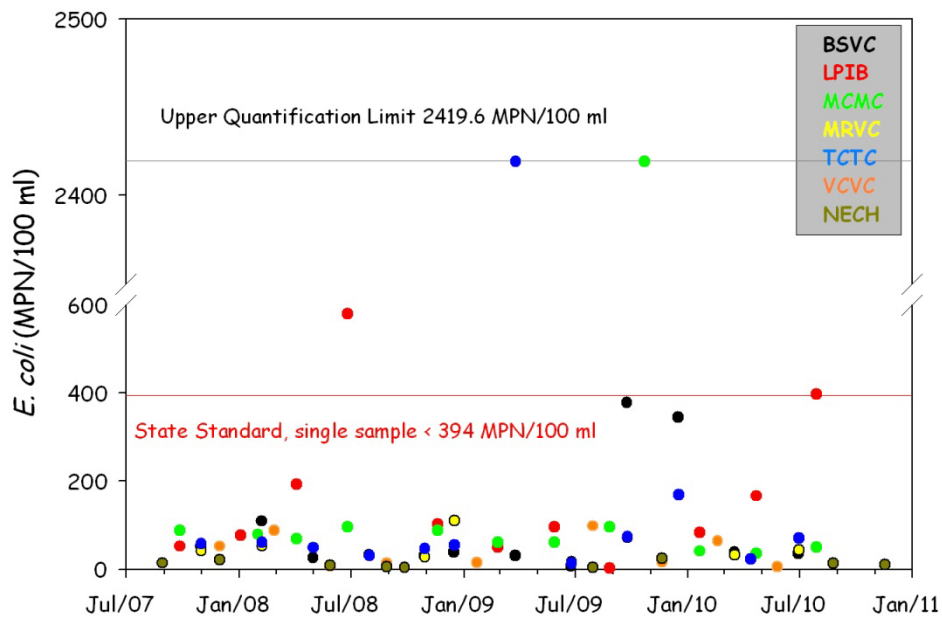


Figure 16. *E. coli* by station at BITH (n = 79).

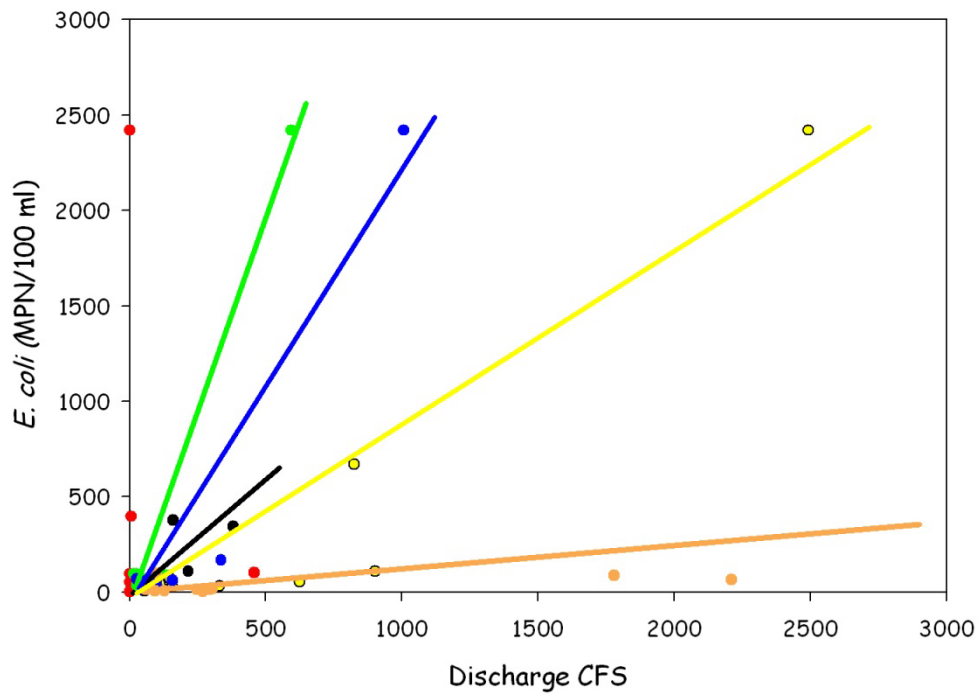


Figure 17. *E. coli* vs. discharge from 2007 to 2010 (n = 63).

Nitrate-Nitrite

Together with ammonia, nitrate-nitrite composes the nitrogen levels monitored at BITH. The principal human sources of nitrate are agricultural, either from animal waste or commercial fertilizers, or from municipal wastewater discharges. The combined nitrate-nitrite values found thus far at BITH are well below the standard expected to be implemented by the state (Figure 18). Nitrogen, either in the form of nitrate or nitrite, is a very mobile ion, in high demand, and typically quickly consumed by plants. Bacteria are an important component of the nitrogen cycle, converting atmospheric nitrogen to forms usable by plants and animals. The analytical method used by the Preserve combines nitrite and nitrate in a single value. To give a sense of scale, if nitrate is assumed to be the dominant form of nitrogen, the state screening level for nitrate is 1.95 mg/l, well above the highest combined nitrite-nitrate found in BITH.

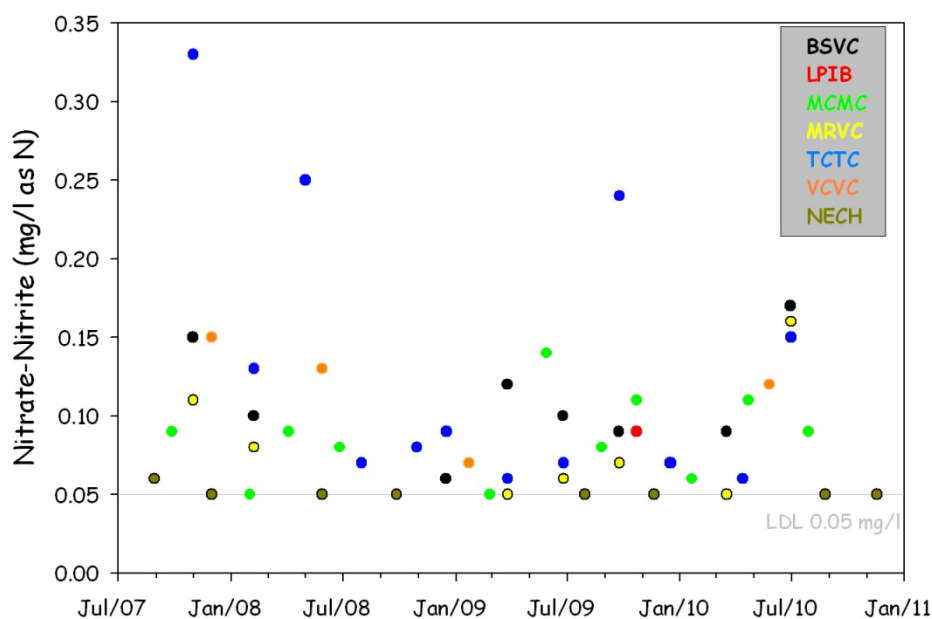


Figure 18. Nitrate-nitrite levels by station at BITH (n = 54).

pH

pH levels at BITH are naturally low (Figure 19). The low pH is fundamentally caused by the high amounts of CO₂ (carbonic acid and tannins [tannic acid]) coupled with limited buffering capacity resulting from low alkalinity (see Figure 10). Both Little Pine Island Bayou and Big Sandy Creek have pH below 6.0 SU. Harrel and Newberry (1981) also recorded that these streams dropped below this limit.

The longest continuous record of pH at sites proximal to the Preserve (Figure 20) indicates that pH fluctuates, rising and falling over the course of the 10-year record. Furthermore, the routine sampling site in Beech Creek (15355) at FM 1013 was consistently below the lower pH standard of 6.0 SU (see appendix). Low pH is also common to the Little Pine Island Bayou station (15346) at FM 326.

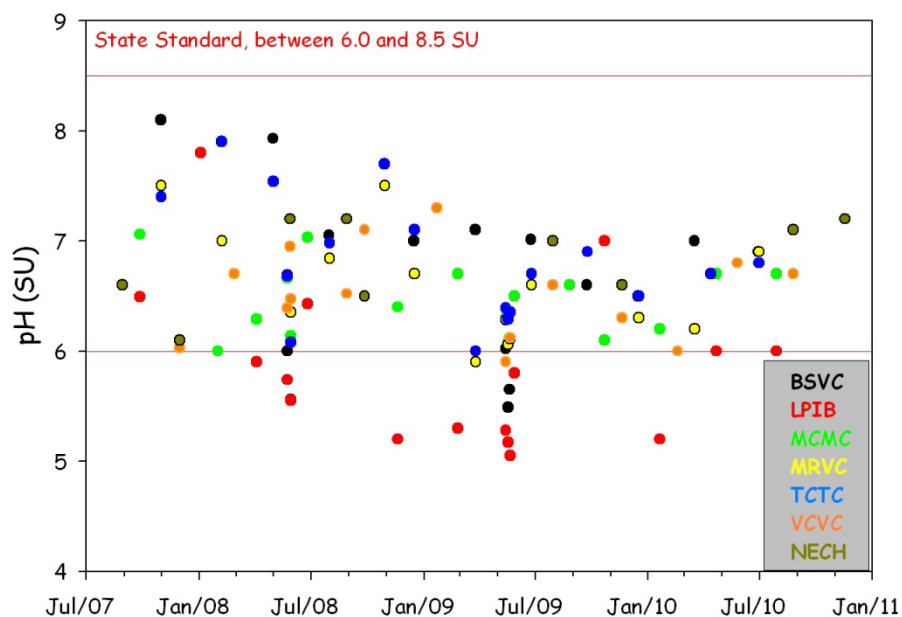


Figure 19. pH by station at BITH (n = 108).

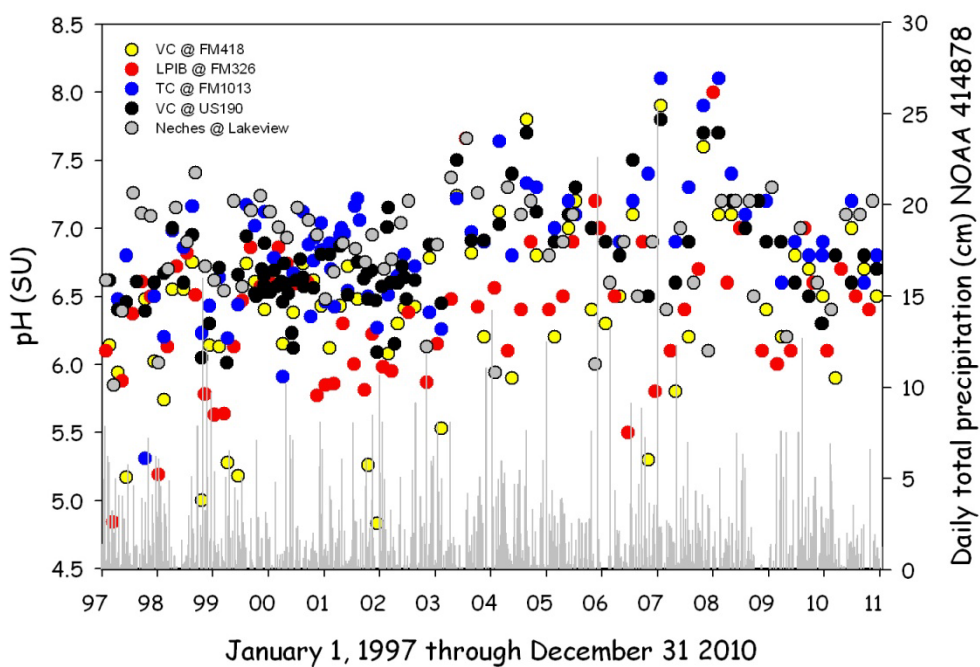


Figure 20. pH (n = 373) at select LNVA water quality sites and daily rainfall as recorded in Kountze, Texas.

Secchi

The streams of the Preserve are by characteristically laden with tannins and lignins, which produce a dark, tea-like color. In addition, suspended clay particles also reduce light transmission, resulting in relatively low water clarity. Examination of Secchi depth alone produces an incomplete portrait of the transparency within the Preserve (Figure 21). Secchi depth must be considered with turbidity and TSS for the source of turbidity to be understood.

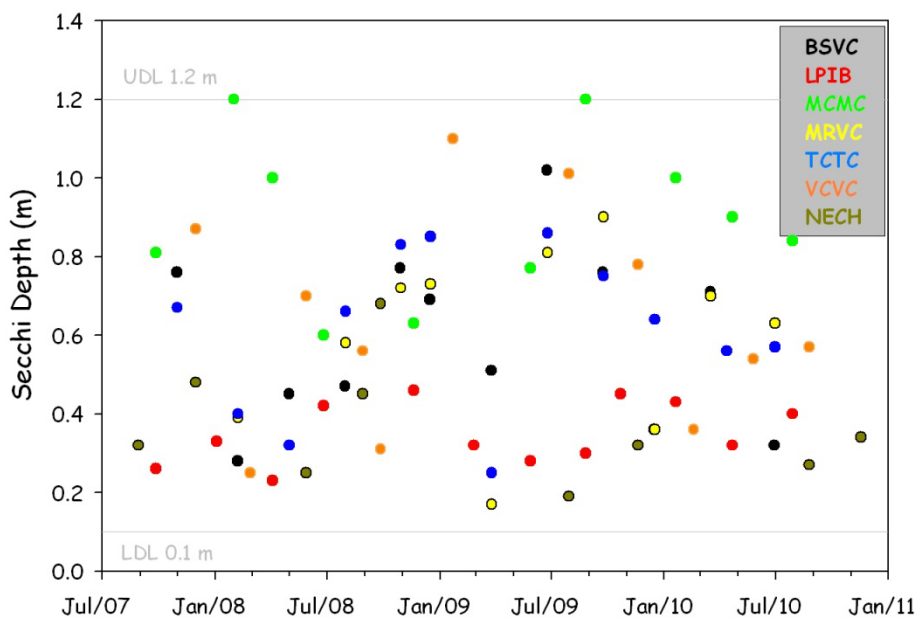


Figure 21. Secchi depth by station at BITH (n = 70).

Specific Conductance

A reliable estimation of dissolved ions, SpC is generally low and stable at the streams monitored under this program (Figure 22). This has not always been the case. As Harrel et al. (Harrel 1977, Harrel and Bass 1979, Harrel and Commander 1980, Harrel and Darville 1978, and Harrel and Newberry 1981) found during his water quality survey 30 years ago, Little Pine Island Bayou had SpC levels around 1,000 $\mu\text{S}/\text{cm}$, and once reached 3,500 $\mu\text{S}/\text{cm}$. Occasional high SpC can be found at the routine site at Pine Island Bayou (10602) at US 69/US 96 (see appendix). These high values were caused by releases of oil field brines into the streams. While Little Pine Island Bayou is typically the highest among these streams, it is an order of magnitude lower than 30 years ago when brines were released into the streams of the Preserve.

Sulfate

Of the 79 samples analyzed, only 11 were above the minimum detection limit of 5.0 mg/l (Figure 23). Two samples with detectable levels of sulfate, Little Pine Island Bayou and mouth of Village Creek, were well below state limits for these water bodies. The other nine detectable levels of sulfate were from the Neches River. While below state standards, the occurrence of sulfate in the Neches may be due to its much larger watershed with a wide variety of land uses and soil types. Sulfate greater than the 5.0 mg/l lower detection limit is rare in the smaller streams routinely sampled at the Preserve, while more common in the Neches River.

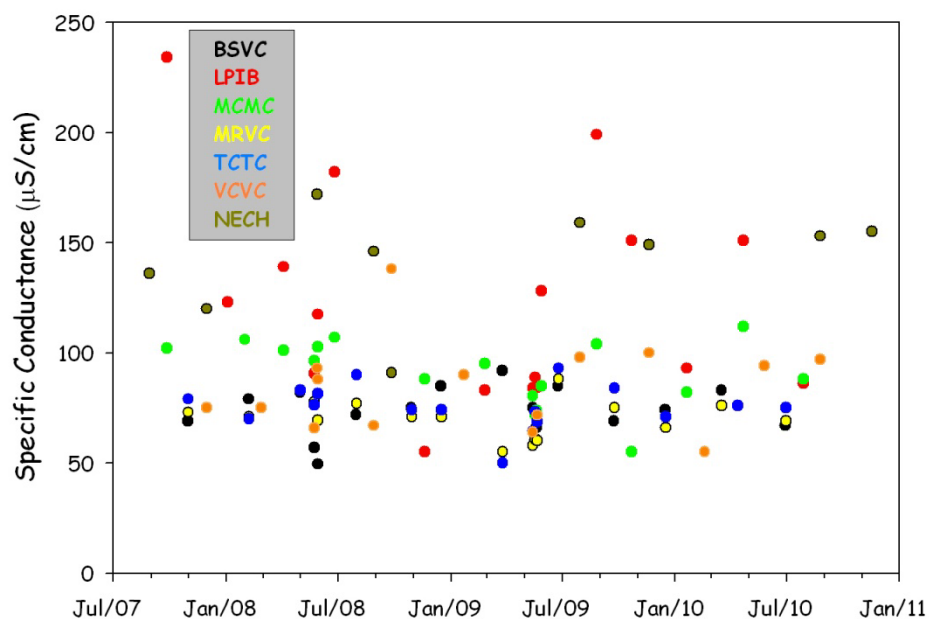


Figure 22. Specific conductance by station at BITH (n = 108).

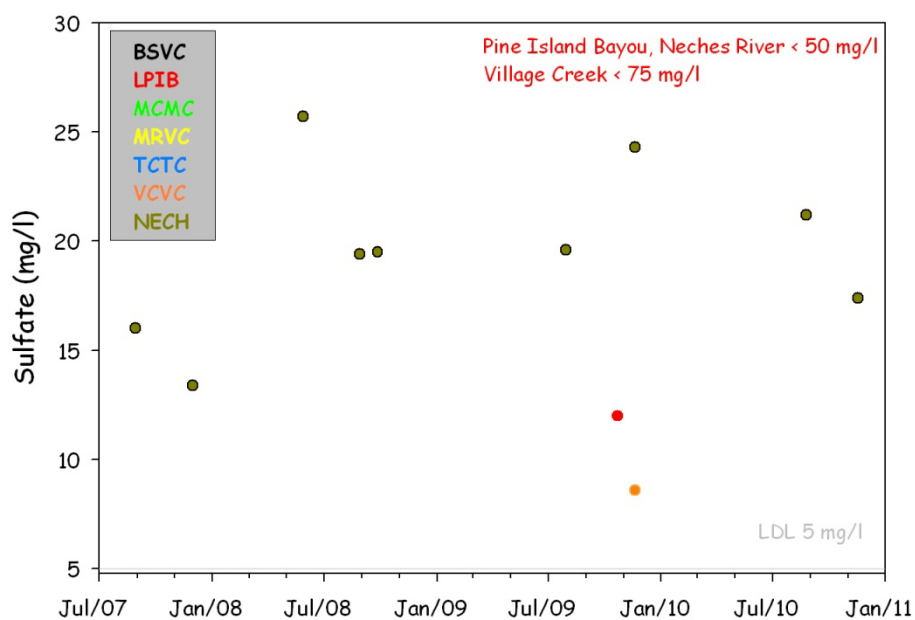


Figure 23. Sulfate by station at BITH (n = 11).

Total Dissolved Solids

Dissolved solids in the streams are reflective of the mineral content in surface and subsurface soils in the watersheds. Little Pine Island Bayou, reflective of past brine contamination, has the highest TDS of the six sampling locations, albeit below the state standard of 200 mg/l (Figure 24). Note how the TDS values mimic that of SpC.

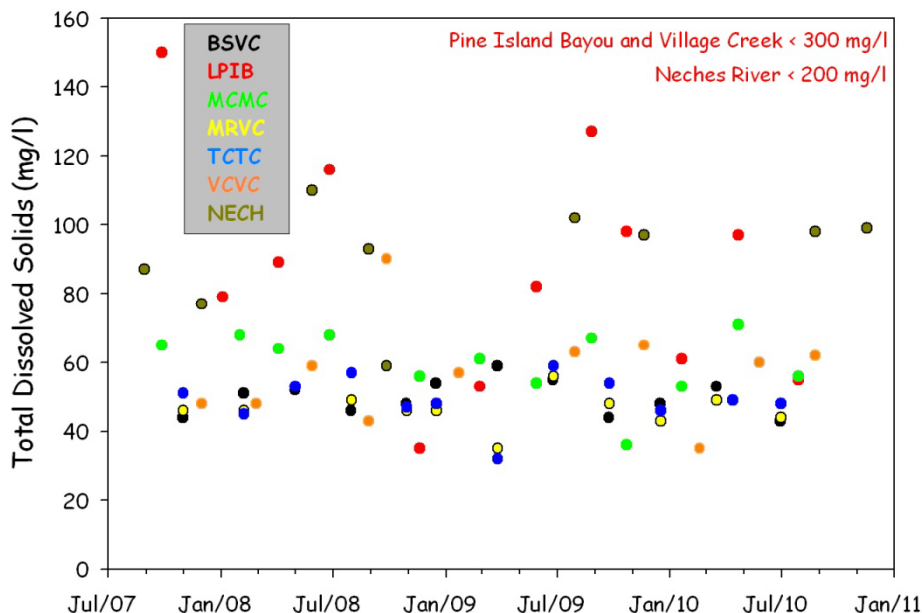


Figure 24. Total dissolved solids by station at BITH (n = 79).

Total Discharge

To examine the flow measured during sample collection it is important to note that nine of the highest flow events were not measured as the water was too high for safe or reasonable discharge determination (Figure 25). Also note that while flow might be high at one site, it might be low at another. While distribution of rainfall accounts for some of the difference, it is more of a sampling artifact as not all sites are sampled on the same day, week, or rainfall event due to the CRP sample scheduling for the Lower Neches River Valley. Recall that *E. coli* was directly linked to discharge earlier. Neches River data are not included in the graph because of the large disparity in range when compared to these smaller tributaries.

Total Hardness

Total hardness, a measure of dissolved calcium and magnesium ions, is expressed as mg/l CaCO_3 . Hardness in watersheds dominated by carbonate strata approximates the relative concentration of bicarbonate (i.e., alkalinity) (see Figure 10). With the exception of Little Pine Island Bayou, total hardness and alkalinity exhibit similar patterns showing limited availability of carbonates (Figure 26). The occasional high hardness values seen in Little Pine Island Bayou suggest an alternative source of calcium and/or magnesium (the method does not discriminate between these divalent ions). The most likely source would be calcium chloride from residual oil field brines, in a similar pattern as seen in chloride (see Figure 12). There are no state criteria for hardness. A general background that mimics alkalinity shows limited contact with bicarbonates. Occasional higher values seen at Little Pie Island Bayou match those seen in chloride, suggesting that residual oil field brines may be a contributor.

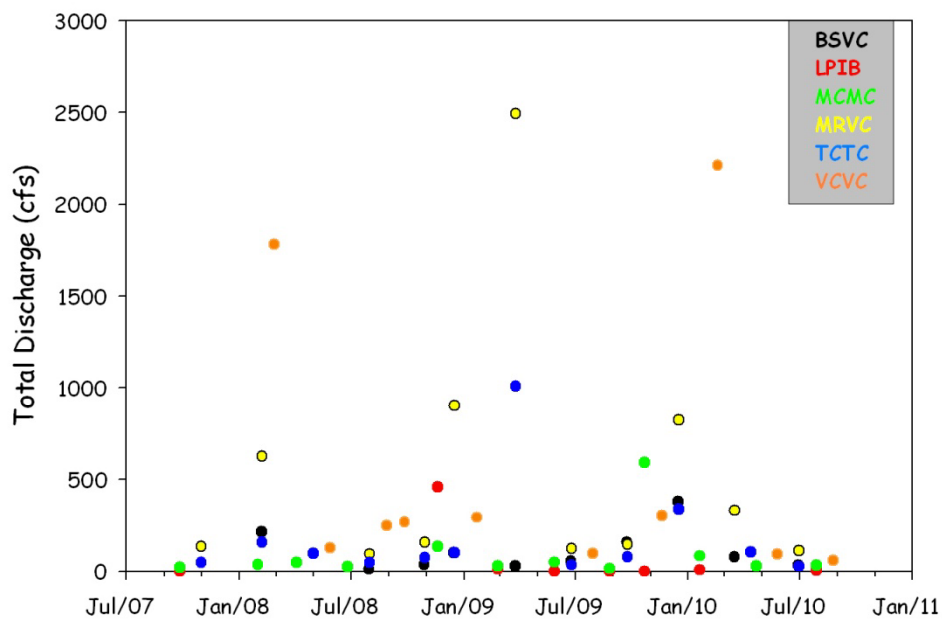


Figure 25. Discharge by station at BITH (n = 61).

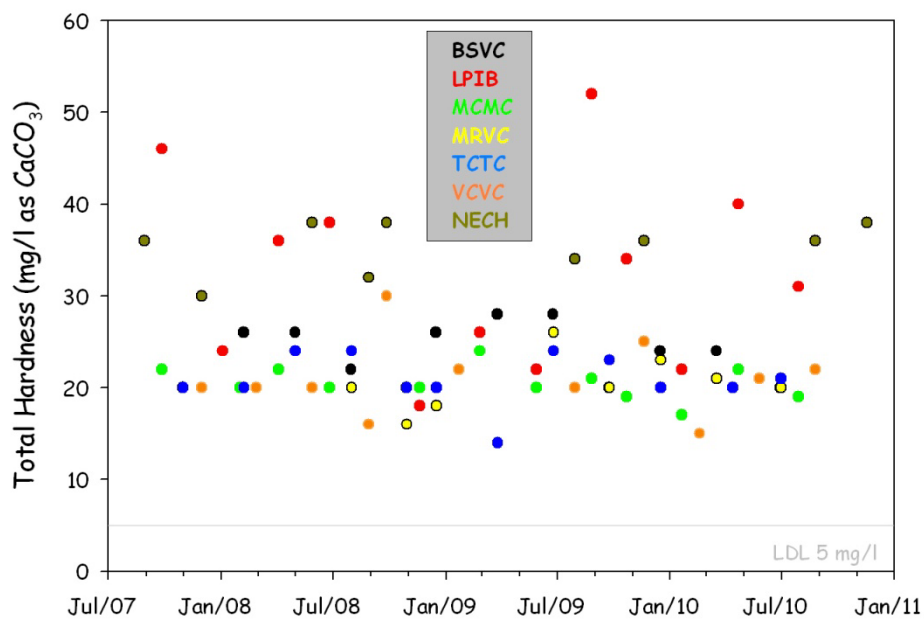


Figure 26. Total hardness by station at BITH (n = 79).

Total Phosphorous

Total phosphorous includes all normally occurring forms of phosphate, but is dominated by the biologically, readily available orthophosphate form. The most common human source of phosphate is fertilizer runoff. There are no state numerical criteria for phosphate; however, the USEPA recommends total phosphate levels be less than 0.05 mg/l in any stream at the point where it enters a lake or reservoir to limit nuisance aquatic plant growth.

Phosphorous levels in Preserve streams are variable in Turkey Creek, Little Pine Island Bayou, and the Neches River and rarely, if ever, found above the lower detection limit (LDL) of 0.06 mg/l at the other sites (Figure 27). Phosphate above detection limits have only been regularly seen in Turkey Creek, Little Pine Island Bayou, and the Neches River. There are not enough data to discern a pattern or suggest a cause. The outlier of 0.27 mg/l, MCMC (10-22-2009) was taken during high flow (16.8 cubic meters per second [593 cfs]).

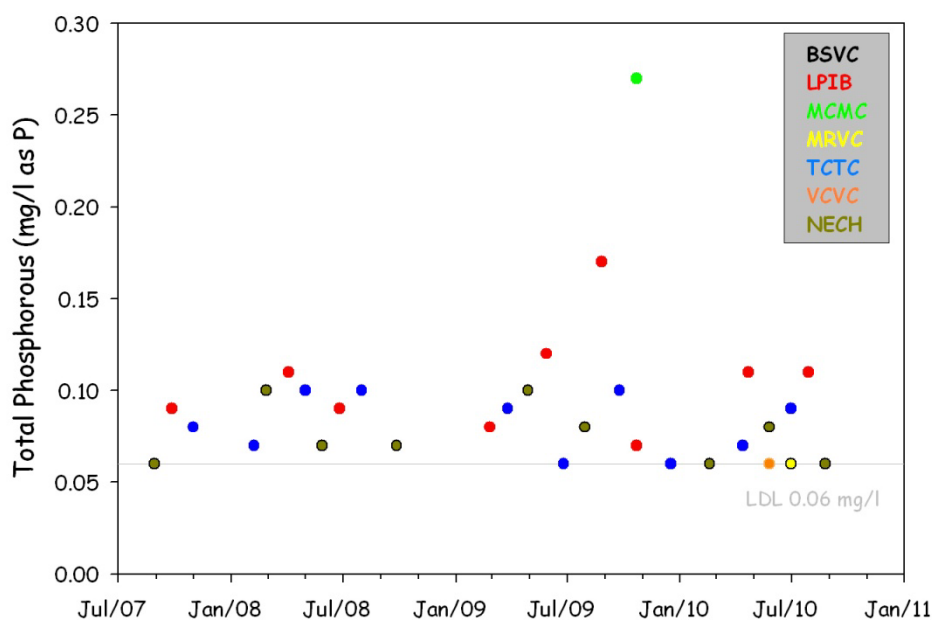


Figure 27. Total phosphorous by station at BITH (n = 32).

Total Suspended Solids

In general, higher TSS occurs during higher flow as particles are suspended in the water column (Figure 28). Although the dataset is small for statistical measures, the highest TSS values generally occur during the highest flows. The exception is Little Pine Island Bayou. The high flow at MCMC (10-22-2009), which produced elevated phosphorus, also resulted in the highest observed TSS value of 80 mg/l. There is no state criterion for TSS.

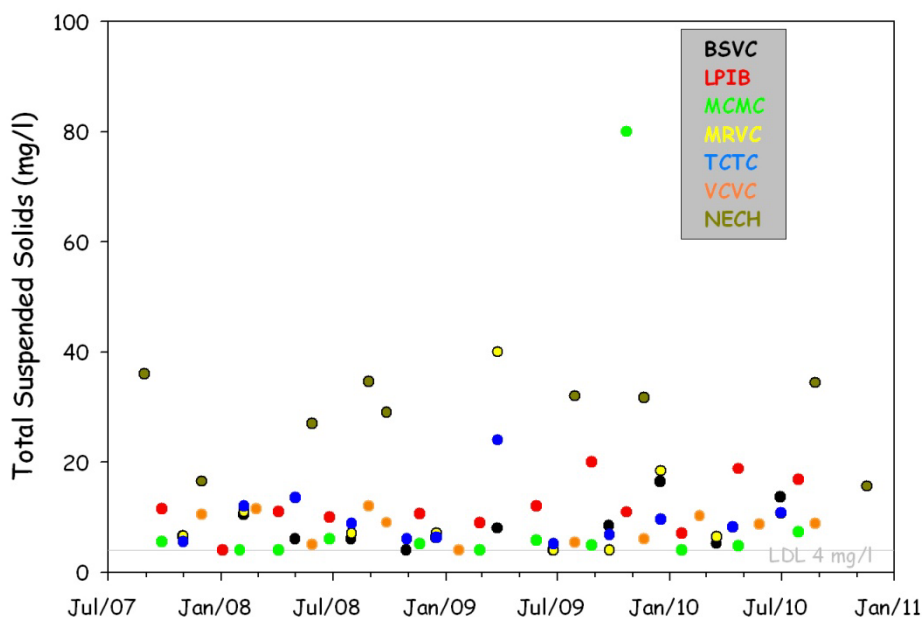


Figure 28. Total suspended solids by station at BITH (n = 79).

Turbidity

Generally the waters of the Preserve, although naturally dark-stained from tannins, have low turbidity from TSS (Figure 29). However, all streams can be very turbid during high-flow events as sediments are suspended in the water column. As shown on Figure 29, each of the higher turbidity values is associated with high flow. As with phosphorous and TSS, the 10-22-2009 sample at MCMC was an outlier at 237 nephelometric turbidity units (NTU).

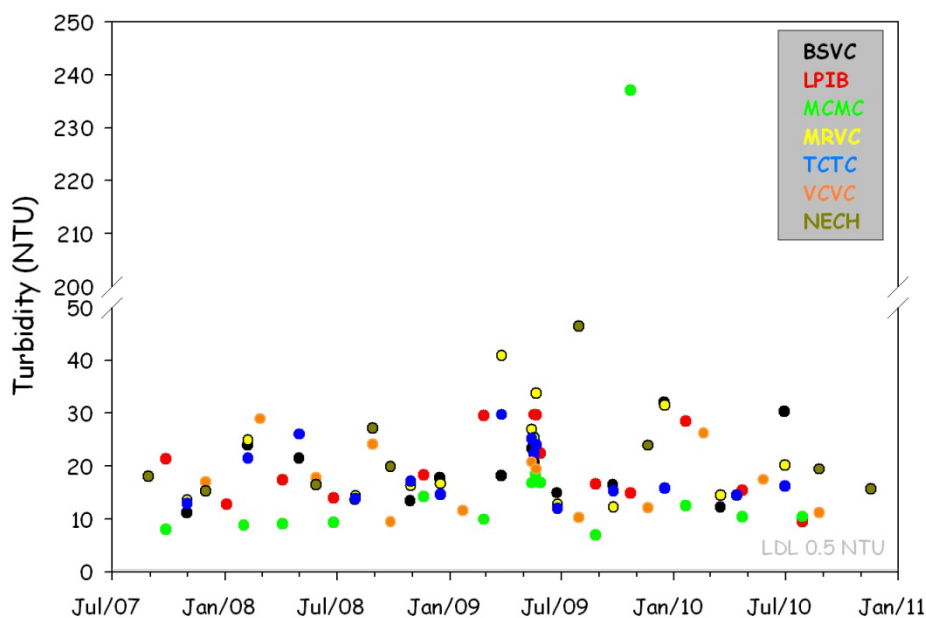


Figure 29. Turbidity by station at BITH (n = 96).

Temperature

Water temperature responds to the seasonal pattern of air temperature, typically spanning nearly 25 °C over the year. The State of Texas has assigned different upper temperature limits for Pine Island Bayou, Village Creek (and their tributaries) and the Neches River. All samples have been below the surface water quality criteria for each of these segments (Figure 30). On three occasions since 1997, water temperature during routine sampling at the Neches River station at US 96 (10508) have exceeded the standard of 32.8 °C (see appendix).

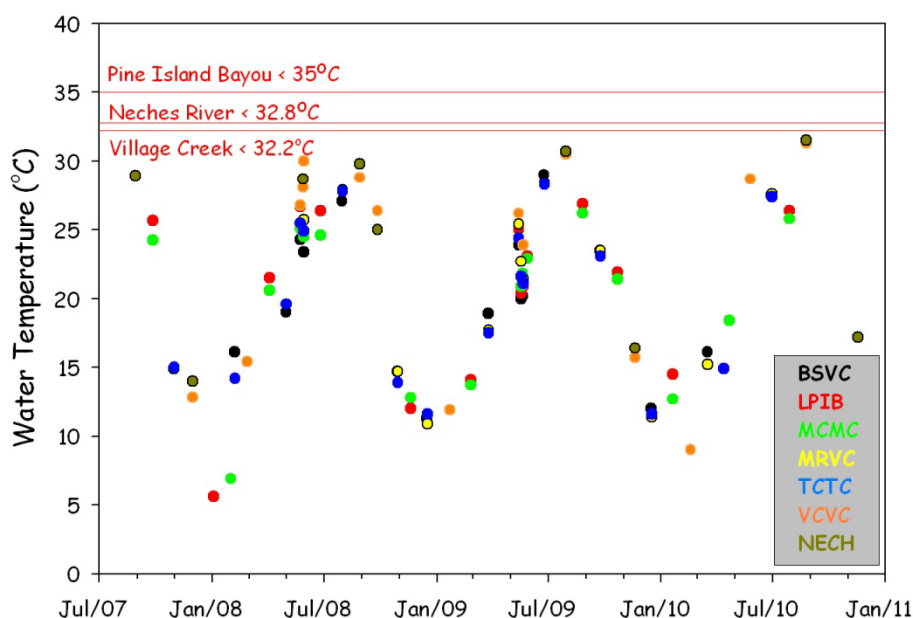


Figure 30. Water temperature (n = 108).

Continuous Recording Results

Index-Period Monitoring

During one week in late May, as waters of the Preserve warm to summer conditions, continuous-recording datasondes are deployed by GULN at each of the six sampling locations. This annual sampling event has occurred since 2008. The purposes of collecting high-temporal-resolution data (data are recorded for temperature, SpC, dissolved oxygen, pH, turbidity, and depth at 15-minute intervals) is to put the grab samples into a sense of diel context, document the diurnal variation of key water quality parameters, and record the response to rainfall events.

For example, a grab sample taken at Little Pine Island Bayou at 18:00 on May 26, 2011, would be 5.6 mg/l, well above the state single-sample low limit of 4.0 mg/l. Figure 31 clearly shows that the DO widely varies over the course of a day, reaching a peak in late afternoon. In this case, oxygen production through photosynthesis by submerged aquatic plants (primarily microalgae) increases DO during the day. When oxygen production ceases in the absence of sunlight, plant, animal, and microbial respiration continue to consume oxygen, resulting in a decrease in DO to below 3.0 mg/l.

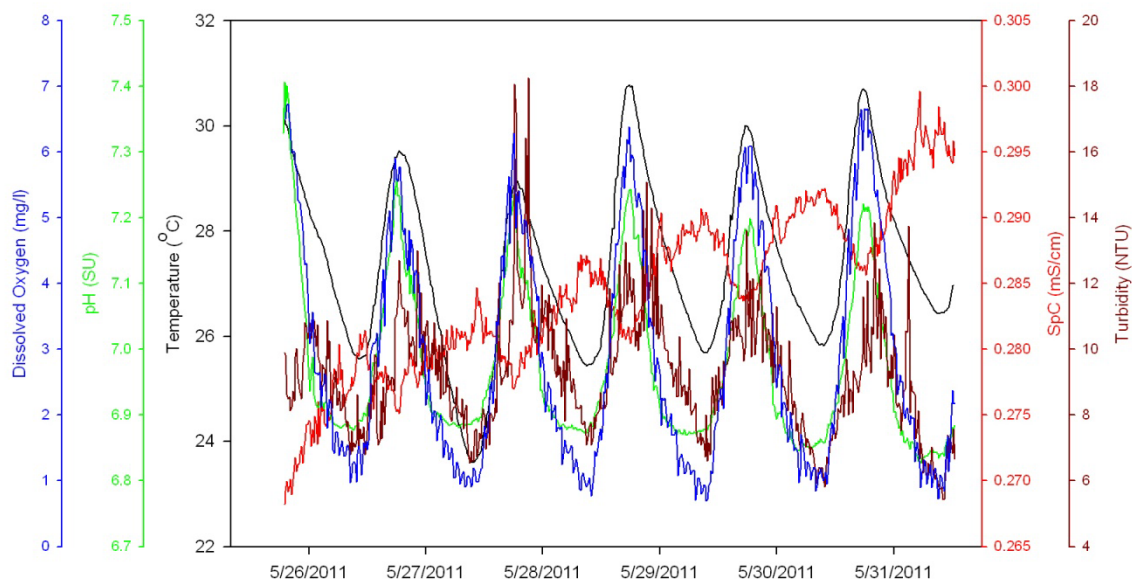


Figure 31. Diel variation at Little Pine Island Bayou (LPIB) at FM 770, May 25–31, 2011.

While scheduled routine grab sampling compiles excellent long-term water quality dataset, instantaneous sample events do not reflect fluctuations in water quality that can occur over the course of a day or during storm events. For example, midway through deployment, a brief but intense thunderstorm occurred over the Menard Creek watershed (Figure 32). An initial peak followed by a sharp drop in SpC marked the displacement of water by a pulse of lower-conductance rainwater. Coincidental to arrival of rainfall runoff is an abrupt spike in turbidity, peaking at 130 NTU from a pre-storm level of 15 NTU. Rising turbidity in advance of the low SpC rainwaters suggests that streambed sediment is resuspended ahead of the pulse of rainwaters and the runoff it brings. After only 24 hours, the stream had nearly returned to its pre-storm turbidity. There is also a sharp increase in dissolved oxygen as stream flow increased aeration. While turbidity quickly returned to near pre-storm values, SpC, dissolved oxygen, and pH remained changed from pre-storm values for many days.

LNVA Salinity Monitoring

Prior to late 2009, the entire Preserve was upstream of the Saltwater Barrier on the Neches River. In April 2009, approximately 2,670 hectares of former cypress forest (commonly referred to as the Lower Cypress Area) was added to the Beaumont Unit of the Preserve. The Beaumont Unit is located on the left bank of the Neches River between the Saltwater Barrier and the Port of Beaumont, approximately 23 river miles upstream from Sabine Lake. The LNVA operates three continuous-monitoring gauges on the Neches — at river miles 30 (upstream of the barrier at the confluence of Pine Island Bayou), 28, and 23. The function of the Saltwater Barrier is not to block the saltwater of storm surges, but to halt the upstream flow of saltwater during low-flow periods in the Neches River. These gauges help the LNVA determine the operations status of the barrier. During summer months, flow in the Neches River diminishes, which results in the upstream encroachment of the saltwater wedge in the Neches River channel (Figure 33). The Saltwater Barrier became necessary because of modifications to the lower 32 km (20 miles) of the Neches River, the Port of Beaumont Channel. The channel has been straightened, deepened,

and widened over the years, beginning in 1908, and presently is dredged to a depth of 12 meters (40 feet). These modifications have increased the frequency and duration of saltwater intrusion. Another round of channel modifications is planned, which will increase these salt water events.

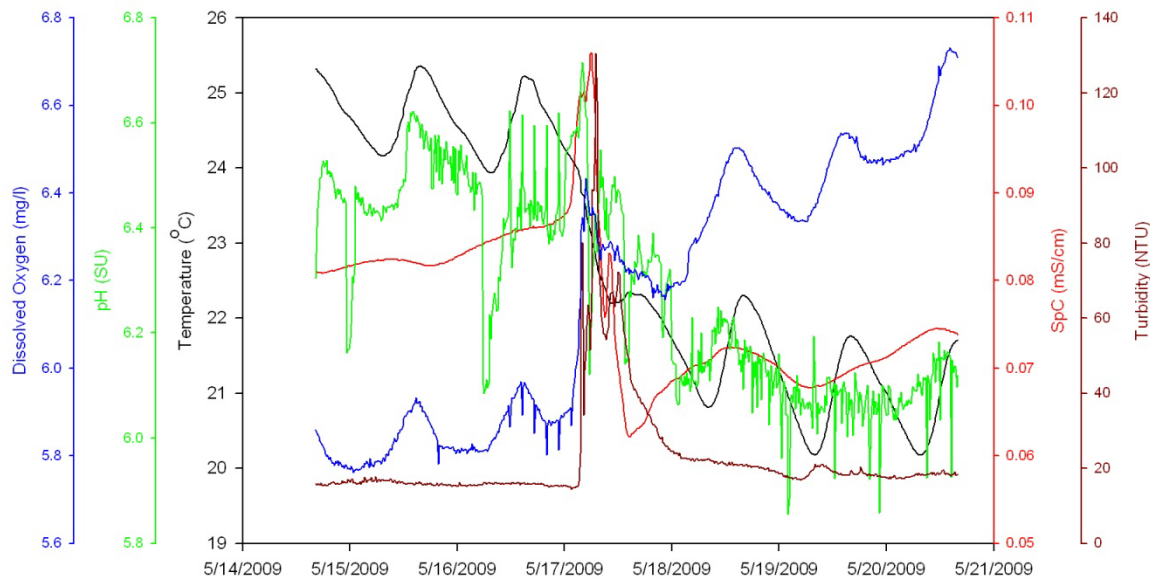


Figure 32. Response to rainfall event at Menard Creek (MCMC) at SH 146, May 14–20, 2009.

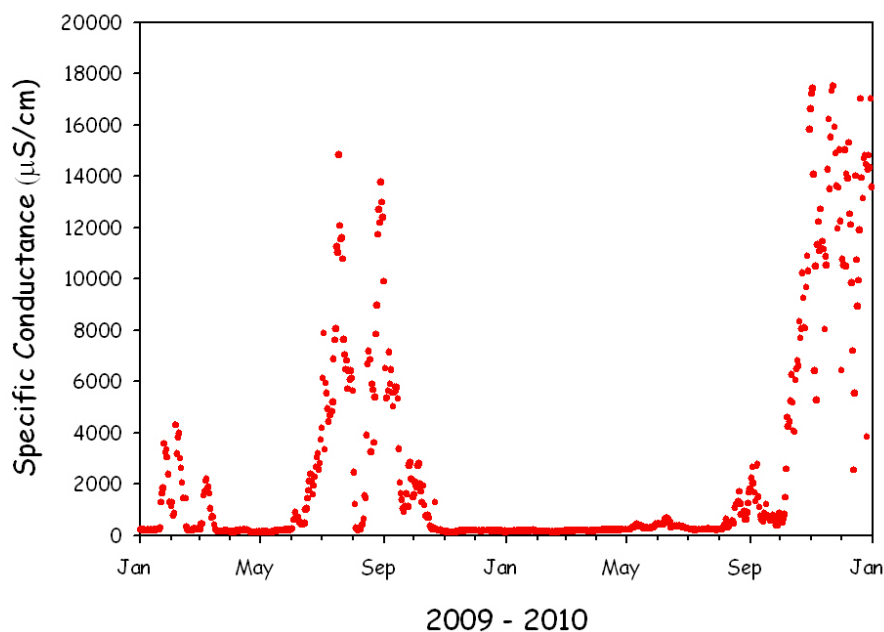


Figure 33. Specific conductance record from the LNVA Station Z at river mile 23 (n = 730). These readings represent daily averages taken at a depth of 3 meters (10 feet). Approximate salinities range from 0 to 11 ppt.

Summary

Water is the unifying resource at Big Thicket National Preserve. The 43,790.29-hectare (108,208-acre) Preserve is essentially a series of riparian corridors centered on the Neches River; Beech, Menard, Big Sandy, Hickory and Village creeks; and Pine and Little Pine Island bayous. An average of 14,500 visitors use the Preserve waters for recreation each year. Preserve managers are responsible for conserving water resources of 930 km (578 miles) of stream, ranging in size from small headwaters to the Neches River. The waterways of the Preserve are home to an estimated 92 fish and 16 mussel species, as well as numerous other aquatic flora and fauna. One of the challenges is that the Preserve represents only about 1.6 percent of the 26,000 km² (6.4 million acres) Neches River watershed.

Water quality and quantity is monitored quarterly at six locations within the Preserve as directed by the GULN. Sampling is performed at 13 sites proximal to the Preserve by the LNVA and at 6 stations in the Lower Neches River Valley by the USGS. Considering that much of the landscape of the Preserve has been altered from its natural condition, it is encouraging that most waters are in good condition for most measured parameters.

The first water quality survey was performed between 1977 and 1981 by Lamar University. Results showed severe impacts from oil fields in Little Pine Island Bayou and depressed oxygen levels in Little Pine Island Bayou and Big Sandy Creek. While large-scale brine events have not been observed in recent years, some stream segments still do not meet state surface water quality standards.

Each stream segment is assigned a designated use (e.g., recreational, aquatic life, or public water supply), which is a reflection of water use. All of Pine Island and Little Pine Island bayous within the Preserve have low dissolved oxygen. Little Pine Island Bayou and the headwaters of Big Sandy Creek exceed limits for *E. coli*.

Some of the stream segments are either listed by the state as not meeting the High Aquatic Life Use due to depressed DO or were identified in this study as having periodic low DO. Depressed oxygen may be caused by a combination of natural hydraulic conditions consisting of warm water, tree canopy shading, and low gradients, which result in little water movement and little aeration. These conditions are exacerbated during summer low flow and warm temperatures. While these conditions are largely natural, low dissolved oxygen may also indicate eutrophication, the processes of a water body receiving excessive nutrients from point and non-point sources.

E. coli is a naturally occurring bacteria found in the intestines and feces of warm-blooded animals. Our data indicate that the majority of *E. coli* found in BITH streams are from non-point sources, as high bacteria levels coincide with high flows. In this study, bacteria levels exceeded the state's surface water quality criterion on three occasions (Menard and Turkey creeks and Little Pine Island Bayou). Due to this relationship with runoff and high flows, it is possible that any stream in the Preserve may exceed the standard after rainfall events.

In March 2010 the DSHS posted a fish-consumption advisory for mercury in the Neches River and all contiguous waters in Angelina, Hardin, Houston, Jasper, Polk, Trinity, and Tyler counties. This includes the entire reach of Village Creek and the Neches River upstream of

Evadale. While mercury is accumulated through the food chain in the Preserve, it is not a problem confined to the Preserve. High mercury content in fish tissue is common among many of the east Texas waterbodies (DSHS 2009). While mercury naturally occurs in the environment, atmospheric deposition also occurs through the burning of fossil fuels, as well as natural sources. The methylization of mercury, which is the path to food chains, is conducive in systems with low pH and high dissolved organic carbon (USGS 2000), which are conditions common to east Texas streams and reservoirs.

The frequency and duration of saltwater intrusion events can be expected to increase as demand for fresh water in the greater Beaumont area increases and the Sabine-Neches Waterway is deepened and widened. While the LNVA Saltwater Barrier will help prevent the intrusion of saltwater into the Preserve upstream from the structure, the new Beaumont unit may experience higher salinities.

The GULN will continue quarterly water quality sampling at the Preserve through the LNVA as part of the TCEQ CRP routine schedule for the Lower Neches River Valley. All aspects of the sampling, transportation, analysis, and data management will continue under the protocols of the GULN and TCEQ. The GULN expects to continue week-long deployments of datasondes during the late May indexing period. If any questions regarding the hydrology or water quality of the Preserve arise, the GULN hydrologist should be contacted.

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Appendix: Clean Rivers Program Routine Monitoring

The following data are from the Texas Commission on Environmental Quality's (TCEQ) Clean Rivers Program routine monitoring for 12 sites that have been monitored from 1997 through the present. These sites are located either in or immediately upstream from the Preserve. These data represent an additional 10 years preceding the Gulf Coast Network Program (GULN) and can provide valuable insight to the water quality within the preserve as well as help interpret the GULN results. Beginning in 2007, the Lower Neches Valley Authority (LNVA) began processing samples in its accredited laboratory. Some methods were changed, thus affecting such attributes as lower detection and reporting limits.

Legend for appendix graphs:

	10581	Neches River at FM 1013 east of Spurger
	10508	Neches River at US 96 near Evadale
	15367	Pine Island Bayou at FM 770/SH 105 near Batson
	10599	Pine Island Bayou at LNVA lower pump station 6.6 km upstream from Neches River
	10602	Pine Island Bayou at US 69/US 96/US 287 at Voth
	10607	Pine Island Bayou at Old Sour Lake Road 5.1 km southeast of Sour Lake
	13625	Village Creek at FM 418 5.4 km northeast of Kountze
	15346	Little Pine Island Bayou at FM 326 north of Sour Lake
	15349	Hickory Creek at US 69 south of Warren
	15353	Big Sandy Creek at US 190 in the Alabama Coushatta Indian Reservation
	15355	Beech Creek at FM 1013 west of Spurger
	15356	Turkey Creek at FM 2013 east of Hillister

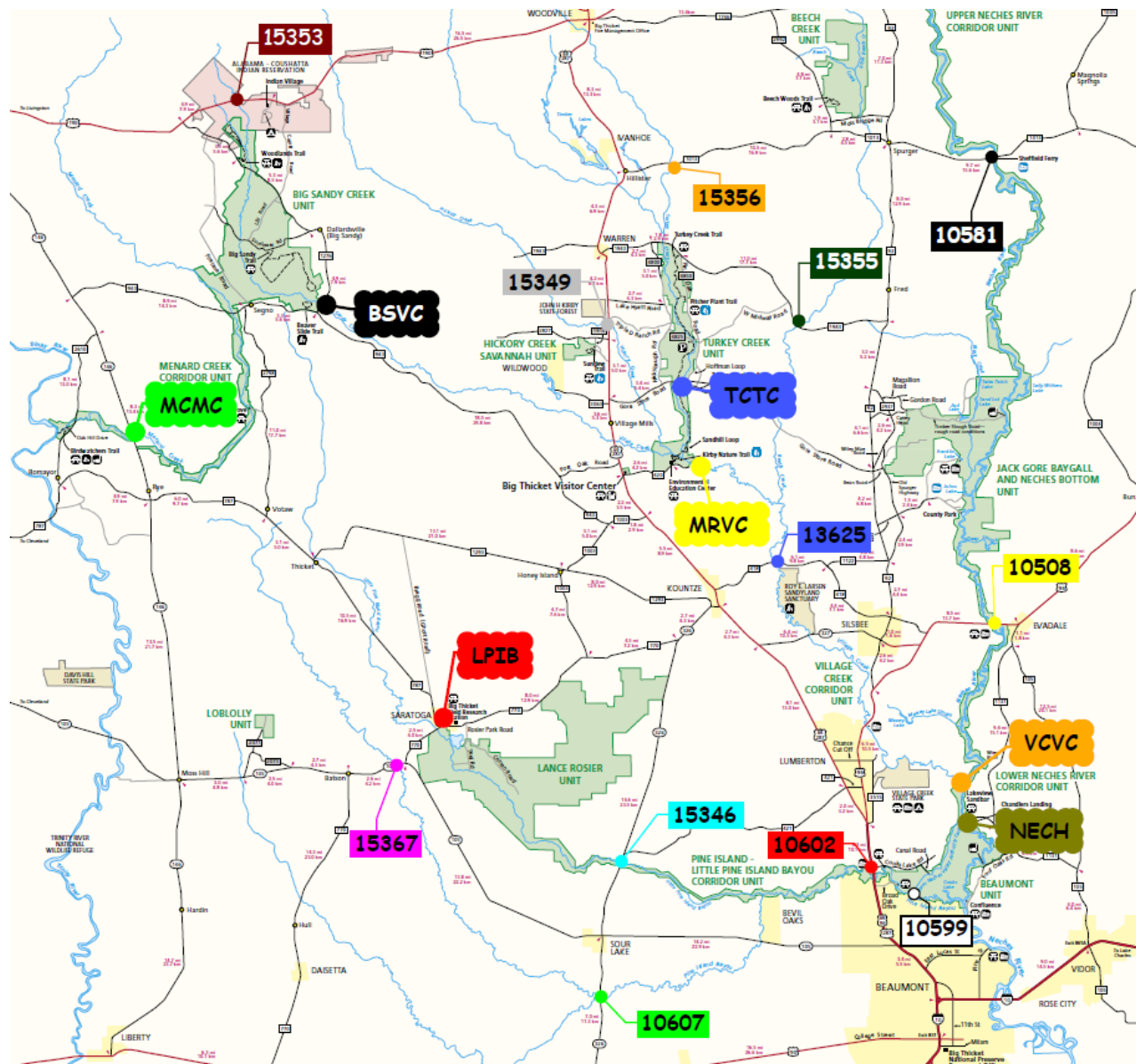
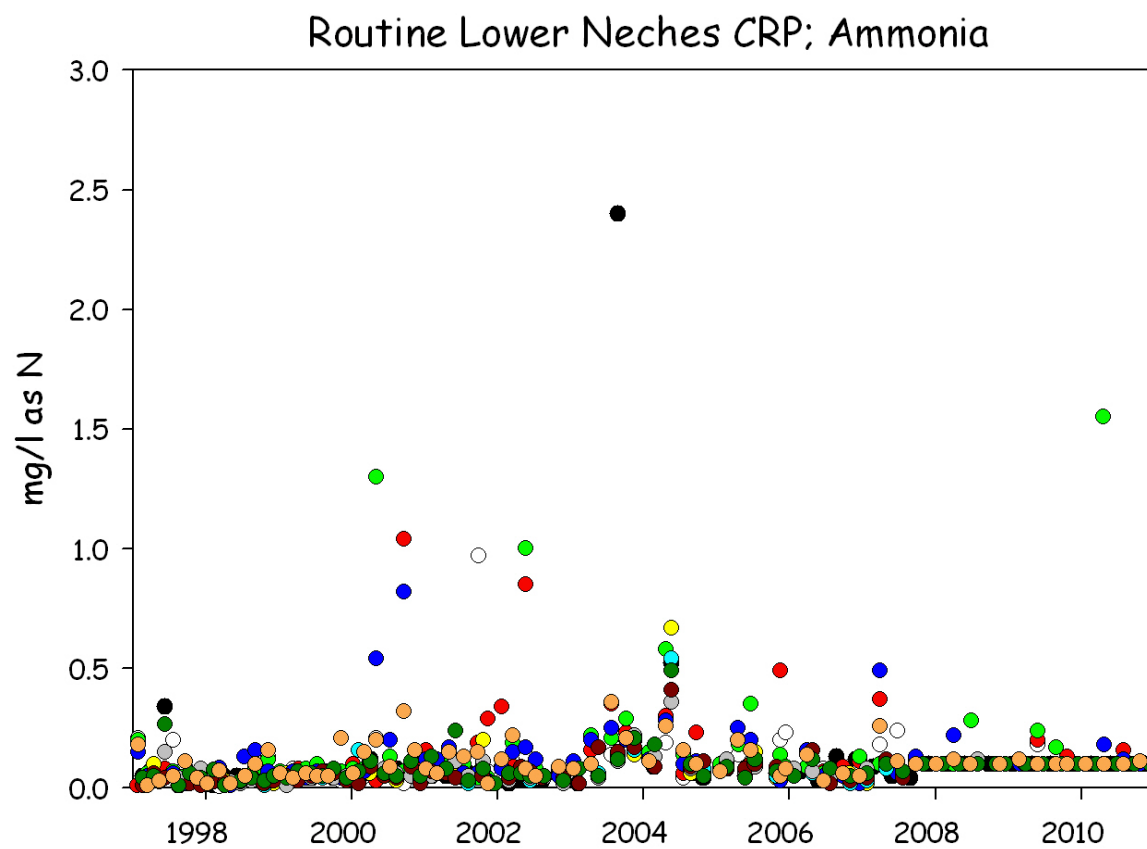
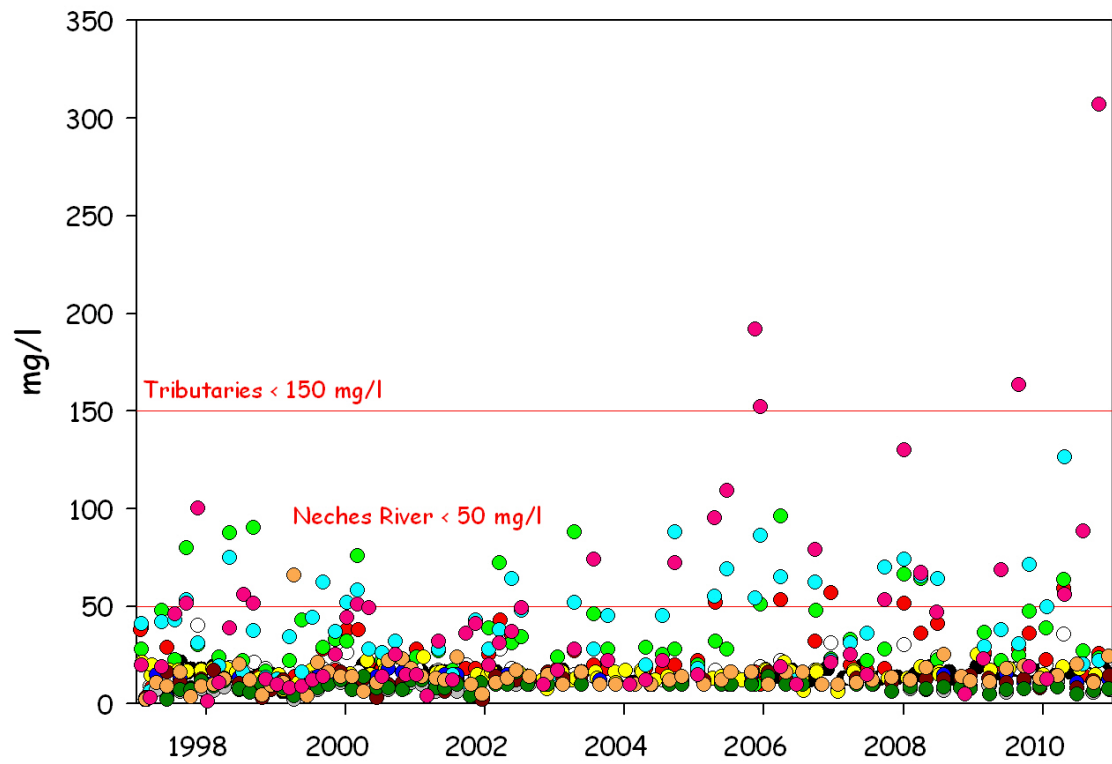


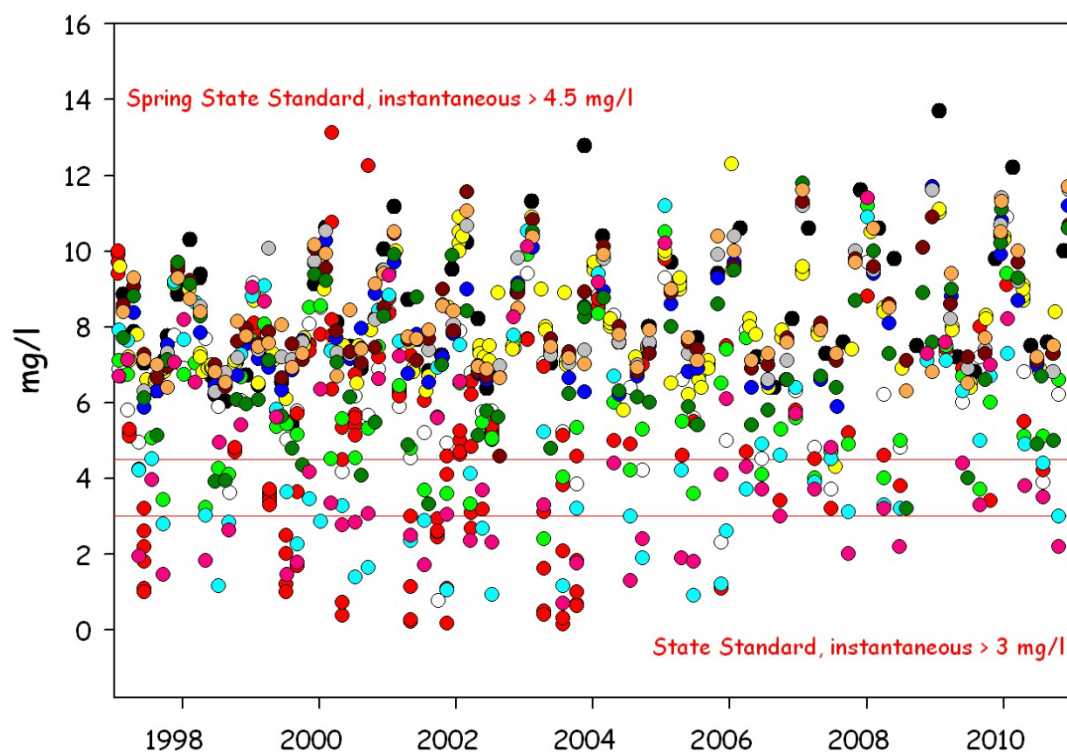
Figure A-1. Map of water quality sampling sites at the Big Thicket National Preserve (BITH). Sites depicted with an irregular border are sampled under the GULN program through a contract with the LNVA. Sites with the rectangular outline are sampled by the LNVA under the TCEQ Clean Rivers Program.



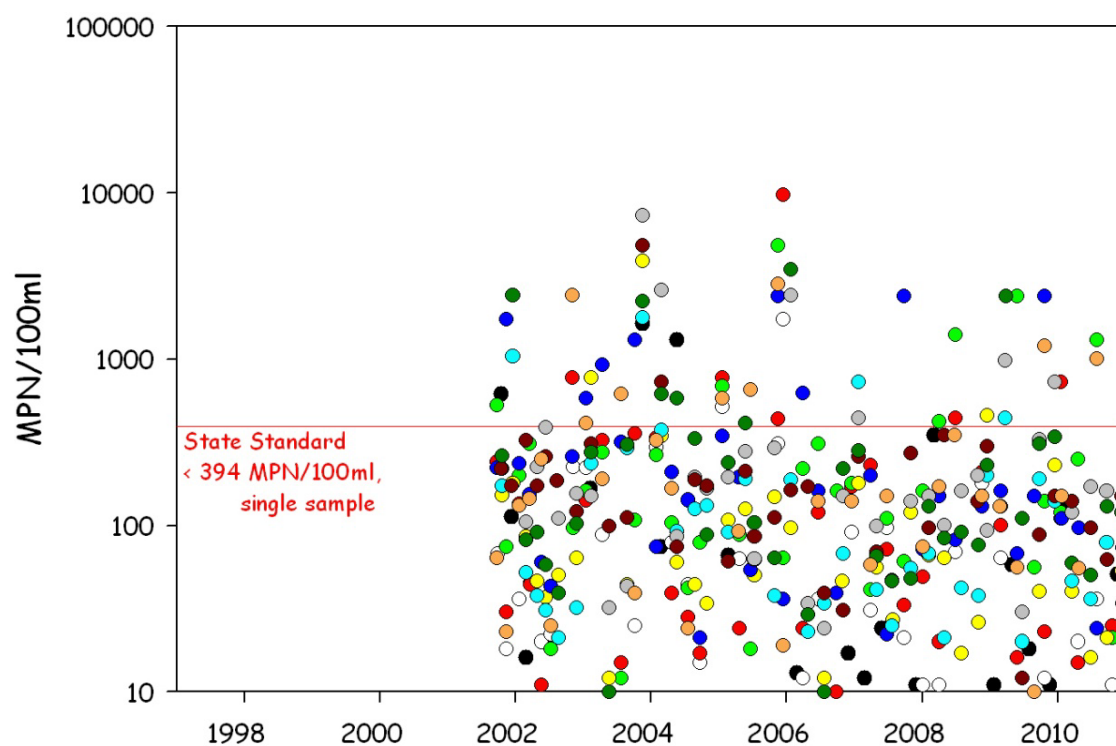
Routine Lower Neches CRP; Chloride

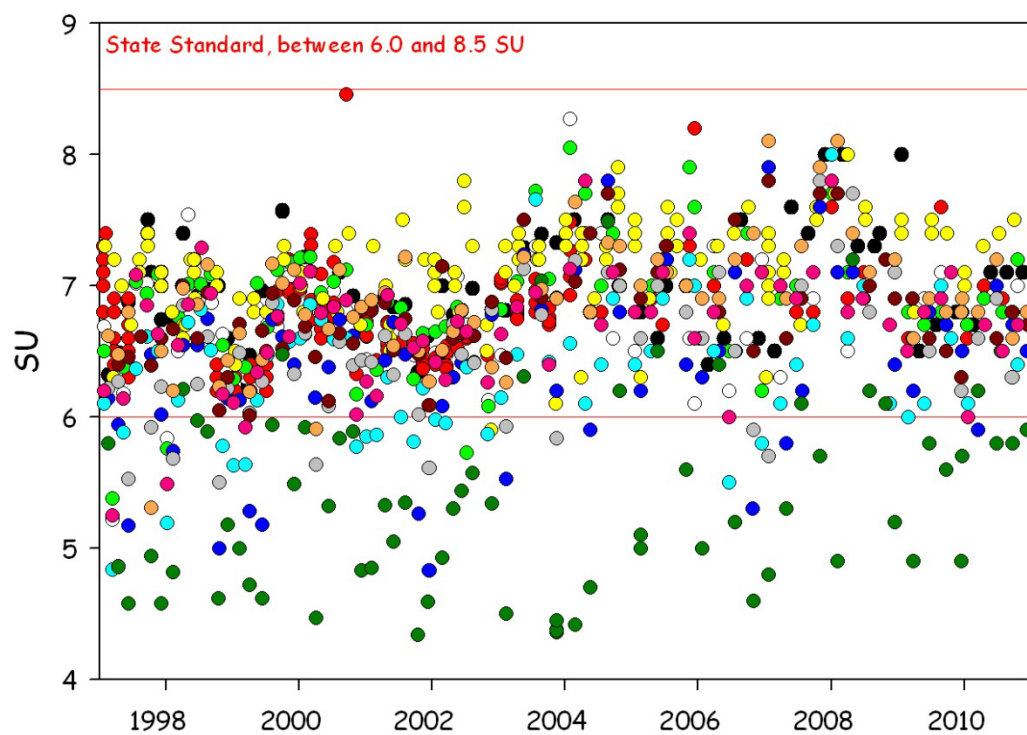
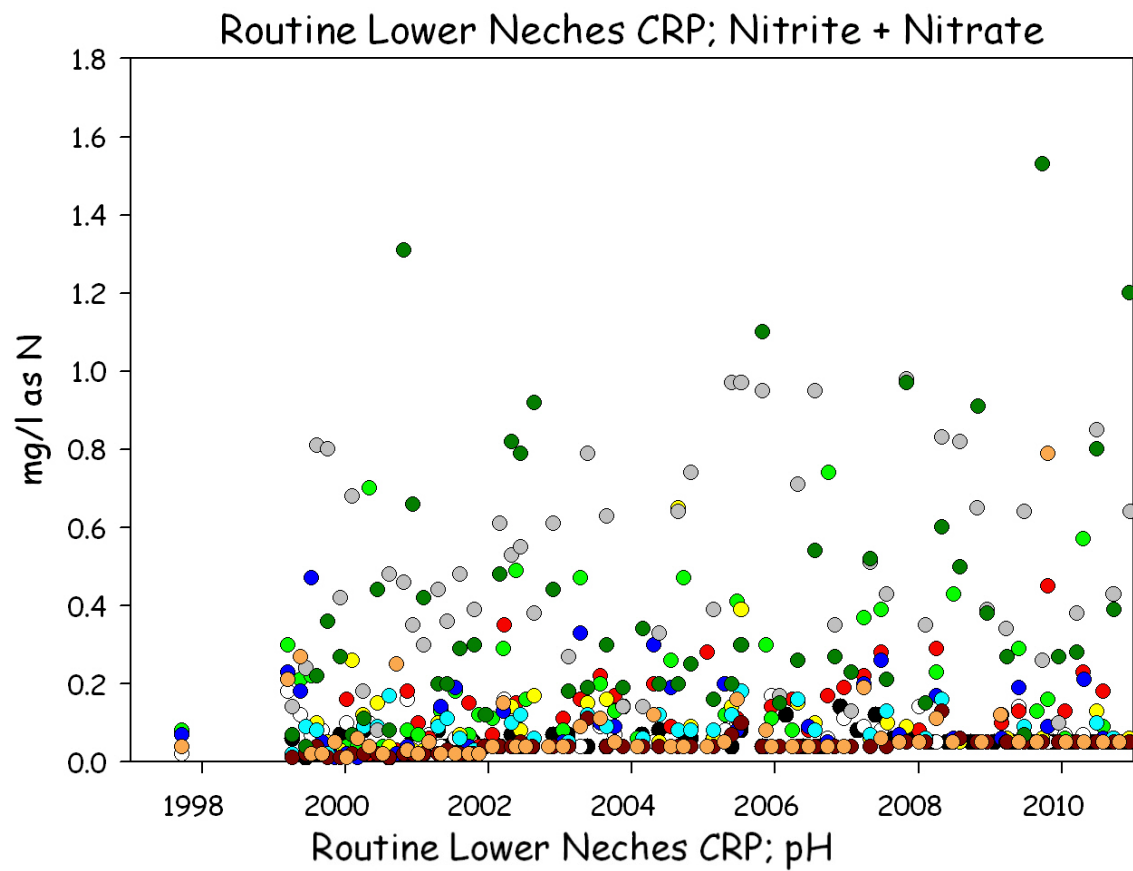


LNVA Routine CRP; Dissolved Oxygen

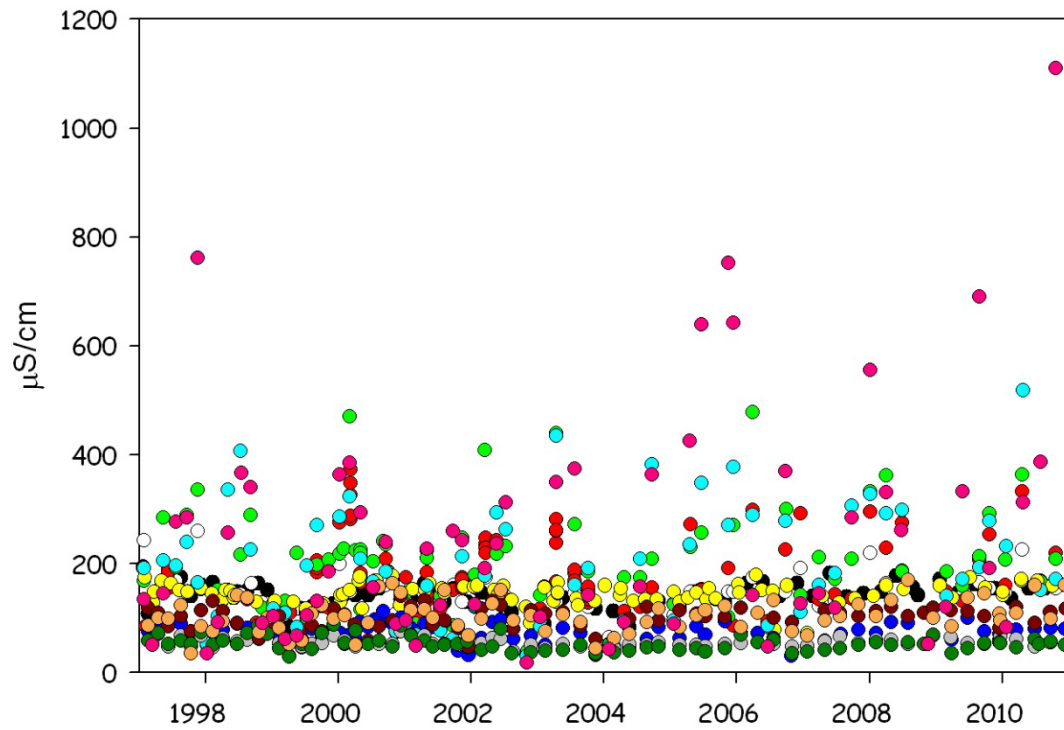


Routine Lower Neches CRP; *E. coli*

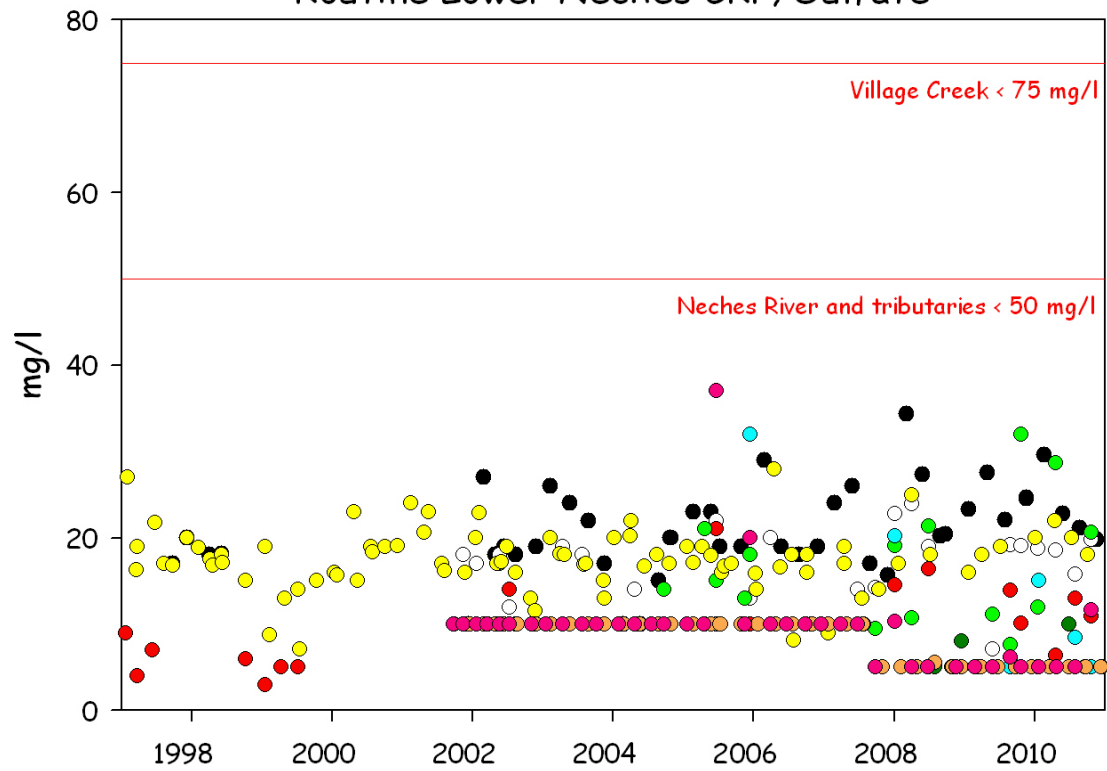




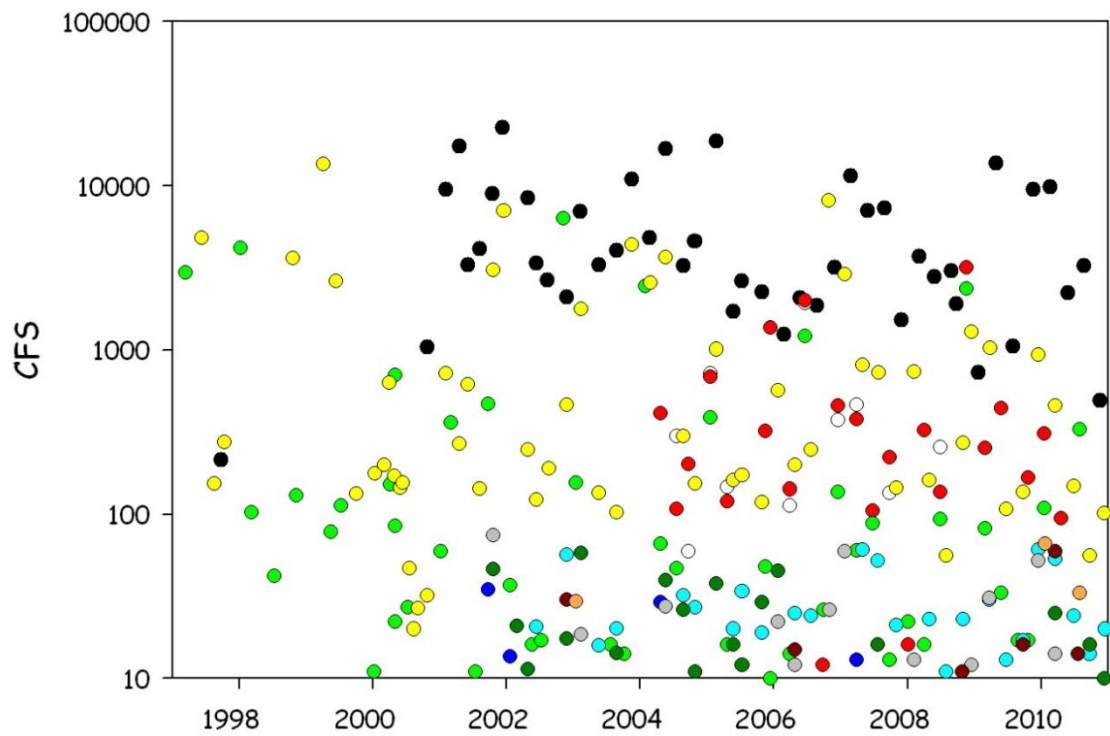
Routine Lower Neches CRP; Specific Conductance



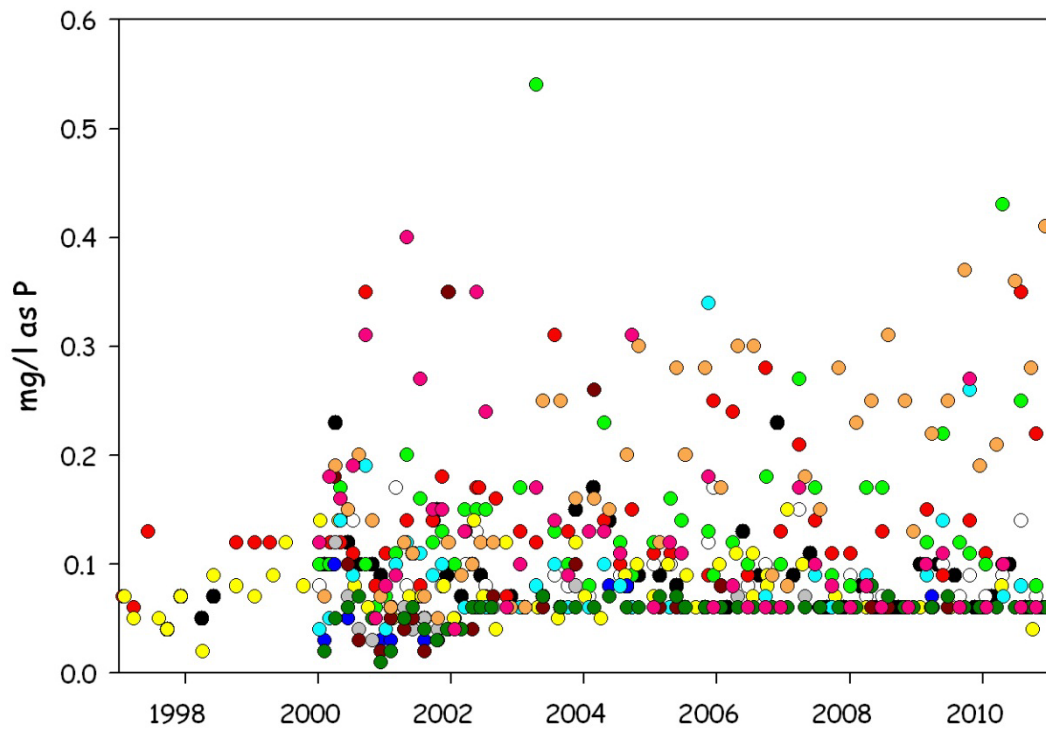
Routine Lower Neches CRP; Sulfate



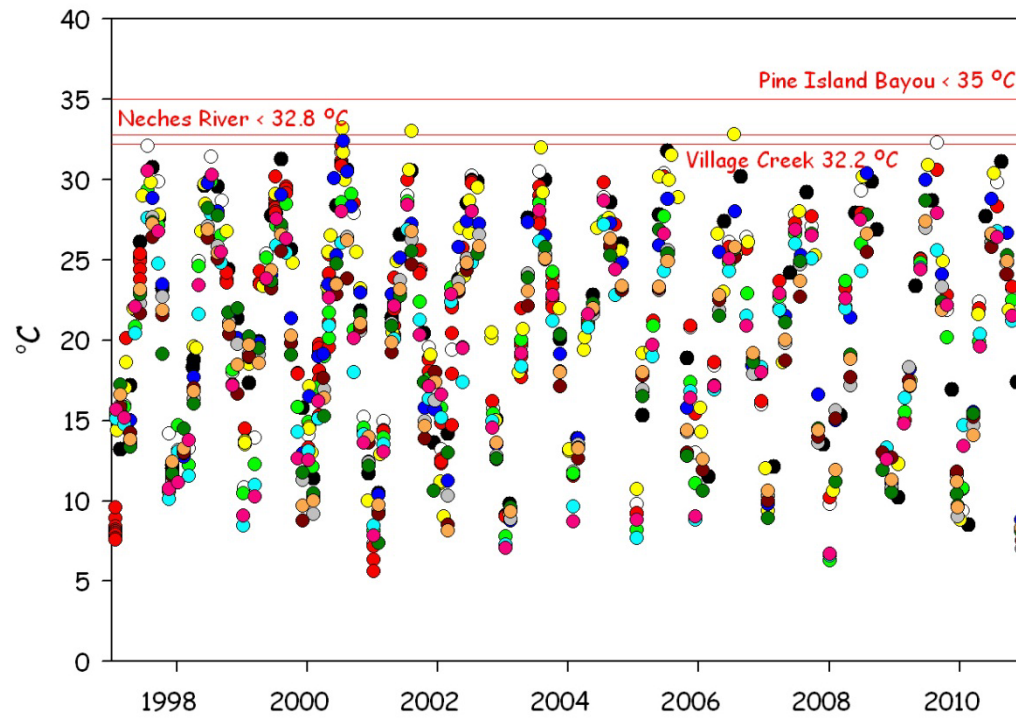
Routine Lower Neches CRP; Discharge



Routine Lower Neches CRP; Phosphorous



Routine Lower Neches CRP; Water Temperature



The Department of the Interior protects and manages the nation's natural resources and cultural heritage; provides scientific and other information about those resources; and honors its special responsibilities to American Indians, Alaska Natives, and affiliated Island Communities.

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