The National Park Service

Inventory and Monitoring

Water Quality Monitoring Program for the Inland Parks of the Gulf Coast Network

December, 2006



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Chapter 1 Introduction

During the summer and autumn of 2006, the Cumberland-Piedmont (CUPN) and Gulf Coast (GULN) Networks Hydrologist, Joe Meiman, traveled to the five inland parks of the GULN to perform hydrologic assessments. Water quality monitoring of the three coastal parks will be addressed in a separate document. The primary objective is to provide information to the GULN Board of Directors and Science/Technical Advisory Committee (STAC) relevant to drafting an effective and efficient water quality monitoring program. The information includes descriptions of water resources; descriptions of past, current, and potential sampling sites; examination of past and present water resources inventories, monitoring activities, and research; examination of water quality data records; identification of data-gaps; and general recommendations of sampling strategies.

A great deal of information was provided by the GULN Data Manager, Whitney Granger. Documents assembled by Mr. Granger will be cited throughout this plan. Christopher Swarzenski, of the United States Geological Survey, Louisiana Water Science Center, provided the GULN with a Phase I Scoping Report which summarized various water-related efforts in each park. Dr. Swarzenski's report provides an introduction to water resources of the GULN parks. Prior to park visits, existing water quality data were reviewed, including the NPS Water Resources Division (WRD) program "Baseline Water Quality Data Inventory and Analysis". Although these reports were not available for every park in the GULN, they certainly were a great help where they exist.

Similar to hydrogeologic assessments conducted previously for the CUPN, parks of the GULN were found to be in various states of water resources knowledge. Some parks, like Big Thicket National Preserve (BITH), have been the focus of numerous water quality studies in the past – from programs initiated by both NPS and cooperators. Other parks, like the Natchez Trace Parkway (NATR), although containing numerous significant waterways, have little information regarding their water resources. The state of information of a park's water resources is, of course, an important element to such assessments as this.

1.1 Monitoring Objectives

Water resources of the GULN range from the ancillary unnamed tributaries which harbor no rare or threatened aquatic species, to waterbodies that provide an aesthetic backdrop to the park area, to nationally significant waters which are the core natural resources of parks. From a water quality perspective, these waters vary from unimpaired upland springs and streams to urban rivers currently on the USEPA 303d list of impaired waters. Some parks waters (BITH and NATR for example) contain rare or endangered species, provide an important recreational opportunity to the public, or may be mentioned in the park's enabling legislation. In other parks (SAAN, for example), the waters do not contain extraordinary biological communities, nor are they used recreationally. They do,

however, provide an important backdrop, in terms of general aesthetics or interpretation. Still, in other parks (VICK) water resources are not particularly important in terms of biological or recreational significance, nor are they important from a general interpretative standpoint. In short, not all water resources, nor management objectives, are equal in all parks of the GULN. Therefore the individual monitoring objectives, including the frequency of sampling and parameter lists must be tailored to meet the overall park management objectives. The monitoring objectives can be stated as follows:

- Determine if concentrations of selected parameters (key nutrients, bacteria, and key physical characteristics) are changing monotonically over time and estimate rates of change.
- Determine if the park is meeting the designated use water quality requirements through annual reports.
- Provide a water quality backdrop to compare changes in the aquatic biologic communities (where applicable).
- Provide data to determine pollutant sources (non-point source contaminants versus point sources).
- Determine impacts to water quality by in-park activities within selected watersheds.
- Determine the basic effects of atmospheric contaminants (acid precipitation).

1.2 General Discussion and Conceptual Plan

The GULN WQ Monitoring Program must keep the following points in focus if it is to be successful:

1) A “One Size Fits All” approach to monitoring water resources within the GULN is not advised. It becomes readily apparent that not all water resources within the GULN are equal, either in specific park mission (Enabling Legislation) or in resource significance and use. In some parks, water resources may be the primary focus of why the park exists (BITH), in others, while not being a main attraction, water resources are generally unexplored (NATR), and water resources in some parks may be considered nearly ancillary (VICK).

2) It must be a “monitoring program” and not a “research program”. This is for two basic reasons: (1) Foremost that the Natural Resource Challenge (NRC) program calls for the long-term monitoring of park resources. The program must be designed to track long-term trends on a specific list of relevant parameters rather than focusing upon a few cause and effect relationships. That is not to say that specific research is not needed. (2) Basic, fundamental water quality data – which is a precursor to research – simply does not exist in some GULN units.

3) The WQ monitoring program must address long-term park resource management goals. Each park must be able to articulate, either by its own personnel or with consultation with water resource professionals, specific park goals for its water resources. This aspect is of extreme importance. There is little use in attaining or maintaining water resource quality goals that are not commensurate with park management objectives. Park objectives establish "designated uses" for water resources and thus set the parameter lists and water quality standards for each park unit.

4) The WQ program must focus on park waters. Although many parks may receive flow from beyond park boundaries, unless real external threats to park waters are identified, we must first focus on park waters. If external waters need to be sampled, the NPS may cooperate with state agencies for monitoring. If the park must sample externally, agreements with property owners must be made to assure long-term monitoring.

5) The WQ monitoring program must be well coordinated with all other natural resources monitoring efforts. Although the WQ program will be drafted and executed to a stand-alone level, if it is to truly function as a component of vital signs monitoring, it must be fully integrated with all other aspects of the NRC Program within the network. Germane to the first point listed above, "all aquatic resources are not equal". If key elements are examined, such as aquatic life, human use, significance to the park, and park management objectives, water resources can be evaluated and ranked accordingly. Parks with highly significant water resources (i.e. central to park mission, supporting important biological communities such as Federally or State listed Threatened or Endangered species, or heavily used recreational waters) are ranked higher than parks with less significant waters.

Each state, as required by the USEPA, has developed water quality standards and protocols for defining designated uses of water resources. Some GULN park waters have been designated by a state, many have not. Specific language and designations are unique to each state; however they are generally categorized based on the fish and wildlife, recreation, and drinking water supply. For GULN waters that are not designated by the state, this plan will, by using the same state protocols, designate these waters, and thus adapt state water quality standards. It should be noted that these are minimum standards – the NPS can impose higher standards than required by the state.

The main body of this report will describe the freshwater water resources of the five inland parks of the GULN. The following paragraphs serve a summary of relative rankings and a presentation of a conceptual plan of the GULN Water Quality (WQ) Monitoring program.

Knowledge of aquatic resources with respect to water quality of the GULN runs the full spectrum. Long-term water quality monitoring efforts have been underway adjacent to Big Thicket National Preserve by the state since the early 1990's, while data from within

the Preserve is scattered. Somewhat surprising, while crossing scores of significant waters (proximal to major universities) little is known about water quality along the Natchez Trace Parkway. Equally surprising, the limited waters of Vicksburg have been the focus of numerous biotic and abiotic inventories over the past decades.

In order to discern what is known relative to a particular park's water quality, a review of existing data was made and summarized in hydrologic assessment sections to follow. Depending on the state of water quality knowledge, the GULN WQ program may call for a water quality inventory phase. This inventory will follow all protocols of the monitoring program – in accordance with the USGS National Water Quality Assessment (NAWQA) program. Adherence to the NAWQA standards serves two main goals: (1) Generation of high-quality, defendable data, and (2) comparison of the GULN water quality data to the NAWQA database as a whole.

Central to the program is non-conditional synoptic sampling, where samples are taken, regardless of flow and weather conditions, on fixed calendar dates. Basic fixed sampling locations occur at integrator sites (locations commonly at tributary confluences or springs which are representative of water quality issues of 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 required. This strategy, over the long-term, has proven to yield statistically valid data used to track long-term trends in water quality.

1.3 Water Resource Ranking

Parks are ranked in accordance to water resource significance through site visits and discussions with park management. They are also reflective of information gained through pre-existing water quality data. Any future changes must be based entirely upon resource and management merit and in adherence to Water Quality Monitoring Protocol SOP 9 (Revising the Protocol).

Category One – Water resources are central to park establishment or mission; High amount of recreational use activities; Contains Federally or State Listed Threatened, Endangered or Rare aquatic or dependent species; Known exceedences of key water quality standards or 303d listed waters; High probability of water resource damage with little or no information of fundamental elements of hydrogeology or water quality. Parks in this category: BITH and NATR.

Category Two – Water resources, although important with respect to general interpretation or aesthetics, not central to park establishment or mission, with limited or no contact recreational use; Contains no Federally or State Listed Threatened, Endangered or Rare aquatic or dependent species.
Park in this category: SAAN.

Category Three – Water resources not central or perhaps even mentioned in park establishment or mission; No contact recreational use; Contains no Federally or State Listed Threatened, Endangered or Rare aquatic or dependent species. In general, water resources are ancillary in nature and management. Parks in this category: PAAL, VICK.

1.4 Monitoring Parameters

Notwithstanding water quality inventories which will be needed to better understand the chemistry and physical nature of some sites, the routine water quality parameter list is driven by park management objectives or parameter list of extant, concurrent water quality programs (Table 1.1). For example, as the Lower Neches Valley and San Antonio River Authorities will be working very closely with the NPS effort (collecting and analyzing samples) in concert with their overall sampling program, it makes sense to draw from their parameter list. In the future it may be necessary to add to the parameter list if associated programs document trends or management concerns.

Table 1.1 Parameter list including those of current water quality programs.

Field Measures	Bacteria	Nutrients	Major ions	Metals	Sediment	Other
Temperature	E. coli	Ammonia-nitrogen	Chloride	Aluminum	Total suspended	Secchi depth
pH		Nitrate	Sulfate	Arsenic		ANC
SpC		Nitrite		Barium		Turbidity
Dissolved oxygen		Total Kjeldahl		Cadmium		Total organic C
Flow		Total phosphorous		Chromium		Total hardness
				Copper		
				Lead		
				Mercury		
				Nickel		
				Selenium		
				Silver		
				Zinc		

From the review of existing water quality data and discussions with park staff a final list of long-term parameters were chosen for each park (Table 1.2). There are (or have been recently) water quality monitoring efforts at all GULN inland parks, with the exception of the Natchez Trace Parkway. The NATR may expand its parameter list during the first year of sampling – to be thought of as a water quality inventory. Conversely, parks like BITH and SAAN have a long history of water quality data tied to programs external to the NPS. These parks, which will be monitored by adding sites to existing programs, will include all parameters under the existing program.

Table 1.2 Water quality parameter groups and parks.

Park	Field Measures	Bacteria	Nutrients	Major ions	Metals	Sediment	Other*
BITH	XX	XX	XX	XX	XX	XX	XX
NATR	XX	XX					XX
SAAN	XX	XX	XX	XX		XX	XX
VICK	XX						XX

*Other represents a suite of parameters: BITH (Secchi depth, turbidity, ANC, total hardness), NATR (turbidity), SAAN (Secchi depth, total organic carbon), VICK (turbidity).

As a final note to this preamble, I would like to thank the many people who either assisted me in the field or the office. These include: Kurt Foote (VICK and NATR), Lisa Jameson and Curtis Hoagland (BITH), Greg Mitchell (SAAN), and Douglas Murphy (PAAL). Of course, such an undertaking is made possible with the assistance of the good people at WRD, including Dean Tucker, Gary Rosenlieb, Roy Irwin, and Pete Penoyer, for their general guidance and assistance.

Chapter 2 Hydrogeologic Assessment of the Parks of the Gulf Coast Network

The following park assessments follow a format that describes the general hydrogeology of the park, past work, water quality threats, human uses, aquatic biological findings, and potential sampling locations. These general categories were based on existing data and reasonable assumption. If water quality data exist and show a degraded condition, then the site was considered "degraded". If there were little or no data and adjacent, upstream land uses indicate a strong potential for water quality degradation, the site was considered "potentially degraded". If data indicate, or we could reasonably assume based on adjacent, upstream land use, that water quality was unimpaired, the site was considered "pristine". If reasonable assumptions could not be made the site was considered "potentially degraded". Table 2.1 lists GULN water quality monitoring sites and the relative state of quality. A reasonable water quality inventory exists at three of the five inland GULN parks.

Several criteria were used in choosing sampling sites.

- The site's utility as an "integrator site" – located at the downstream end of a stream, spring, or tributary which are of interest because of presence or absence of significant sources of pollutants within their watersheds.
- The presence of significant aquatic resources in a stream segment, where water quality trend information is needed to corroborate biological trends, or to provide park managers an early warning of potential problems.
- The management interest of a particular site, be it either legislative (protection status mandated by park legislation or management plans) or regulatory placement on non-attainment (303d) list.
- The presence of existing water quality data at a given site. While most sites identified in this document have not been sampled prior to this program, some have. An existing water quality record adds to the utility of establishing long term trends if reoccupied in this program.
- The availability of easy and quick access to the site. Since each park will be sampled synoptically during a single day, sites must be chosen that allow easy and quick access during all flow conditions.
- The ability to safely access a sampling site. Since many water samplers will be alone, sites must be accessed safely in all conditions.

Table 2.1 Water quality monitoring sites of inland parks and general state of overall quality.

Park	Pristine	Potentially Degraded	Degraded
BITH	0	2	4
NATR	4	15	1
PAAL	0	0	0
SAAN	0	3	2
VICK	2	1	0
Total	6	21	7

There are nine waters of the GULN that were listed on the most recent state 303d lists – waters not meeting their designated uses. The park, stream and reason for non-attainment, follows:

BITH: Big Sandy Creek, bacteria
BITH: Turkey Creek, bacteria
BITH: Beech Creek, low dissolved oxygen
BITH: Village Creek, low pH
BITH: Little Pine Island Bayou, low dissolved oxygen (each currently monitored by the Lower Neches Valley Authority)
NATR: North Fork Coles Creek, biological impairment
SAAN: Upper San Antonio River, bacteria (There are two sites on this stream.)
VICK: Yazoo River, aquatic life support (This site will not be monitored under this program).

2.1 Big Thicket National Preserve (Site Visit August 22-24, 2006)

2.1.1 Hydrogeology

It would be difficult to overstate the importance of freshwater at Big Thicket National Preserve. Sprawled over an area of 9000 km2, the park manages 390 km2 or 3,900 hectares and over 300 km of stream corridor. These streams, ranging from headwater creeks to the Neches River, play a vital role in the ecologic function of the Preserve. Draining the southwestern portion of the Lower Neches River, these streams originate in the gently rolling sandy terrain – the adjoining the Trinity River lies to the west – and soon cross the vast flat-lying Costal Plain of Southeast Texas. Adjacent riparian forests depend on regular flooding to replenish nutrients and to support obligate wetland and flood tolerant species.

Streams of the Big Thicket, as they cross the broad southeast Texas Coastal Plain, do not exist as a function of this plain, but as drainage features of the hills to the north. As rain

falls upon the flat-lying sands of the plain, it serves as groundwater recharge, with very little recharging the streams as surface runoff. Indeed, rain must fall in immediate proximity to the stream to serve as surface recharge. Runoff from the slopes of the north is augmented into the numerous ephemeral channels that feed the headwater streams of the Preserve.

With the exception of Menard Creek, all streams within the Preserve drain into the Neches River. Although containing several tributaries, there are two main streams that are in some part managed by the NPS: 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

Big Thicket manages the Neches River corridor – a swath as great as a couple of kilometers wide, or in places, right at the river's edge – from the outfall of the B.A. Steinhagen Lake (US Army Corps of Engineers project) to the salt water barrier just below the confluence with Pine Island Bayou on the edge of Beaumont, Texas. The Neches River below the lake can be divided, from north to south, into the Upper Neches River Corridor, the Jack Gore Baygall and Neches Bottom Unit, and the Lower Neches River Corridor Unit.

The NPS manages approximately 130 km of this highly meandering river corridor. It should be noted that the NPS does not actually own the Neches, or its bed. According to the State of Texas Parks and Wildlife website (2006): "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."

One cannot discuss the hydrology of the Lower Neches River without mention of the Lower Neches Valley Authority (LNVA). This quasi-governmental entity was created by the state of Texas in 1933, primarily to serve the ever-increasing need of freshwater in the lower section of the Neches valley. Land-use was dominated by agricultural activities – with row crops such as potatoes, cotton, oats, and hay in the rolling hills of the northern counties and rice to the south. The LNVA is in the business of providing (selling) water.

Throughout the entire valley, oil and gas exploration was becoming more prevalent during the middle of the 20th century. In order to increase shipping capabilities at the Port of Beaumont, the Neches River downstream to Port Arthur was dredged – wider, deeper, and straighter than natural. This channel modification allowed saltwater from the

gulf to more easily flow “upstream” to Beaumont, 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 US Army Corps of Engineers (USACOE) began a tree-year project to construct a permanent structure just downstream of the confluence of Pine Island Bayou (Figure 2.1). Completed in 2003, the Saltwater Barrier is operated by the LNVA through a federal cost-share agreement.



Figure 2.1 The Saltwater Barrier of the Neches River.

The LNVA, as stated earlier, is in the business of selling water. To assure an ample supply, the LNVA relies on the operation of two USACOE projects, the Sam Rayburn and B.A. Steinhagen Reservoirs. The LNVA has secured rights from the state for 267 trillion gallons per year – projected to be an adequate volume well into the 21st century. The LNVA delivers their water to customers via canals cut into the Neches River and Pine Island Bayou. A potential daily volume of one billion gallons per day is delivered to a variety of cities, water districts, industries and farms.

Village Creek

Village Creek is the largest of the NPS-managed streams. It is fed by Big Sandy Creek – with headwaters in the Alabama-Cousatta 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 park manages over 90% of the main stem of Village Creek, which also passes through the Nature Conservancy's Roy E. Larsen Sandyland Bird Sanctuary and Village Creek State Park.

The park manages none of the Hickory Creek watershed – with exception of a couple 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 of the lower segment of Turkey Creek. Its upper watershed is privately owned and contains several small lakes near Ivanhoe, Texas.

Heading up just southwest of the B.A. Steinhagen Reservoir, is Beech Creek. 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 in large part contained within the Coastal Plain (little of this watershed extends into the hillier north). Pine Island Bayou is comprised of 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.

Menard Creek
The only stream managed by the Preserve that is not within the Neches River watershed is Menard Creek. This stream, heading in the gently rolling hills of the north, parallels the headwaters of Village Creek – actually coming within a couple kilometers of each other – 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.

2.1.2 Past Inventories/Monitoring/Research Activities

The waters of the Preserve, and most notably, the Lower Neches River, have received much attention over the past several decades. The Lower Neches River, with its dependent water users from the LNVA, has been the focus of numerous water quality monitoring programs and thousands of water quality samples. In accordance to state law, the LNVA collects and analyzes water samples approximately every other day for a variety of field measures (pH, temperature, dissolved oxygen, specific conductance, total hardness, total alkalinity, chloride, turbidity, tannin and lignin, true color, ammonia, nitrite, nitrate, orthophosphate, and total phosphate). They conduct monthly measures of Secchi depth and fecal coliform.

In addition to this routine monitoring of the Lower Neches, there has been a considerable effort underway, generally beginning in about 1997, at several locations within the

Preserve's watershed. These sites are sampled quarterly as part of routing monitoring by the LNVA (see maps at end of this assessment).

Neches River at FM 1013, near Spurger, TX (LNVA site 10581)
Neches River near Lakeview Community (LNVA site 15343)
Little Pine Island Bayou at FM 326, north of Sour Lake, TX (LNVA site 15346)
Pine Island Bayou at Old Sour Lake Road, south of Sour Lake (LNVA site 10607)
Pine Island Bayou at SH 105/FM 770, near Batson, TX (LNVA site 15367)
Pine Island Bayou at LNVA Neches 1st Lift, Beaumont (LNVA site 10599)
Pine Island Bayou at US 69/US 96/US 287 (LNVA site 10602)
Big Sandy Creek at US 190 on the Alabama Coushatta Indian Res (LNVA site 15353)
Turkey Creek at FM 1013, near Hillister, TX (LNVA site 15356)
Village Creek at FM 418, near Kountze, TX (LNVA site 13625)
Hickory Creek at US 69, south of Warren, TX (LNVA site 15349)
Beech Creek at FM 1943, near Fred, TX (LNVA site 15355)
Cypress Creek at US 69 at Kountze, TX (LNVA site 13622)

Currently, according the Texas Commission on Environmental Quality (TCEQ) Clean Rivers Program, these sites have been sampled on a quarterly routine basis since 1996 for a variety of field and laboratory measures. It is the objective of this National Park Service program to effectively "fill in the gaps" within this coordinated effort. Those "gaps" are largely within the Preserve.

2.1.3 Associated Land Uses and Water Quality Threats

Threats to water quality of the Lower Neches in general 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 the scale. The Lower Neches alone drains approximately 25,400 km2. Conversely, on a local scale, the two main tributaries of the Lower Neches within the Preserve are Village Creek (2,230 km2), and Pine Island Bayou (1,640 km2 above pump station). Within any of these three watersheds, the NPS owns, and thus controls a very small portion. Consider a conservative estimate in that the Big Thicket National Preserve, 390 km2, comprises approximately 1.5 % of the entire Neches River watershed.

Land-uses in many ways, define non-point source threats to water quality. Within the Neches watershed are thousands of hectares of agricultural and silvicultural activities – each lending a degree, or at least the potential, of water quality threat. There are many oil and gas wells and their associated point source threats to water quality. According to the NPS "Baseline Water Quality Data Inventory and Analysis" (1995), there are fourteen permitted industrial discharges within the Preserve's watershed.

Specific water quality non-attainments will be addressed for each proposed water quality site below. There are many other streams draining into the Preserve that have made the 303d list. While they will not be included in this monitoring effort – they are routinely monitored by the LNVA – the reader should be informed of these documented degraded streams upstream of park lands.

Pine Island Bayou is listed as non-attainment, from its confluence with the Neches River to its headwaters, for depressed dissolved oxygen. Both point and non-point sources are cited for these low concentrations. Several tributaries of Pine Island Bayou are listed as 303d waters; Boggy Creek, Little Pine Island Bayou, Willow Creek, and Cypress Creek (depressed dissolved oxygen). Willow Creek was also flagged for exceeding the acute aluminum concentration. Lake Kimball, an impoundment of Kimball and Village Creeks, exceeded the mercury standard in fish tissue.

2.1.4 Human Use and Aquatic Biology

Within the Preserve, human use generally consists of primary and secondary recreational contact on the Neches River and limited secondary contact on 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: Saltwater Barrier (operated by the LNVA), Confluence (is this a place?), Lakeview Sandbar, and Evadale.

Boating and fishing activities on the tributaries are limited (due to stream size) to the lower portions of the watersheds. There is a boat ramp on Pine Island Bayou (near the US 287 bridge), and canoe launching is provided on Village Creek at the US 96 bridge and in the Village Creek State Park. Fishing access is gained by the Birdwatchers Trail at the mouth of Menard Creek as well.

While there are no federally listed aquatic species in the Preserve, several are listed as threatened by the state of Texas. Fish include: blue sucker (Cycleptus elongates), bluehead shiner (Nottropis hubbsi), creek shubsucker (Erimyzon oblongus), paddlefish (Polyodon spathula), and the river goby (Awaous tajasica). The alligator snapping turtle is also listed as threatened by the state.

The Big Thicket region of Texas has been a favorite of aquatic biologists for decades and has been the recipient of numerous biological inventories. Parks, et al. (1954) conducted a general biological survey – assessing 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. While effects of land-use change were noted at this time as timber was cut and land was put into agrarian uses, Parks, et al. were amazed at the biological diversity of the Big Thicket.

McCullough (1974) compiled existing surveys of invertebrate fauna of the proposed preserve. He reported that 51 species of mollusca had been found – including 14 species of helicidae (snails) and 37 species of unioidae (mussels).

Suttkus and Clemmer (1979) were contracted by the National Park Service 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 note 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 of the Town Bluff Dam (B.A. Steinhagen Reservoir) supports one of the most abundant and diverse unionid assemblages remaining in Texas. However, he also reports that there are few living mussels in the area downstream of Silsbee/Evadale. 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 (family Cyprinidae) and sunfishes (family Centrarchidae). Reaches with smaller channel sizes had higher species richness that the larger reaches of the Neches River and Pine Island Bayou. Riffle beetles (family Elmidae) and midges (family Chironomidae) dominated aquatic insects. The EPT index (Ephemeroptera – Plecoptera – Trichoptera) was the smallest in Little Pine Island Bayou – a stream also included in the state 303d list. Moring (2003) also concluded that the percentage of urban land-use was negatively correlated to reach structure index, which indicates less stable habitat for aquatic biota.

2.1.5 Proposed Water Quality Monitoring Locations

This program will focus on the Village Creek watershed. It is the largest watershed within the preserve (with exception, of course, the Neches River), and more importantly, contains the largest tracts of NPS land. There are adequate extant long-term WQ monitoring efforts in both the Lower Neches River (by both the USGS and LNVA), and Pine Island Bayou (TCEQ) to allow us to concentrate on Village Creek.

The following six site descriptions include:

Photo of Site:	Taken during site visit August, 2006 (Figures 2.2 – 2.7)
Site Name:	Four digit park code and four digit site code
Site Description:	Brief report of site
Public Access:	Does the park provide public access to water?
Recreation:	Type 1 (primary contact; emersion, swimming), Type 2 (secondary contact; wading or fishing.
Listed Species:	State or Federally listed aquatic species.
State Designated Use:	Designated use classified by specific state. Those in italics were not classified by state, but were by the author using state criteria.
303d list:	Is this water on the most recent state 303d impairment list?

Interpretative display: Does the park provide an interpretative display relative to water?
Water Quality: Depending on existing data, either demonstrated or anticipated water quality: pristine, potentially degraded, or degraded.
Coordinates: Geospatial coordinates of site in NAD83; locations shown in Figure 2.8

303d listed waters include the following category; 5c – The water body does not meet its water quality standards, but additional data will be collected before a TMDL (total maximum daily load) is scheduled). 303d list ranks include; “D” – additional data will be collected before a TMDL is scheduled, while a rank “S” indicates that a standards review will be conducted before a TMDL is scheduled.



Figure 2.2 Menard Creek (BITH_MCMC)

This is the only stream in the Preserve that does not contribute flow to the Neches River – it flows into the Trinity River – and will be sampled at its mouth. 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 an easy 300 m stroll along the "Birdwatcher's Trail".

Public Access: Yes
Recreation: Type 1 and 2
Listed Species: Unknown
State Designated Use: Aquatic Life, Contact Recreation
303d list: No
Interpretative display: No
Water Quality: Potentially degraded
Coordinates (NAD 83):
30 26 15.7 94 50 29.6



Figure 2.3 Big Sandy Creek (BITH_BSVC)

This stream – which changes its name 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. This site represents a headwater site within the Village Creek watershed. Two additional sites will be sampled, at approximate mid and end-points of Village Creek. Upstream of the Big Sandy Creek is the Alabama-Coushatta Indian Reservation (location of a TCEQ Clean Rivers sampling site). Access is gained from the approach to the FM 1276 bridge. Note oil pipeline crossing stream in foreground. This is very common throughout the Preserve.

Public Access: No
Recreation: No
Listed Species: Possible
State Designated Use: Aquatic Life (High), Contact Recreation, Public Water Supply
303d list: Yes; bacteria, non-point source, category 5c, rank D
Interpretative display: No
Water Quality: Degraded
Coordinates (NAD 83):
30 34 35.4 94 37 50.5



Figure 2.4 Village Creek at Kirby Nature Trail (BITH_KTVC)

Near its mid-point, Village Creek will be sampled at the crossing of the Preserve's Kirby Nature Trail. This site is immediately downstream of the confluence of Hickory Creek, a significant tributary to Village Creek on which the NPS has no lands, currently. The site is accessed by an easy 1 km walk along the Kirby Nature Trail and sampled below the footbridge crossing.

Public Access: No
Recreation: No
Listed Species: Possible
State Designated Use: Aquatic Life (High), Contact Recreation, Public Water Supply
303d list: No
Interpretative display: No
Water Quality: Potentially degraded
Coordinates (NAD 83):
30 28 13.3 94 20 47.7



Figure 2.5 Turkey Creek (BITH_TCTC)

Turkey Creek, another significant tributary to Village Creek, will be sampled immediately upstream of its mouth at the crossing of the Kirby-Turkey Creek Trail. Unlike Hickory Creek, the Preserve manages a considerable portion 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. The site is accessed by an additional 1 km walk beyond the Village Creek bridge, and sampled below the Turkey Creek footbridge crossing.

Public Access: No
Recreation: No
Listed Species: Possible
State Designated Use: Aquatic Life (High), Public Water Supply
303d list: Yes; bacteria, non-point source, category 5c, rank D
Interpretative display: No
Water Quality: Degraded
Coordinates (NAD 83):
30 42 33.2 94 20 29.0



Figure 2.6 Beech Creek (BITH_MBBC)

The Preserve controls much of the headwaters of Beech Creek (the Beech Creek Unit), which is also a tributary of Village Creek. The NPS has proposed acquisition of the remaining headwaters of Beech Creek. This headwater stream will be sampled at the crossing of the Moss Road Bridge. Access is gained by the approach to this low bridge.

Public Access: No
Recreation: No
Listed Species: Possible
State Designated Use: Aquatic Life (High), Public Water Supply
303d list: Yes; depressed dissolved oxygen, point source and non-point source, category 5c, rank D
Interpretative display: No
Water Quality: Degraded
Coordinates (NAD 83):
30 42 33.2 94 11 57.0



Figure 2.7 Village Creek at Village Creek State Park (BITH_SPVC)

This State Park site represents the third and most downstream sampling location along Village Creek. By this point Village Creek has grown from shallow headwater streams of Big Sandy, Hickory, Turkey, and Beech Creeks to a navigable waterway. The site is accessed at the primitive canoe launch of Village Creek State Park.

Public Access: Yes
Recreation: Type 1 and 2
Listed Species: Possible
State Designated Use: Aquatic Life (High), Contact Recreation, Public Water Supply
303d list: Yes; low pH, non-point source, category 5c, rank S
Interpretative display: No
Water Quality: Degraded
Coordinates (NAD 83):
30 15 20.9 94 10 14.2

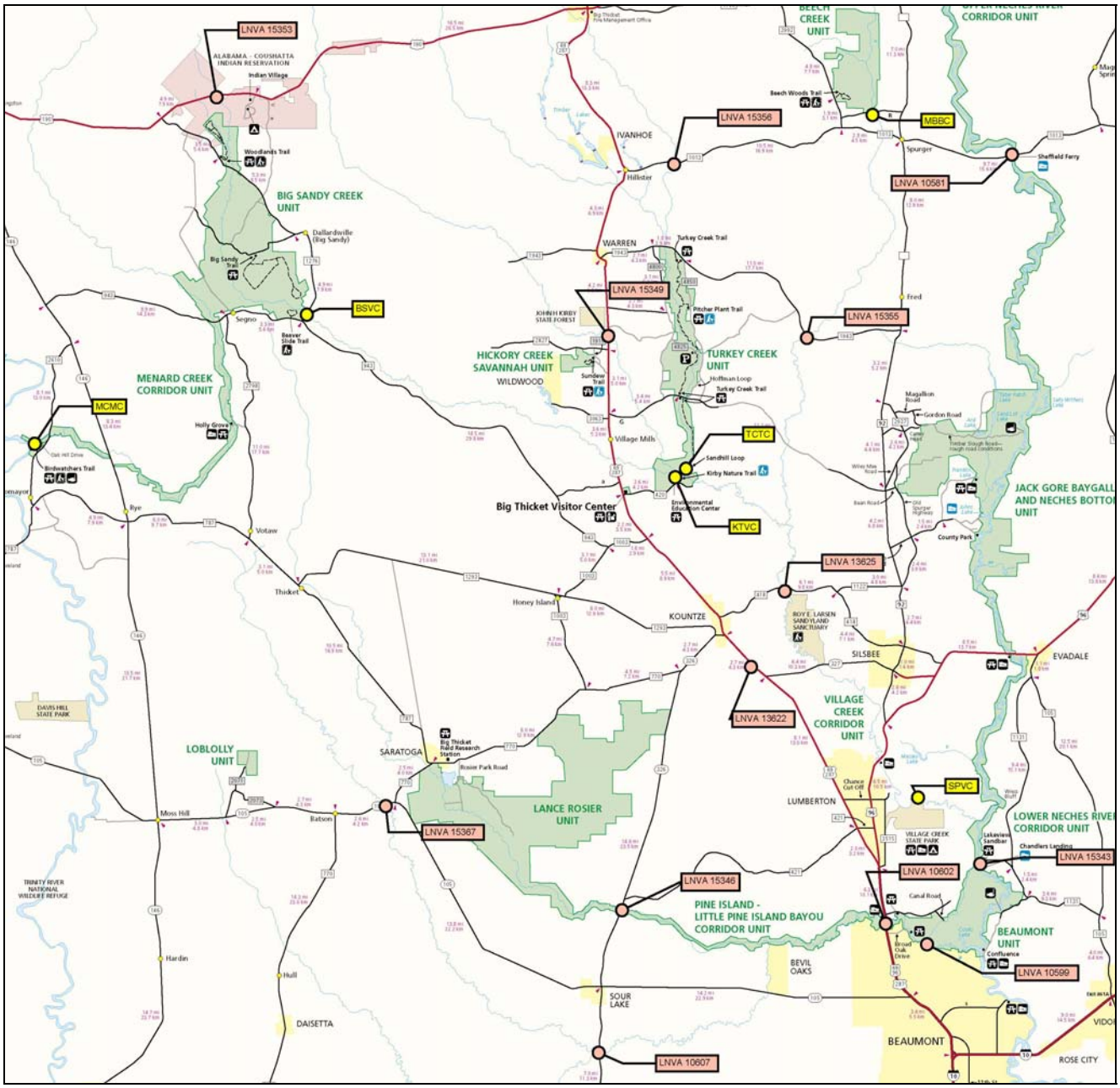


Figure 2.8 Map of existing LNVA (red) and proposed GULN (yellow) water quality sampling sites BITH.

2.2 Natchez Trace Parkway (Site Visit August 7-9, 2006)

2.2.1 Hydrogeology

For a park not known for its water resources, there is a considerable amount of quality water resources along the parkway. From the bedrock streams of Tennessee, through the loess banks of northern Mississippi, and onto the cypress sloughs and swamps of the lower Trace, water is ubiquitous. The 740 kilometers of the parkway crosses eight watersheds: the Cumberland, Duck, Buffalo, Tennessee, Tombigbee, Yockanookany, Pearl, the Big Black rivers, and several smaller watersheds (classified by the state as "South Independent Streams" in southwestern Mississippi. While the vast majority of streams are crossed without access or even signage, there are dozens that provide an interpretative backdrop, both cultural and natural, and recreational stops to cool a summer traveler.

While initially daunting – how to choose among scores or streams and springs – determination of potential water quality monitoring sites became relatively easy when one becomes a tourist of the park. Notwithstanding management goals and objectives, the presence of Threatened and Endangered species, or 303d list waters, waters that should be important to the park are the waters that are important to the visitor. All along the trip the visitor is directed to dozens of water sites; a family splashing through the shallows of Garrison Creek, a couple in a swimming hole at Metal Ford of the Buffalo, a group of school-aged kids and a bike riding couple cooling off in Glenrock Branch. At nearly every stop where access (and an interpretative message) was given, visitors were found. These are the waters, if for no other reason for those outlined above, which should become the core of the water quality monitoring program at the Natchez Trace Parkway (NATR).

2.2.2 Past Inventories/Monitoring/Research Activities

Although proximal to several Universities – Tennessee State and Vanderbilt near the northern terminus, Mississippi State near its midpoint, and Louisiana State near its southern end – and represented by scores of streams, little water quality inventories, studies or monitoring has occurred. Regardless of the reasons why the parkway's water quality has been neglected from an academic scope, it is safe to state that little has been done. There are, however, many studies done within the various watersheds that are traversed by the parkway. To list and discuss each would not be beneficial at this point as none directly address park resources.

2.2.3 Associated Land Uses and Water Quality Threats

It is reasonable to assume that a parkway that is 740 km long and bisects over 30 significant streams (order 2 or higher), that land-use upstream from each stream crossing will be manifested in water quality where it crosses the parkway. The vast majority of the

parkway winds through the rural south. Watersheds are dominated by agrarian and sylvan land uses. The parkway does pass through two urban areas: Tupelo and Jackson Mississippi. Several small streams are partially drained by these municipalities, albeit, mainly residential in land use.

In 1998 the Mississippi Lignite Mining Company proposed the construction of a 2,300 hectare surface lignite mine and 440 megawatt power plant along 8 km of the Parkway (as close as 150 m to the boundary) near the Jeff Busby Unit (Moss and VanMouwerik, 1998). While the project was supported by state and local interests, the National Park Service was concerned about potential impacts of air and water quality, as well as degradation of the viewshed from Little Mountain. Negotiations between the mining company and the Park Service resulted in collection of baseline water quality data and an aquatic biological inventory of potentially affected streams (Middle and Little Bywy Creeks).

2.2.4 Human Use and Aquatic Biology

Human recreational contact is prevalent in streams, especially in the high-gradient, bedrock and gravel channels of Tennessee and Alabama. Recreation diminishes southward as sluggish streams and banks are bedded in mud and silt. A typical summer weekend sees nearly every visitor access-point situated along a waterbody full of vehicles and their associated streams full of visitors. Although each state may classify recreational contact with different language, we can generally apply both primary-contact (swimming and wading), and secondary-contact (fishing and other non-emersion activities) at most streams of the parkway.

A review of species lists indicates the presence of three federally (threatened) listed fish: bayou darter (Etheostoma rubrum), slackwater darter (Etheostoma boschungi) and spotfin chub (Cyprinella monacha). Seven mussels are also federally listed as endangered: birdwing pearly (Conradilla caelata), cumberland monkeyface pearly (Quadrula intermedia), orange-footed pearly (Plethobasus cooperianus), pale lilliput pearly (Toxolasma cylindrellus), tan riffle shell (Epioblasma walkeri), turgid-blossom pearly (Epioblasma turgidula) and yellow-blossom pearly (Epioblasma florentina florentina). The American alligator (Alligator mississippiensis), federally threatened, is also listed for the Parkway. State listings include the fish; crown darter (Etheostoma corona), crystal darter (Crystallaria asprella) and flame chub (Hemitremia flammea), and the aquatic amphibians; hellbender (Cryptobranchus alleganiesis) and northern spring salamander (Gyrinophilus prophynriticus).

There have been three aquatic biological studies within the parkway. Ross (1994) conducted an inventory of fishes within the vicinity (10 km buffer) of the Mississippi portion of the parkway. This study did not include field sampling, but rather was an examination of pre-existing collections, dating from 1853 to the early 1990s. This compilation found 122 species of fish (12 orders, 18 families) including two State listed (Etheostoma rubrum and Crystallaria asperlla). The former is also listed as Federally endangered. The network is currently undertaking a new and comprehensive fish

inventory for NATR. That inventory will provide a current list of species found in park waters.

Johnson and Phillips (1999) completed a fish and mussel survey of the Bear Creek watershed (Mississippi). This study, prepared as a comparison to a 1968 work, sampled various locations along Bear Creek and its tributaries. Two sites were located within (or at least adjacent to the parkway) for this project, but were not part of the 1968 study, hence comparative analysis is not possible for the two park sites. The authors report the inventory of 18 species of mussels and 14 species of fish at the two park sites in 1999.

Paxton (et al.) conducted a survey of the fisheries of the Tennessee portion of the parkway in 2000. These researchers collected fish by seining streams crossing or originating within the parkway within 10 km of the parkway. There is an extremely limited discussion of results as the report largely consists of species and location tables.

2.2.5 Proposed Water Quality Monitoring Locations

The list of potential WQ monitoring sites was reduced to include only those sites where visitors are directed to and participate in aquatic recreational activities, or sites that display a water-resources interpretative message, or that have been previously used to establish base-line water quality information. The only exceptions lie in Mississippi. As there is a dearth of "desirable" recreational streams, I have included several streams from the Magnolia State, as to give, at least some spatial representation along the Trace.

The following twenty site descriptions include:

Photo of Site:	Taken during site visit August, 2006 (Figures 2.9 – 2.28)
Site name:	Four digit park code and four digit site code
Site Description:	Brief report of site
MM:	Closest Mile Marker
State:	State where site is located.
Public Access:	Does the park provide public access to water?
Recreation:	Type 1 (primary contact; emersion, swimming), Type 2 (secondary contact; wading or fishing.
Listed Species:	State or Federally listed aquatic species.
State Designated Use:	Designated use classified by specific state. Those in italics were not classified by state, but were by the author using state criteria.
303d list:	Is this water on the most recent state 303d impairment list?
Interpretative display:	Does the park provide an interpretative display relative to water?
Water Quality:	Depending on existing data, either demonstrated or anticipated water quality: pristine, potentially degraded, or degraded.
Coordinates:	Geospatial coordinates of site in NAD83; locations shown in Figure 2.29



Figure 2.9 Garrison Creek (NATR_GCGC)

Located adjacent to horse trailer parking lot and picnic ground. This stream receives much public use and is proximal (10 m) from horse riding trail head. Garrison Creek can be sampled easily and safely in all conditions.

MM 428
State: TN
Public Access: Yes
Interpretative Display: No
Recreation: Type 2
Listed Species: Unknown
State Designated Use: Fish and Aquatic Life; Recreation
303d list: No
Water Quality: Potentially degraded
Coordinates (NAD 83):
35 52 31.9 87 01 50.1



Figure 2.10 Burns Branch (NATR_BBBB)

Burns Branch is typical of small order streams draining this portion of the parkway. This site is located adjacent to the parking lot and picnic grounds. A horse riding trail parallels this stream for some distance upstream.

MM 425
State: TN
Public Access: Yes
Interpretative display: No
Recreation: Type 2
Listed Species: Unknown
State Designated Use: Fish and Aquatic Life; Recreation
303d list: No
Water Quality: Potentially degraded
Coordinates (NAD 83):
35 50 53.7 87 03 11.9

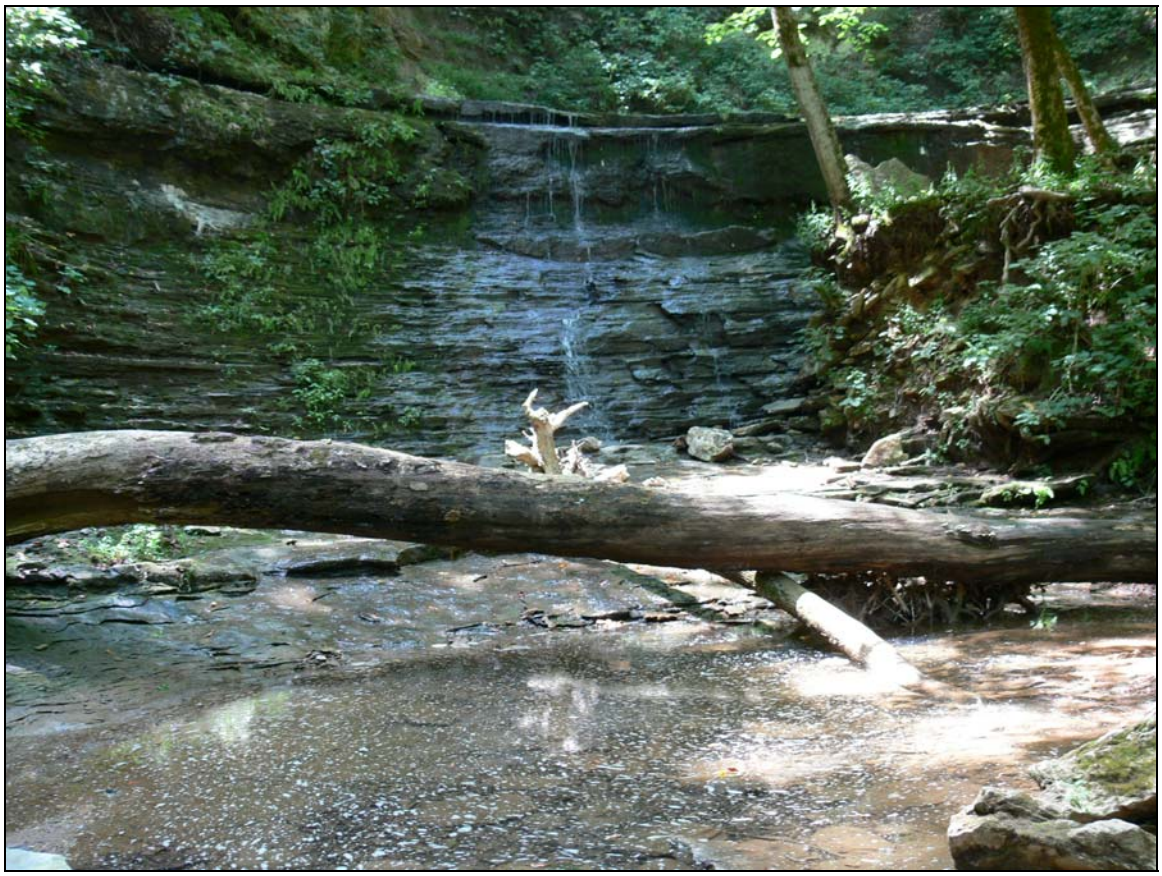


Figure 2.11 Jackson Falls (NATR_JFJF)

Jackson Falls drains a portion of Jackson Branch largely originating within the parkway corridor. Access is gained via a nature trail and should be safe in all conditions (the sampler should exercise caution during times of ice and snow).

MM 425
State: TN
Public Access: Yes
Interpretative display: Yes
Recreation: Type 2
Listed Species: Unknown
State Designated Use: Fish and Aquatic Life; Recreation
303d list: No
Water Quality: Pristine
Coordinates (NAD 83):
35 41 48.4 87 17 45.9



Figure 2.12 Fall Hollow (NATR_FHFH)

Fall Hollow, similar to Jackson Falls, generally originates from within the parkway corridor. The site is accessed via a nature trail leading from the parking lot. Caution should be used during wet and icy conditions.

MM 393
State: TN
Public Access: Yes
Interpretative display: No
Recreation: Type 2
Listed Species: Unknown
State Designated Use: Fish and Aquatic Life; Recreation
303d list: No
Water Quality: Pristine
Coordinates (NAD 83):
35 35 01.3 87 25 44.6



Figure 2.13 Little Swan Creek (NATR_LSLS)

Little Swan Creek flows along a picnic grounds near a public access point. Again, this area is typical of moderate-gradient riffle-pool streams of the northern section of the Trace. Access is easy and safe in all conditions.

MM 385
State: TN
Public Access: Yes
Interpretative Display: No
Recreation: Type 2
Listed Species: Unknown
State Designated Use: Fish and Aquatic Life; Recreation
303d list: No
Water Quality: Potentially degraded
Coordinates (NAD 83):
35 31 47.0 87 27 12.8

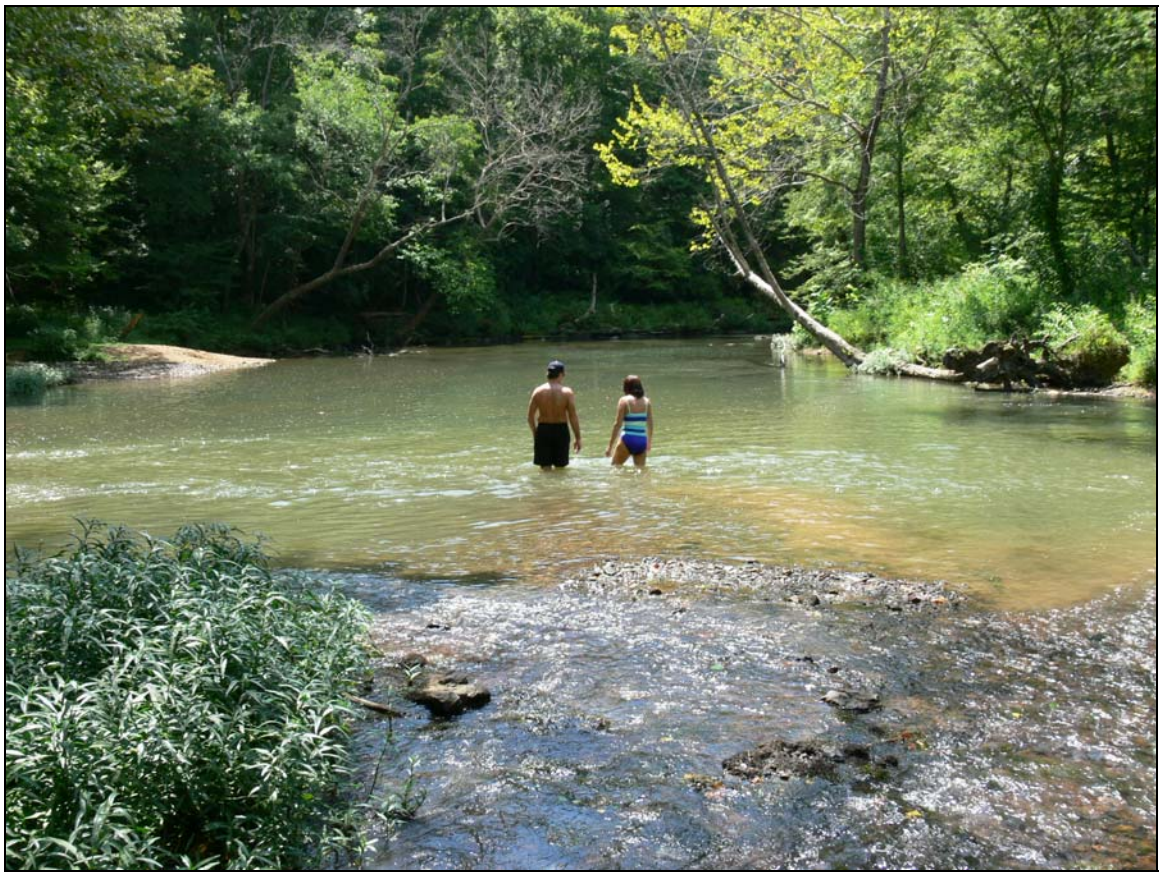


Figure 2.14 Metal Ford (NATR_MFBR)

The upper Buffalo River can be sampled at the public access point at Metal Ford. This is the largest public-accessible stream along the Trace. This site, which is highly visited by recreationalists, is easily sampled in all conditions.

MM 383
State: TN
Interpretative display: Yes
Public Access: Yes
Recreation: Type 1 and 2
Listed Species: Unknown
State Designated Use: Fish and Wildlife; Recreation
303d list: No
Water Quality: Potentially degraded
Coordinates (NAD 83):
35 27 48.6 87 28 47.3



Figure 2.15 Jacks Branch (NATR_JBJB)

Jacks Branch is typical of a moderate rock and gravel bedded stream – a modest gradient with frequent riffles and pools. Access is gained via a path from the adjacent parking lot.

MM 378
State: TN
Public Access: Yes
Interpretative display: No
Recreation: Type 2
Listed Species: Unknown
State Designated Use: Fish and Aquatic Life, Recreation
303d list: No
Water Quality: Potentially degraded
Coordinates (NAD 83):
35 24 49.6 87 30 58.4



Figure 2.16 Glenrock Branch (NATR_GBGB)

Glenrock Branch is a popular recreational site for park visitors. Gravel riffles typify the stream as it flows past limestone outcrops. The majority of its watershed is within the parkway, with the remaining portion in forested land. Access is gained from the adjacent parking lot.

MM 364
State: TN
Public Access: Yes
Interpretative display: No
Recreation: Type 1 and 2
Listed Species: Unknown
State Designated Use: Fish and Aquatic Life, Recreation
303d list: No
Water Quality: Pristine
Coordinates (NAD 83):
35 15 16.3 87 30 58.4



Figure 2.17 Sweetwater Branch (NATR_SBSB)

Sweetwater Branch drains private forested lands west of the parkway. Similar to streams throughout the region, this gravel-bedded stream flows through riffles and pools. Access is gained via the adjacent parking lot.

MM 363
State: TN
Public Access: Yes
Interpretative display: No
Recreation: Type 2
Listed Species: Unknown
State Designated Use: Fish and Aquatic Life, Recreation
303d list: No
Water Quality: Potentially degraded
Coordinates (NAD 83):
35 15 03.0 87 39 06.5



Figure 2.18 Cypress Creek (NATR_CCCC)

Cypress Creek, also a popular recreational site, is a broad gravel-bedded stream that parallels the parkway for several kilometers. This sampling site is at the picnic grounds and public access point 50 m from the parking lot.

MM 344
State: TN
Public Access: Yes
Interpretative display: No
Recreation: Type 2
Listed Species: Unknown
State Designated Use: Fish and Aquatic Life; Recreation
303d list: No
Water Quality: Pristine
Coordinates (NAD 83):
35 01 51.3 87 49 19.2

While sampling site for Cypress Creek is within the state of Tennessee, it is important to note that the state of Alabama, downstream from the site, considers Cypress Creek an outstanding water (listed in the National Rivers Inventory). The state considers this water a “Significant recreational site”, and is a “Designated canoe trail.



Figure 2.19 Colbert Creek (NATR_RSCC)

Colbert Creek, at this sampling location, is dominated by flow from Rock Springs – approximately 50 m upstream. The watershed of Rock Spring is not known as no groundwater tracing has occurred. Access is gained by a short hike from the Rock Springs parking lot.

MM 331
State: AL
Public Access: Yes
Interpretative display: No
Recreation: Type 2
Listed Species: Unknown
State Designated Use: Fish and Wildlife
303d list: No
Water Quality: Potentially degraded
Coordinates (NAD 83):
34 51 25.9 87 54 17.6



Figure 2.20 Buzzards Roost Spring (NATR_BSBS)

Buzzards Roost Spring is a small limestone spring draining, like Rock Springs to the north, an unknown area. Access is gained from the adjacent parking lot.

MM 320
State: AL
Public Access: Yes
Interpretative display: Yes
Recreation: Type 2
Listed Species: Unknown
State Designated Use: Fish and Wildlife
303d list: No
Water Quality: Potentially degraded
Coordinates (NAD 83):
34 45 35.5 88 01 24.5



Figure 2.21 Bear Creek (NATR_BCBC)

Bear Creek, while not providing easy public access, is nonetheless used recreationally. It is also the location of one of the few biological studies conducted along the Trace. While free flowing as it passes the Trace, its headwaters are impounded.

MM 313
State: AL
Public Access: No
Interpretative display: No
Recreation: Type 1 and 2
Listed Species: Unknown
State Designated Use: Fish and Wildlife
303d list: No
Water Quality: Potentially degraded
Coordinates (NAD 83):
34 40 23.0 88 05 20.9



Figure 2.22 Jourdan Creek (NATR_JCJC)

Jourdan Creek represents the southern-most of the gravel-bedded streams along the Trace. Located near Mile Marker 295, this stream is accessed via an adjacent parking lot.

MM 295
State: MS
Public Access: Yes
Interpretative display: No
Recreation: Type 2
Listed Species: Unknown
State Designated Use: Fish and Wildlife
303d list: No
Water Quality: Potentially degraded
Coordinates (NAD 83):
34 31 00.9 88 1 29.4



Figure 2.23 Middle Bywy Creek (NATR_MBMB)

Draining lands around the Jeff Busby campground, the preservation of the quality of Middle Bywy Creek was of concern during the early 1990s. This site can be accessed from the parkway at a bridge crossing.

MM 195
State: MS
Public Access: No
Interpretative display: No
Recreation: No
Listed Species: Unknown
State Designated Use: Fish and Wildlife
303d list: No
Water Quality: Potentially degraded
Coordinates (NAD 83):
33 25 20.9 89 15 53.1



Figure 2.24 Little Bywy Creek (NATR_LBLB)

Draining lands around the Jeff Busby campground, the preservation of the quality of Little Bywy Creek was of concern during the early 1990s. This site can be accessed from the parkway at a bridge crossing.

MM 193
State: MS
Public Access: No
Interpretative display: No
Recreation: No
Listed Species: Unknown
State Designated Use: Fish and Wildlife
303d list: No
Water Quality: Potentially degraded
Coordinates (NAD 83):
33 24 25.1 89 16 30.0

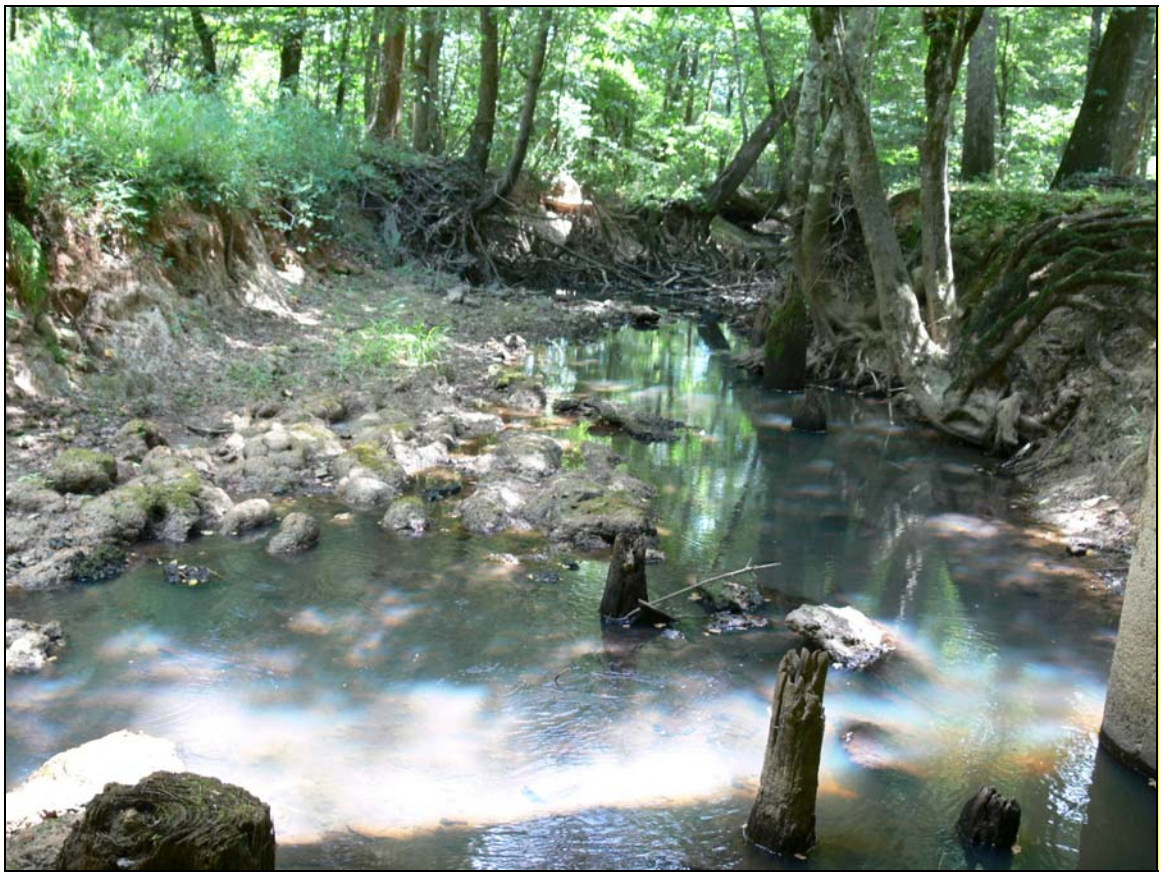


Figure 2.25 Hurricane Creek (NATR_HCHC)

Hurricane Creek, located near Mile Marker 165, shows signs of severe erosion of its loess banks. It is one of the few streams with turbulent flow in this section of the parkway. Sampling will occur at the parkway bridge near the Hurricane Creek parking lot.

MM 165
State: MS
Public Access: No
Interpretative display: Yes
Recreation: No
Listed Species: Unknown
State Designated Use: Fish and Wildlife
303d list: No
Water Quality: Potentially degraded
Coordinates (NAD 83):
33 04 59.0 89 31 30.1



Figure 2.26 Little Sand Creek (NATR_RSLS)

Located beside the Rocky Springs (which no longer flows) Campground, Little Sand Creek flows over course gravels through small riffles and pools.

MM 55
State: MS
Public Access: Yes
Interpretative display: Yes
Recreation: Type 2
Listed Species: Unknown
State Designated Use: Fish and Wildlife
303d list: No
Water Quality: Potentially degraded
Coordinates (NAD 83):
32 05 28.4 90 47 53.4



Figure 2.27 Mud Island Creek (NATR_MIMI)

Mud Island Creek typifies the loess-banked, fine substrate low-gradient streams of southern portion of the Trace. The site is accessed by a path leading from the parking lot through the picnic grounds.

MM 22
Public Access: Yes
Interpretative display: No
Recreation: Type 2
Listed Species: Unknown
State Designated Use: Fish and Wildlife
303d list: No
Water Quality: Potentially degraded
Coordinates (NAD 83):
31 46 00.1 91 09 50.5

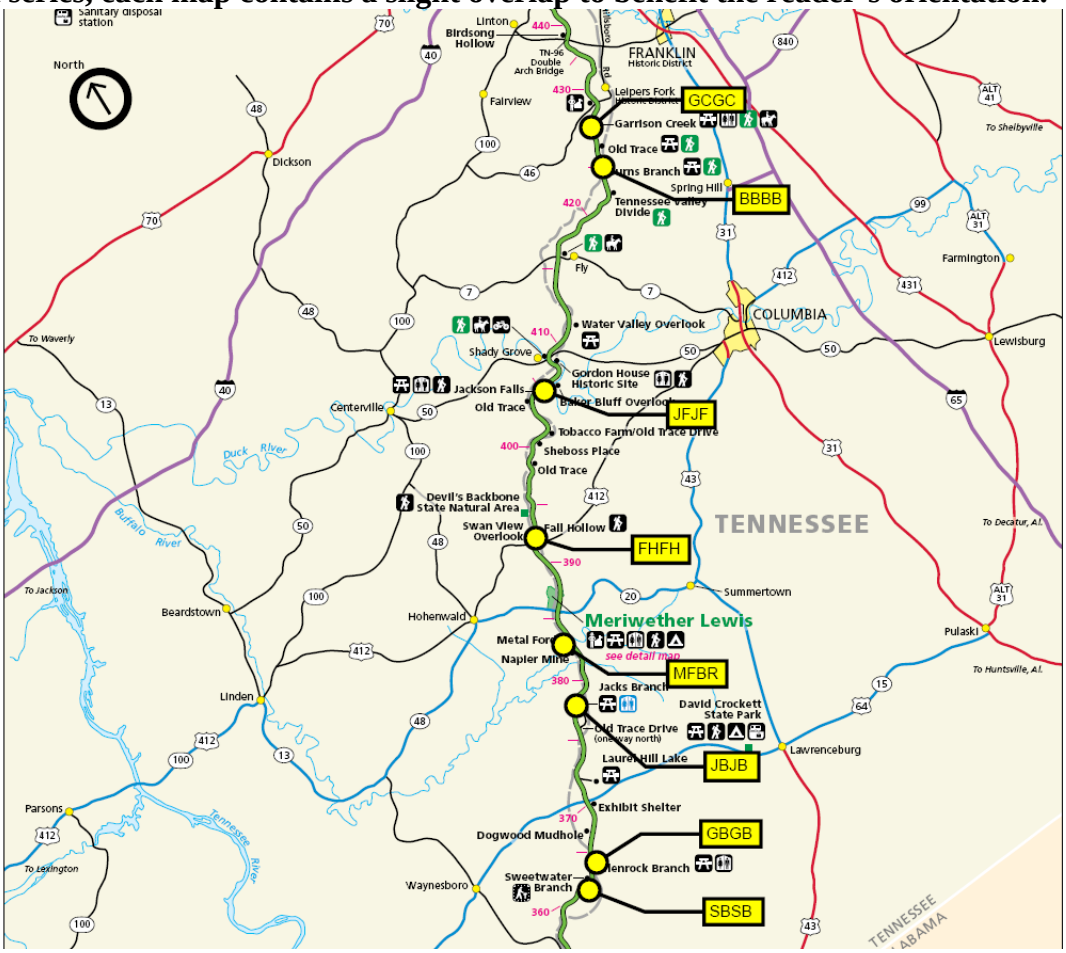


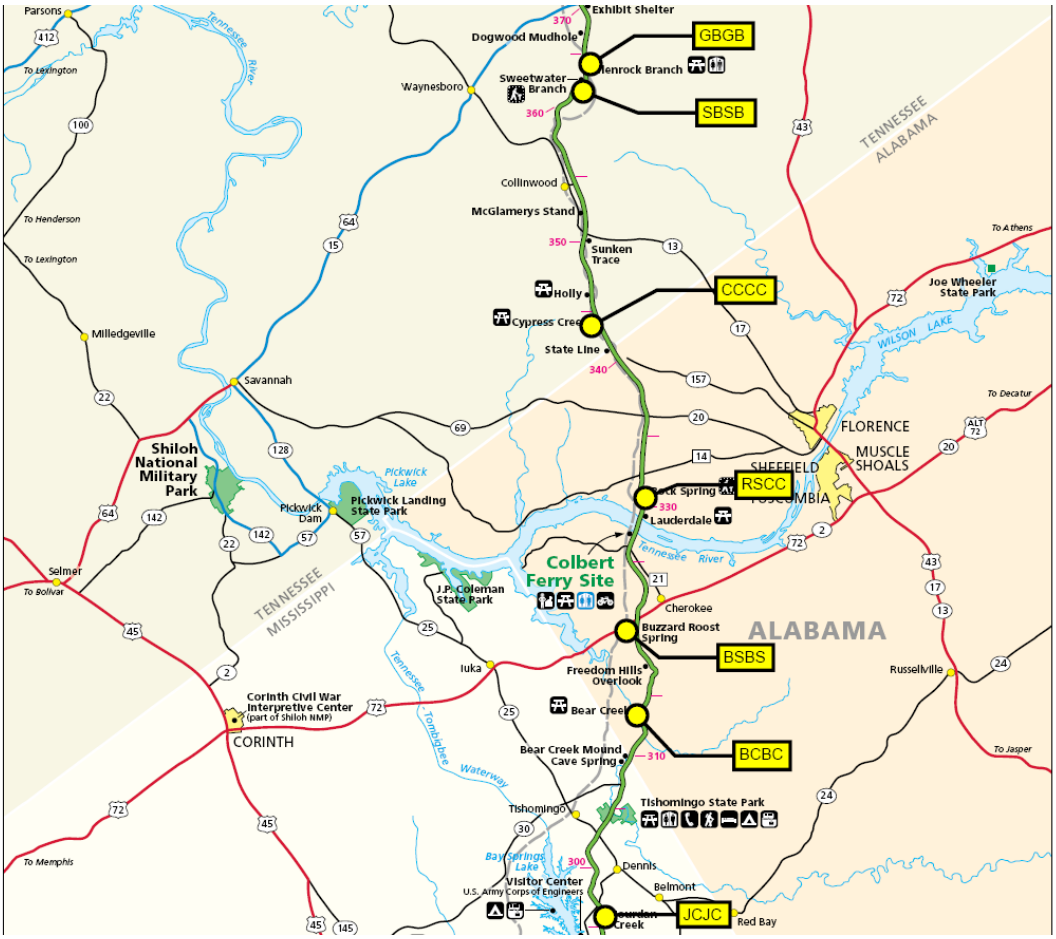
Figure 2.28 North Fork Coles Creek (NATR_NFCC)

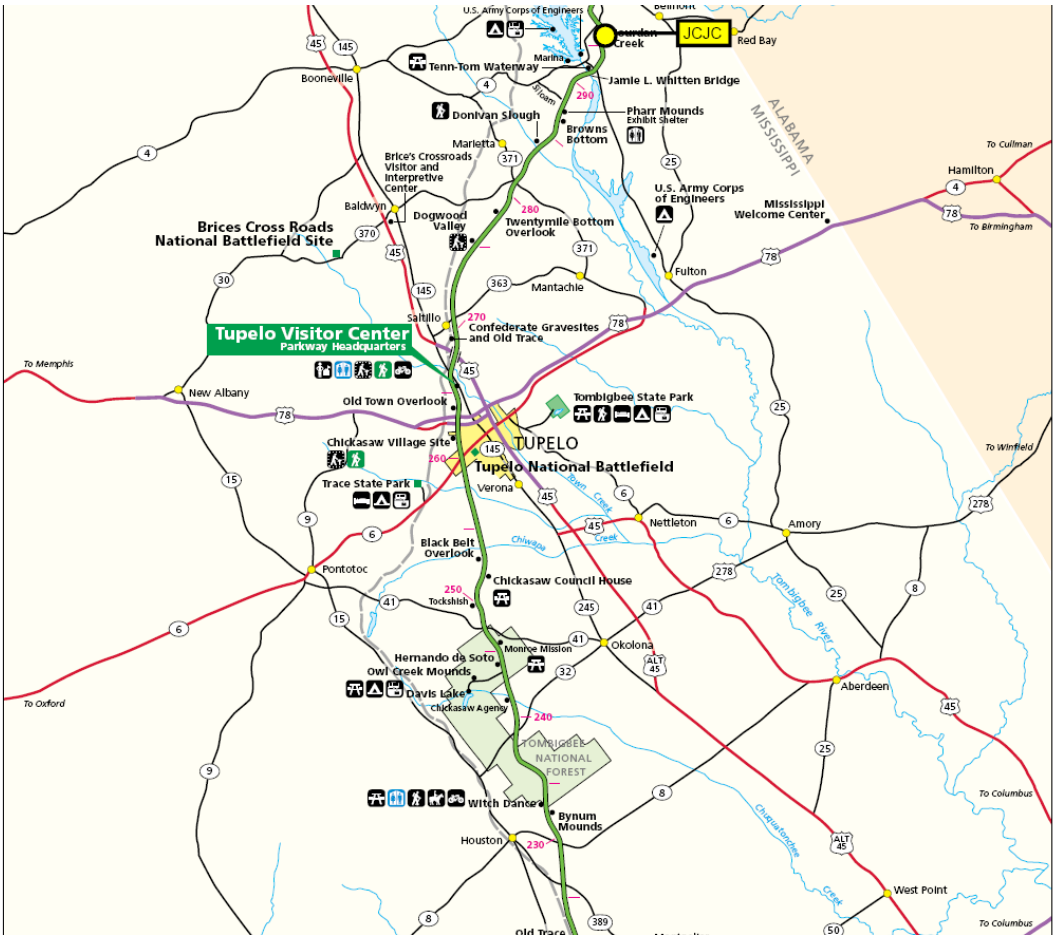
North Fork Coles Creek is the only current 303d listed stream in the Trace. The entire main stem of the North Fork has been classified as non-attainment due to biological impairment. There is no easy public access.

MM 24
State: MS
Public Access: No
Interpretative display: No
Recreation: No
Listed Species: Unknown
State Designated Use: Fish and Wildlife
303d list: Yes, Biological impairment.
Water Quality: Degraded
Coordinates (NAD 83):
31 46 47.9 91 08 26.1

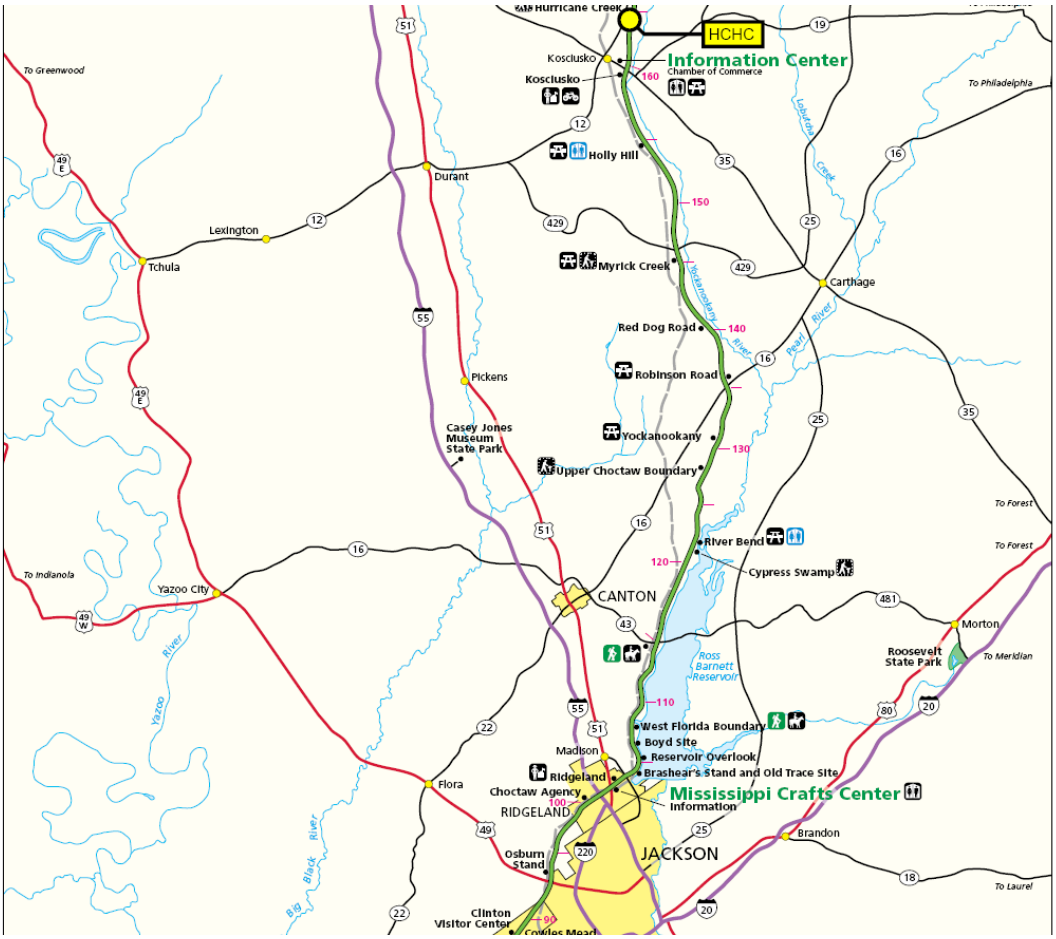
Figure 2.29 Due to the long, linear nature of the Parkway its map will be presented in a series, each map contains a slight overlap to benefit the reader's orientation.

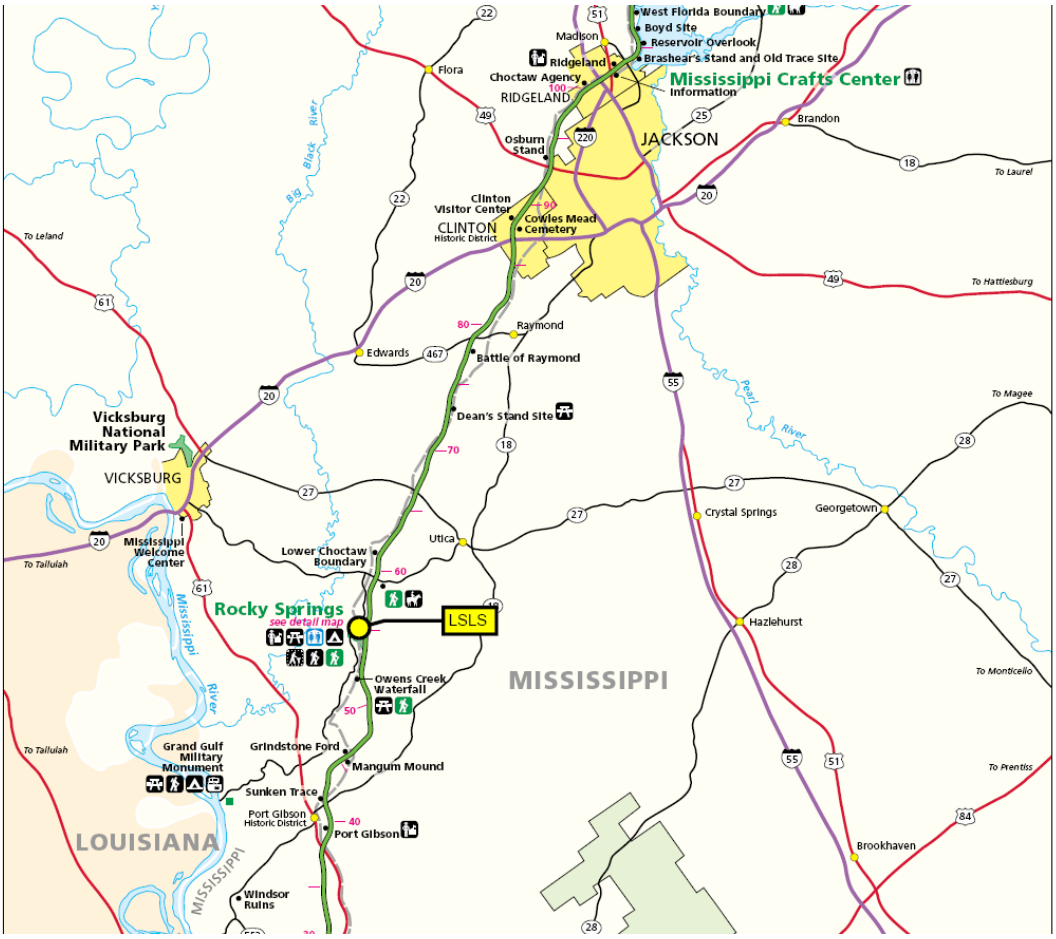


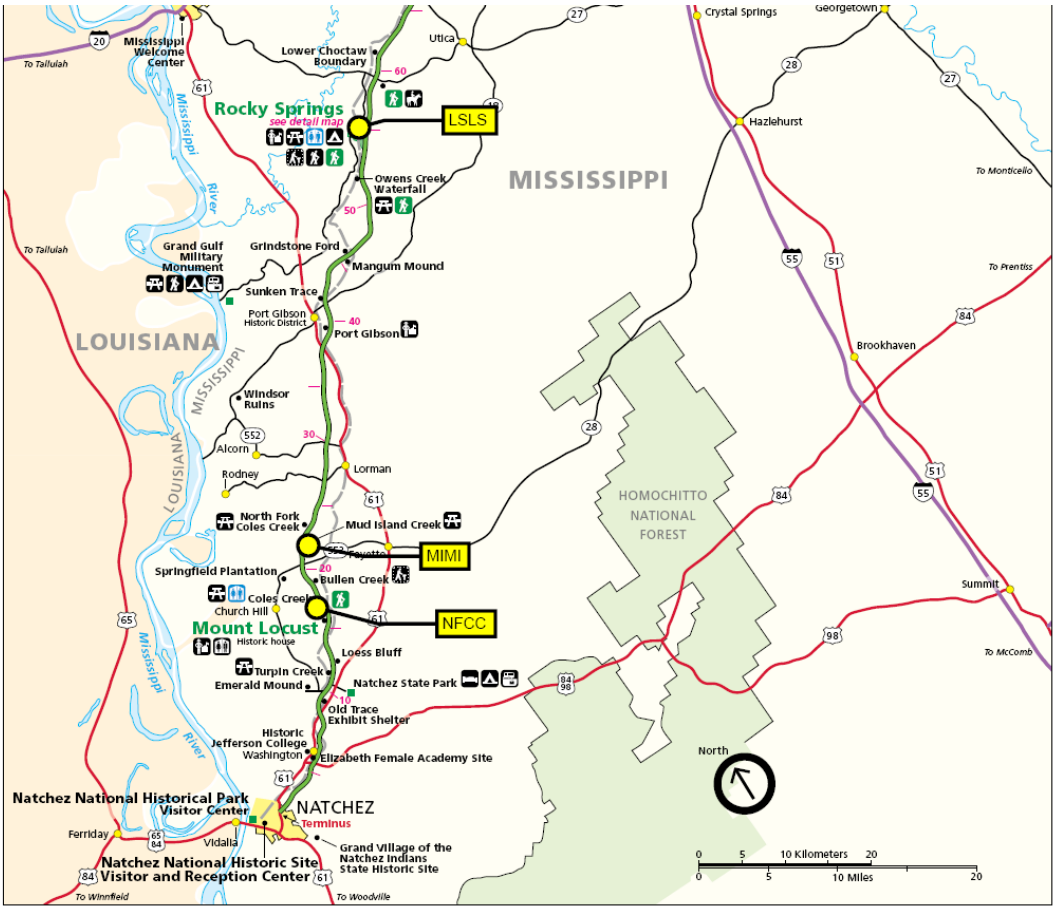

Exhibit Shelter
GBGB
Dogwood Mudhole
Tenrock Branch
Sweetwater Branch
SBSB
Waynesboro
Collinwood
McGlamerys Stand
Sunken Trace
CCCC
Holly
Cypress Creek
State Line
Milledgeville
Savannah
Shiloh National Military Park
Pickwick Dam
Pickwick Landing State Park
Pickwick Lake
RSCC
Lauderdale
Colbert Ferry Site
Tennessee River
J.P. Coleman State Park
Selmer
TENNESSEE
MISSISSIPPI
ALABAMA
Cherokee
Buzzard Roost Spring
BSBS
Iuka
Freedom Hills Overlook
Bear Creek
Corinth Civil War Interpretive Center (part of Shiloh NMP)
CORINTH
Bear Creek Mound Cave Spring
BCBC
Tennessee Tombigbee Waterway
Tishomingo
Tishomingo State Park
Bay Springs Lake
Visitor Center
U.S. Army Corps of Engineers
Dennis
Belmont
JCJC
Red Bay
FLORENCE
MUSCLE SHOALS
SHEFFIELD
TENNESSEE
ALABAMA
WILSON LAKE
Joe Wheeler State Park
Russellville
To Athens
To Decatur
To Jasper
To Memphis
To Bolivar
To Lexington
To Henderson
Parsons


JCJC
Red Bay
Tenn-Tom Waterway
Jamie L. Whitten Bridge
Pharr Mounds
Exhibit Shelter
Donivan Slough
Browns Bottom
Marietta
Brice's Crossroads Visitor and Interpretive Center
Baldwyn
Dogwood Valley
Twentymile Bottom Overlook
Brices Cross Roads National Battlefield Site
U.S. Army Corps of Engineers
Mississippi Welcome Center
Fulton
Mantachie
Saltillo
Confederate Gravesites and Old Trace
Tupelo Visitor Center
Parkway Headquarters
New Albany
Old Town Overlook
Tombigbee State Park
Chickasaw Village Site
TUPELO
Tupelo National Battlefield
Trace State Park
Verona
Nettleton
Amory
Black Belt Overlook
Pontotoc
Chickasaw Council House
Tockshish
Monroe Mission
Okolona
Hernando de Soto
Owl Creek Mounds
Davis Lake
Chickasaw Agency
Aberdeen
TOMBIGBEE NATIONAL FOREST
Witch Dance
Bynum Mounds
Houston
West Point
Hamilton
ALABAMA
MISSISSIPPI
To Memphis
To Oxford
To Cullman
To Birmingham
To Winfield
To Columbus
To Columbus


Old Trace
Montpelier
Mantee
Calhoun City
Dancy
Line Creek
STARKVILLE
Maben
Mathiston
Pigeon Roost
Hugh White State Park
Grenada Lake
Hugh White State Park
MISSISSIPPI
Eupora
Ballard Creek
Old Trace
MBMB
Jeff Busby
gas station
see detail map
LBLB
TOMBIGBEE NATIONAL FOREST
Grenada
Louisville
Winona
French Camp
French Camp
Bethel Mission
Cole Creek
Valden
Ethel
Hurricane Creek
HCHC
Information Center
Chamber of Commerce
Kosciusko
Kosciusko
Holly Hill
To Columbus
To Brooksville
To Macon
To Memphis
To Greenwood
To Greenwood
To Philadelphia
To Philadelphia


HCHC
Information Center
Chamber of Commerce
Kosciusko
Holly Hill
Durant
Lexington
Tchula
Myrick Creek
Carthage
Red Dog Road
Robinson Road
Pickens
Casey Jones Museum State Park
Yockanookany
Upper Choctaw Boundary
River Bend
Cypress Swamp
CANTON
Yazoo City
Morton
Roosevelt State Park
Ross Barnett Reservoir
West Florida Boundary
Boyd Site
Reservoir Overlook
Brashear's Stand and Old Trace Site
Madison
Ridgeland
Choctaw Agency
Flora
RIDGELAND
Mississippi Crafts Center
Information
Brandon
Osburn Stand
JACKSON
Clinton Visitor Center
To Greenwood
To Philadelphia
To Indianola
To Meridian
To Forest
To Laurel
Yazoo River
Big Black River
Pearl River
Natchez Trace
Lobutcha Creek


West Florida Boundary
Boyd Site
Reservoir Overlook
Brashear's Stand and Old Trace Site
Madison
Ridgeland
Choctaw Agency
RIDGELAND
Flora
Mississippi Crafts Center
Information
Brandon
JACKSON
Osburn Stand
Big Black River
Clinton Visitor Center
Confederate Mound Cemetery
CLINTON
Historic District
To Laurel
To Leland
To Hattiesburg
Raymond
Edwards
Battle of Raymond
Dean's Stand Site
Pearl River
To Magee
Vicksburg National Military Park
VICKSBURG
Crystal Springs
Georgetown
Utica
Mississippi Welcome Center
To Tallulah
Lower Choctaw Boundary
Rocky Springs
see detail map
LSLS
Hazlehurst
Mississippi River
Owens Creek Waterfall
MISSISSIPPI
To Monticello
Grand Gulf Military Monument
Grindstone Ford
Mangum Mound
Sunken Trace
To Prentiss
Port Gibson
Historic District
Port Gibson
LOUISIANA
Brookhaven
MISSISSIPPI
Windsor Ruins


Mississippi Welcome Center
To Tallulah
Lower Choctaw Boundary
Utica
Crystal Springs
Georgetown
Rocky Springs
see detail map
LSLS
Hazlehurst
MISSISSIPPI
Owens Creek Waterfall
To Monticello
Grand Gulf Military Monument
Grindstone Ford
Mangum Mound
To Prentiss
Sunken Trace
Port Gibson Historic District
Port Gibson
LOUISIANA
Brookhaven
Windsor Ruins
Alcorn
Rodney
Lorman
HOMOCHITTO NATIONAL FOREST
North Fork Coles Creek
Mud Island Creek
MIMI
Springfield Plantation
Bullen Creek
Coles Creek
Church Hill
NFCC
Summit
Mount Locust
Historic house
To McComb
Loess Bluff
Turpin Creek
Emerald Mound
Natchez State Park
Old Trace Exhibit Shelter
Historic Jefferson College
Washington
Elizabeth Female Academy Site
North
Natchez National Historical Park Visitor Center
NATCHEZ
Terminus
Ferriday
Vidalia
Grand Village of the Natchez Indians State Historic Site
Natchez National Historic Site Visitor and Reception Center
To Winnfield
To Woodville
0 5 10 Kilometers 20
0 5 10 Miles 20

2.3 Palo Alto National Historic Site (Site Visit October 24, 2006)

2.3.1 Hydrogeology

Before this narrative begins, the reader must understand that there are no perennial surface water resources at Palo Alto National Historic Site. Contrary to other reports, there are none.

Situated on the broad coastal flood plain between the Rio Grande to the south, the Arroyo Colorado to the north, and the Laguna Atascosta to the east, lay the grass and salt prairie lands of Palo Alto, a landscape devoid of perennial surface waters. At times of great rains – typically supplied by tropical storms – several resecas (abandoned stream channels) in the park temporarily retain water (Figure 2.30). Several years may pass between such events, as this fleeting retention of waters last only a few days.



Figure 2.30 Reseca on the battlefield of Palo Alto National Historic Site. Note semi-linear change in vegetation just beyond boardwalk.

Previous investigators that described surface waters – Main Ditch Number 2 and a pond – may have been confused as to the actual authorized boundary. While the authorized boundary contains a small pond (which must be recharged via pump from the drainage ditch), the authorized boundary stops at the southern edge of Main Ditch Number 2, which is controlled and owned by Cameron County.

The natural hydrogeology of this entire portion of the coastal plain has been greatly altered. No longer can annual or semi-annual floodwaters spill from the Rio Grande or the Arroyo Colorado and fill the resecas of the park. The Rio Grande is diminished to a trickle at Brownsville, impounded and withdrawn along its course. Lying between Palo Alto and the Rio Grande is the Brownsville Ship Channel. This canal, built in the late 1930s, interrupts any overland flow from the south – if there even was any overland flow from the south. The Arroyo Colorado has also been modified and no longer floods onto the adjacent plain.

2.3.2 Past Inventories/Monitoring/Research Activities

The NPS Water Resources Division produced the "Baseline Water Quality Data Inventory and Analysis" for the park in 2000. Among the thousands of water quality records in this database, not one was generated within the park. None were taken upstream of the park, as there is no "upstream" of the park.

2.3.3 Associated Land Uses and Water Quality Threats

It is difficult to make a case of land uses and threats to water resources in a park without surface water resources. It is worth mentioning that the area surrounding Palo Alto, in a fashion typical throughout the lower Rio Grande Valley, is rapidly developing. New subdivisions are creeping northward from Brownsville.

A real and documented threat to water at the Historic Site involves groundwater. The water table is extremely shallow (less than two meters below the surface) and overlain by sandy soils. Contaminants are easily introduced into this unconsolidated shallow aquifer. Prior to federal ownership, the battlefield was home to a ranching operation. Signs of this recent past use are common as several resecas are modified in hopes of better water retention, and several small livestock watering holes were scraped out of the soil. Directly adjacent to the park's interpretative trail is a cattle dip tank. This pit is lined with block and during its use, filled with a pesticide containing arsenic. Cattle were immersed in this solution to kill the fever tick. Today the dip tank remains open, groundwater exposed at the bottom. The park contracted for soil and groundwater testing and has identified a plume of contaminated material, and now awaits funding to remediate the site.



Figure 2.31 Cattle dip tank at Palo Alto National Historic Site. Note groundwater (green hue) in the bottom of the structure.

2.3.4 Human Use and Aquatic Biology

There is no human use of the water resources at Palo Alto as there are no surface waters in the park. The same can be said of aquatic biological resources. Hays (2004) recently completed a biological inventory, including fishes, at the Historic Site. While no surface waters were found within the park, Hays attempted to sample the pond east of the park. When finally securing permission to sample on this private land, the pond was found to be dry.

It is worth noting that long-time park resources specialist and interpreter (Douglas Murphy) did observe many small fish in a reseca following a tremendous tropical rain in the early 2000s. No specimens were collected and this fish remain a mystery.

2.3.5 Proposed Water Quality Monitoring Locations

There are no proposed water quality monitoring locations at PAAL.

2.4 San Antonio Missions National Historical Park (Site Visit October 26-27, 2006)

2.4.1 Hydrogeology

The availability of a constant, reliable water supply has greatly affected human cultural geography. In a semi-arid land like south-central Texas, the spring-fed San Antonio River has been a cultural oasis for centuries. The importance of this water is evident throughout the 331 hectares of San Antonio Missions National Historical Park (SAAN). Indeed, the missions would not have been built if not for the river as missionaries and native peoples (the Coahuiltecans) irrigated their fields via an intricate system of acequias – gravity-driven ditches tapped into the river above a dam.

Today the river, and its supplying aquifer, still plays a vital role in supplying the ever-growing demand of drinking water for the San Antonio area. The San Antonio River's course is heavily altered through flood control channels as it flows through the center of the city and the park. While the park does not own any portion of the San Antonio River – it does own land down to the high-water mark in some areas – the quality and quantity of water plays not only an important aesthetic interpretative backdrop, but also directly supplies flow to the acequias which are owned and maintained by the park. The park retains water rights to the two remaining mission acequias – the active Acequia de Espada, flowing along the west side of the river, and the currently inactive Acequia de San Juan on the east side. The park plans to soon open flow into the Acequia de San Juan – inactive for over 40 years – upon remediation of a hazardous spill site along its course. The park also manages a short segment of Piedras Creek, from the Acequia de Espada Aqueduct to its confluence with the San Antonio River.

The San Antonio River leaves the greater urban area and becomes a free-flowing, undeveloped stream to the south. Approximately 100 km downstream the river flows along the Ranchero de las Cabras unit – used during mission times to graze livestock. The Ranchero de las Cabras also includes the seasonal Picosa Creek, which joins the San Antonio River in the park.

2.4.2 Past Inventories/Monitoring/Research Activities

Perhaps no other park in the GULN has been the beneficiary of more non-NPS water quality monitoring. Water quality and quantity have been important issues to the San Antonio region for decades, and as growth continues, they will remain well into the future. In order to monitor the river's (and its tributaries') quality, several efforts have been underway over the past decade. The San Antonio River Authority (SARA) works in conjunction with the Texas Clean Rivers Program (CRP) and the US Geological Survey in regional water quality monitoring planning. Through this combined effort, 13 water quality sampling locations are routinely (six times per year) sampled throughout the upper San Antonio River.

Three of these SARA permanent water quality stations have direct monitoring benefits to the Park; the river immediately upstream and immediately downstream of the Missions, and immediately upstream of the Ranchero de las Cabras unit. These stations have been occupied six times each year since 1996. Parameters include; temperature, pH, specific conductance, dissolved oxygen, flow, total suspended solids, E. coli, nitrogen, phosphorous, total organic carbon, chloride, and sulfate.

As stated above, the park does not own or manage the river, but it does retain water rights to the acequias. Very little water quality monitoring has been done in the acequias, as it is generally assumed that, as the river is the sole source of acequias water, its quality must be similar, if not identical. However, in a NPS-funded inventory, the SARA found low dissolved oxygen and elevated phosphorous in the Acequia de Espada at the Piedras Creek Aqueduct (Gonzalez and Moran, 2005). This study also sampled Peidras Creek as it entered the park at the Aqueduct. The heavily urbanized watershed also displayed low dissolved oxygen and elevated phosphorous, indicative of non-point source contamination.

2.4.3 Associated Land Uses and Water Quality Threats

No other park in the GULN has as much alteration, modification, or development of its watershed and surrounding area as SAAN. It is beyond the scope of this report to list all threats to the water quality to the San Antonio River. In essence, the park is surrounded and drained from a metropolitan area of 1.25 million people. Nearly every conceivable land use is present. The NPS “Baseline Water Quality Data Inventory and Analysis” report identified 17 permitted industrial dischargers above the Missions unit, and an additional 11 dischargers above the Ranchero unit. This, of course, is in addition to urban and highway runoff and countless other non-point sources. It is no wonder that much of the Upper San Antonio River, including the entire reach through the Mission Unit, is on the Texas 303d list for non-attainment as bacteria levels exceed the standard for contact recreation.

2.4.4 Human Use and Aquatic Biology

The San Antonio River, through the Missions Unit, is classified by the state of Texas as contact recreation with a high diversity of aquatic life. The park does not promote or provide direct access to the river. There is no prevalent recreational use of the waters managed by the park: the acequias and Piedras Creek.

There are no federally listed aquatic species for SAAN. The state of Texas lists the Guadalupe bass (Micropterus treculii) as a rare species.

The most recent fish inventory was completed by the SARA by Gonzalez and Moran (2005). This report provides and excellent overview of the fishes found in the river, Piedras Creek, Acequia de Espada, and Picosa Creek. In addition to the fish survey, water quality samples were collected and results provided. Gonzalez and Moran (2005) collected 4,912 individuals, representing 27 species. Non-native fishes made up 37% of

all species and 36% of all individuals collected. Species diversity was largely a reflection of habitat. They conclude that the water quality parameters indicate conditions that can support a high aquatic life use (a condition reflective with the designated stream use).

2.4.5 Proposed Water Quality Monitoring Locations

The following five site descriptions include:

Photo of Site:	Taken during site visit August, 2006 (Figures 2.32 – 2.36)
Site Name:	Four digit park code and four digit site code
Site Description:	Brief report of site
Public Access:	Does the park provide public access to water?
Recreation:	Type 1 (primary contact; emersion, swimming), Type 2 (secondary contact; wading or fishing.
Listed Species:	State or Federally listed aquatic species.
State Designated Use:	Designated use classified by specific state. Those in italics were not classified by state, but were by the author using state criteria.
303d list:	Is this water on the most recent state 303d impairment list?
Interpretative display:	Does the park provide an interpretative display relative to water?
Water Quality:	Depending on existing data, either demonstrated or anticipated water quality: pristine, potentially degraded, or degraded.
Coordinates:	Geospatial coordinates of site in NAD83; locations shown in Figure 2.37

303d listed waters include the following category; 5a – A TMDL (total maximum daily load) is underway, scheduled or will be scheduled). 303d list ranks include; “U” –a TMDL is underway.



Figure 2.32 Piedras Creek (SAAN_PCPC)

Piedras Creek will be monitored as it enters park lands at the crossing of Acequia de Espada Aqueduct. Piedras, also know as Six Mile Creek, drains a highly urbanized watershed west of the river and has displayed elevated nutrients during high flow.

Public Access: Yes
Recreation: No
Listed Species: No
State Designated Use: Aquatic Life
303d list: No
Interpretative display: No
Water Quality: Potentially degraded
Coordinates (NAD 83):
29 19 56.7 98 27 40.8



Figure 2.33 Acequia de Espada (SAAN_AEAE)

This site is directly superjacent to the Piedras Creek site, and representative of waters of the Acequia de Espada. Note heavy growth of Hydrilla verticillata.

Public Access: Yes
Recreation: No
Listed Species: No
State Designated Use: Aquatic Life
303d list: No
Interpretative display: Yes
Water Quality: Potentially degraded
Coordinates (NAD 83):
29 19 43.4 98 27 42.8

The following three sites are part of the SARA routine sampling network.



Figure 2.34 San Antonio River (SARA site 17066)

This site is not within the park but directly upstream of the Missions Unit and is routinely monitored by the SARA. Note the river flows within a flood-control channel at this site. Red shopping carts provide scale

Public Access: No
Recreation: No
Listed Species: No
State Designated Use: Aquatic Life (high), Contact Recreation
303d list: Yes, bacteria, point source, non-point source, category 5a, rank U
Interpretative display: No
Water Quality: Degraded
Coordinates (NAD 83):
29 55 48 98 29 24



Figure 2.35 San Antonio River (SARA site 12897)

This site is located immediately downstream of the Missions unit. It is routinely sampled by the SARA. Again, the river flows within a flood control channel through this site.

Public Access: No
Recreation: No
Listed Species: No
State Designated Use: Aquatic Life (high), Contact Recreation
303d list: Yes, bacteria, point source, non-point source, category 5a, rank U
Interpretative display: No
Water Quality: Degraded
Coordinates (NAD 83):
29 19 12 98 27 0



Figure 2.36 San Antonio River (SARA site 12883)

This site is directly upstream of the Ranchero de las Cabras Unit and is routinely sampled by the SARA. Note at this point the river is free-flowing in a natural channel.

Public Access: No
Recreation: No
Listed Species: No
State Designated Use: Aquatic Life (high), Contact Recreation
303d list: No
Interpretative display: No
Water Quality: Potentially degraded
Coordinates (NAD 83):
29 10 12 98 12 0

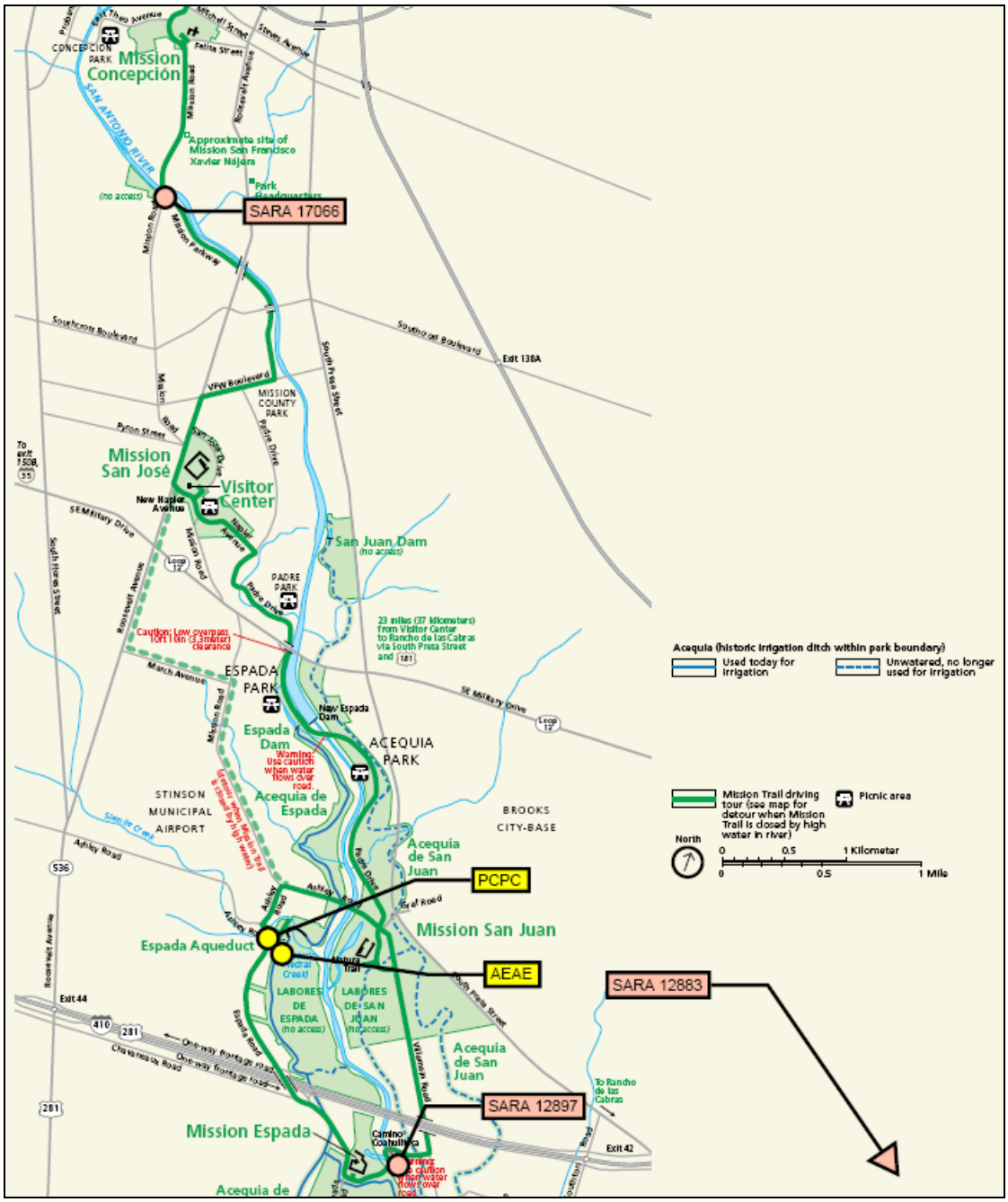


Figure 2.37 Map of WQ monitoring sites at SAAN. Those in red are part of the routing sampling network by SARA, those in yellow are proposed GULN sites. The SARA site 12883 is situated just upstream of the Ranchero de las Cabras unit.

2.5 Vicksburg National Military Park (Site Visit August 10, 2006)

2.5.1 Hydrogeology

Water resources at Vicksburg National Military Park were by far a more serious matter in the summer of 1863 than that of 2006. Following a ridge siege-line where Confederate and United States forces squared off during the early summer of 1863, the park traces the general form of a numeral 7. Situated within the loess bluffs high above the confluence of the Mississippi and Yazoo Rivers, the ridge terminates at the "top" of the 7 above the Yazoo to the north.

The park drains via three small, perennial streams: Mint Spring Creek, Glass Bayou, and Stouts Creek (also known as Stout's Bayou). The former two drain to the Yazoo while the latter flows to the Mississippi. It is important to note that although Mint Springs Creek is contained within the park to its confluence with the Yazoo River, the stream is divided into the Upper and Lower reaches by a six meter high waterfall over the loess escarpment. This waterfall, located adjacent to the National Cemetery, forms a natural impediment for fish. The Lower reach can be adversely affected by the multitude of land and water uses on the Yazoo during times of flooding.

Although the park tour road crosses each of the three streams, there are no interpretive signs or public access to the streams. Each stream was at, or near, summer base flow (on the order of two to five l/s) during the morning of the site visit, but all responded immediately to a 1 cm rainfall event. Discharges increased by an order of magnitude, and although there are no disturbed lands upstream, all were very turbid – the product of steep slopes and loess soils.

For most, if not by all arguable points, the water resources of Vicksburg National Military Park are ancillary. They are not labeled on the park map, visitors are not directed towards them, and with the exception of the Yazoo River, not mentioned in the primary interpretative message.

2.5.2 Past Inventories/Monitoring/Research Activities

Dr. Eric Dibble of Mississippi State University has made dozens of inventory and monitoring rounds at the park. While most describe the aquatic biology of the streams, he and his students have made an effort to sample the basic core water quality measures, as well as site habitat descriptions, while conducting their biotic work. Each of the three streams was examined at several points along their courses. The general water quality of the streams is quite similar. Dibble (2004) reported the temperature, pH, specific conductance (SpC), dissolved oxygen, turbidity, and flow estimation during each site visit from 1996 through 2003. In general the streams of the park are relatively high in SpC (in the 400 to 800 S range), basic to slightly acidic (from the high 6s to low 8s). Dissolved oxygen, for the most part is high, as flow courses down rather steep gradients. Depressed oxygen levels were reported occasionally for discrete sections of Mint Spring

Creek. Flow can range from zero during times of drought to about 7 m3/s during times of storm flow. Turbidity increases in direct response to an increase in flow.

2.5.3 Associated Land Uses and Water Quality Threats

With the exception of the head of a northern tributary, the watershed of Mint Spring Creek is contained within the park. This privately-owned portion of the watershed consists of light residential land use. Conversely, the majority of the Glass Bayou watershed lies upstream of the park boundary. Glass Bayou generally cuts through the siege-line ridge, along the Jackson Road. One may think of this stream as somewhat transient to the park. Land use is generally residential. Stouts Creek, the smallest of the three streams, originates within the park.

2.5.4 Human Use and Aquatic Biology

There is no human recreation in the streams within the park. Human recreation, as applied throughout this document, concerns both primary-contact (swimming and wading), and secondary-contact (fishing and other non-emersion activities).

The only federally listed (threatened) specie listed for the park is the American alligator (Alligator mississippiensis). The state lists the alligator snapping turtle (Macrochelys temminiki) and the Mississippi map turtle (Graptemys psuedogeographica) as species of special concern.

Dibble has, by far, conducted the majority of aquatic inventory and monitoring efforts. His efforts over the past decade have provided the park with aquatic inventories of fish (1997-2003), and benthic macroinvertebrates (1998-2003), in addition to the core water quality and habitat information discussed above.

While Dibble (2004) found 18 species of fish in Mint Spring Creek, only two fishes were found in the Upper section of the creek – that portion above the 6 m waterfall. Of these two species, one is considered a non-native invasive (the fathead minnow, Pimephales promelas), and the other is also thought to be introduced (the green sunfish was introduced into Mint Spring Creek in 1999), suggesting that there are no fish native to the stream above the falls. A NPS project in the autumn of 2006 is planned to kill all fish in this upper section, thus restoring the natural fishery to zero species.

Dibble (2004) also sampled the park for benthic macroinvertebrates. Between 1998 and 2003 he and his students collected and identified over 9,500 specimens, representing 31 taxa.

2.5.5 Proposed Water Quality Monitoring Locations

The following three site descriptions include:

Photo of Site:	Taken during site visit August, 2006 (Figures 2.38 – 2.40)
Site Name:	Four digit park code and four digit site code
Site Description:	Brief report of site.
Public Access:	Does the park provide public access to water?
Recreation:	Type 1 (primary contact; emersion, swimming), Type 2 (secondary contact; wading or fishing.
Listed Species:	State or Federally listed aquatic species.
State Designated Use:	Designated use classified by specific state. Those in italics were not classified by state, but were by the author using state criteria.
303d list:	Is this water on the most recent state 303d impairment list?
Interpretative display:	Does the park provide an interpretative display relative to water?
Water Quality:	Depending on existing data, either demonstrated or anticipated water quality: pristine, potentially degraded, or degraded.
Coordinates:	Geospatial coordinates of site in NAD83; locations shown in Figure 2.41

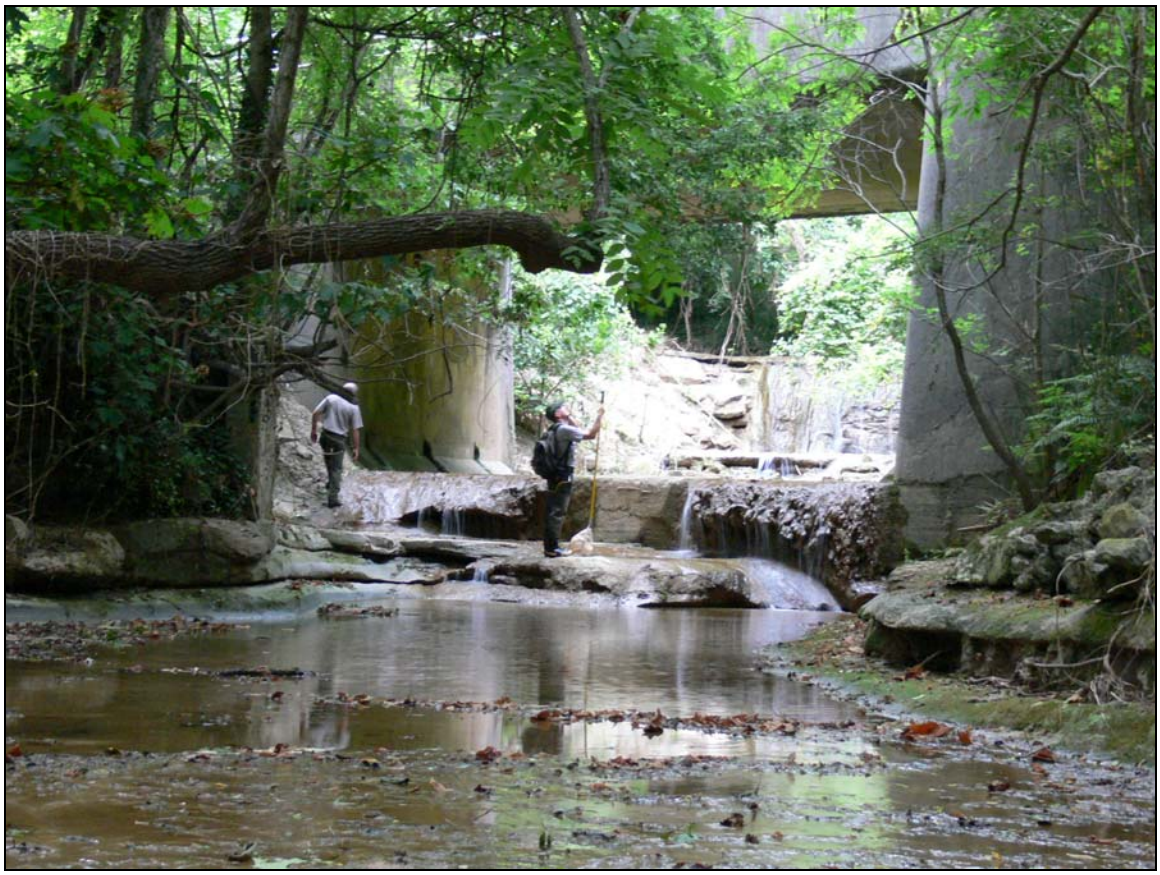


Figure 2.38 Mint Spring Creek (VICK_UPMS)

Located 100 m above the waterfall, the upper reaches of Mint Spring Creek can be sampled at the crossing of Connecting Avenue. This location, which is easily and safely accessed in all conditions, is removed from downstream influences of the Yazoo River and thus a better reflection of water quality draining the largely park-managed watershed.

Public Access: No
Recreation: No
Listed Species: No
State Designated Use: Fish and Wildlife
303d list: No
Interpretative display: No
Water Quality: Pristine
Coordinates (NAD 83):
32 22 22.5 90 52 02.3



Figure 2.39 Glass Bayou (VICK_UAGB)

Glass Bayou will be sampled as the stream enters the park along the Jackson Road, as it crosses under Union Avenue. Site access is easy and safe at all times. The sampler may find access more favorable from the Jackson Road.

Public Access: No
Recreation: No
Listed Species: No
State Designated Use: Fish and Wildlife
303d list: No
Interpretative display: No
Water Quality: Potentially degraded
Coordinates (NAD 83):
32 21 46.3 90 50 25.8



Figure 2.40 Stouts Creek (VICK_UASC)

Stouts Creek is sampled just before it leaves the park as it crosses under Union Avenue. Upstream of this location, Stouts Creek is fully contained within the park and should be reflective of water quality of undisturbed lands. The site is easily and safely accessed in all conditions.

Public Access: No
Recreation: No
Listed Species: No
State Designated Use: Fish and Wildlife
303d list: No
Interpretative display: No
Water Quality: Pristine
Coordinates (NAD 83):
32 20 41.0 90 50 51.0

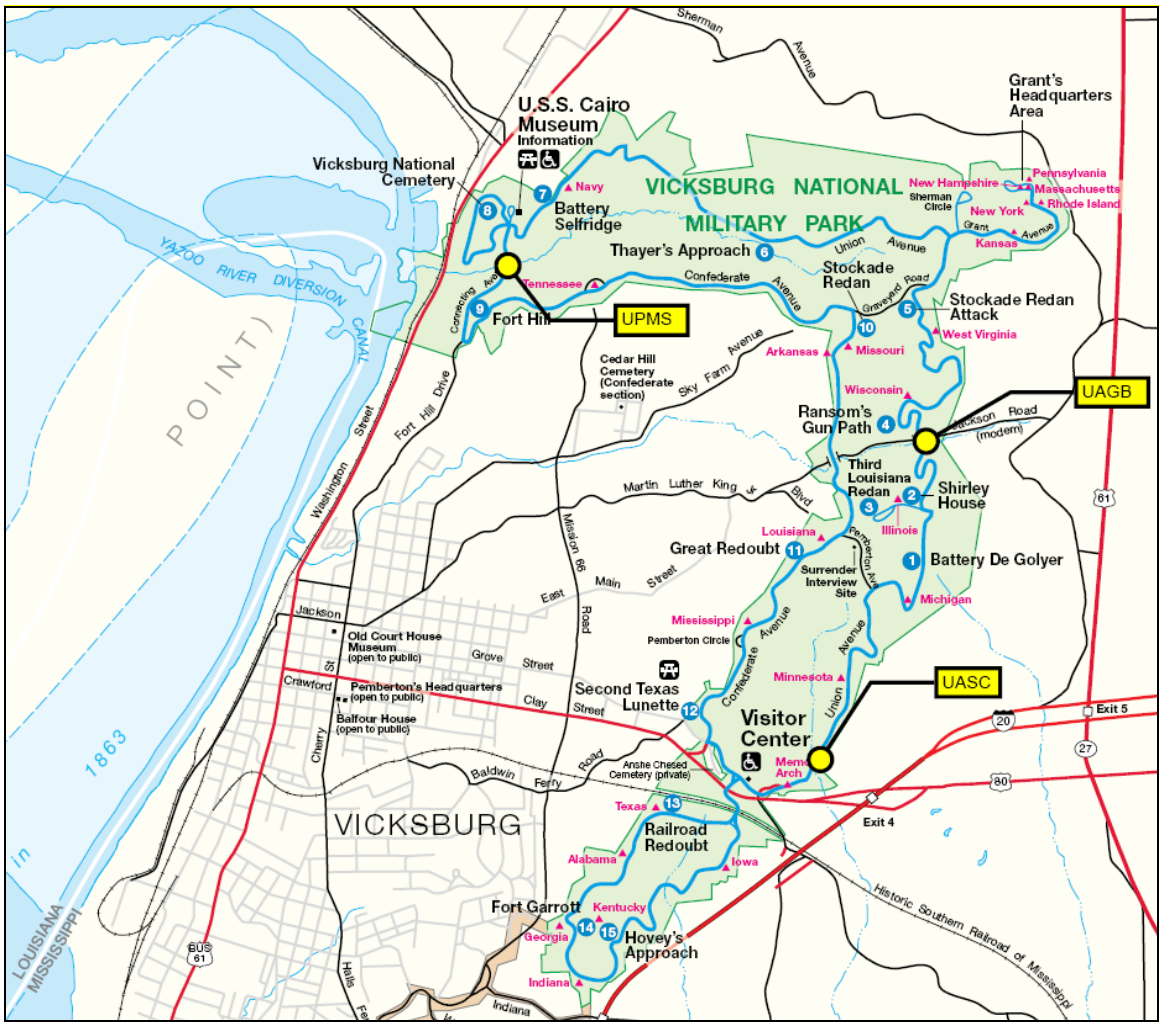


Figure 2.41 Map of proposed WQ monitoring sites at VICK.

Chapter 3 Water Quality Monitoring Program

3.1 Introduction

Paramount to the conservation of the surface and subsurface aquatic ecosystems of a park is the knowledge of, and the ability to recognize, long-term trends in water quality. Over the next few years many inventory efforts, including those pertaining to aquatic biota, will be conducted throughout the Gulf Coast Network (GULN). For the first time many park managers and researchers will be able to see the effects of landscape-scale land-use and change upon the dependent aquatic ecosystems. Central to any long-term aquatic monitoring effort are water quality monitoring data.

It is necessary to have a basic understanding of the relationship between park waters and their watersheds to better understand threats to the aquatic ecosystems. Each park of the GULN is recharged by land outside park boundaries. Each land-use that occurs within a particular watershed contributes to the overall water quality. It must be noted that the parks themselves are not immune to contributing to water pollution, including roadways, parking lots, developmental erosion, pesticide and fertilizer use, and septic fields. Some land-uses produce contaminants, which can be divided into three main categories:

1) Acute Non-Point Source: Agricultural pollutants (animal waste, suspended sediments, and pesticides) and some urban pollutants (parking lot and road runoff) accumulate on the surface in virtual storage until they are washed into the streams or aquifers during rainfall events. Each year thousands of tons of sediments, animal wastes, nutrients, and pesticides are introduced into the streams of GULN parks from these lands.

2) Chronic Non-Point Source: From land-uses such as oil and gas exploration and production (hydrocarbons and brines), urban development (septic waste), and agriculture (wastes deposited directly into streams), these pollutants are released into the watersheds at a relatively steady rate, regardless of precipitation.

3) Point-Source: Traversing the watersheds of many parks are transportation corridors. These roadways and railroads are sources of spills of hazardous materials. Any contaminant released along these routes is quickly washed into park streams.

3.2 Sampling Program

Water quality monitoring of the five inland parks of the GULN will be based on a simple sample collection rationale, but consistent with two related sampling protocols; the USGS National Water Quality Assessment (NAWQA) Program and the Texas Commission on Environmental Quality (TCEQ) Clean Rivers Programs (CRP). This is necessary to take advantage of extant water quality efforts where they exist and to accommodate parks

beyond the reaches of such programs. Of the five inland parks of the GULN, two (NATR and VICK) will be monitored "in-house" by NPS staff under USGS protocols (see section 3.2.1), and two (BITH and SAAN) will be incorporated into existing River Authority programs and monitored under TCEQ CRP protocols (see section 3.2.2). The remaining inland park, PAAL has no perennial surface water resources and will not be included in routine sampling. Examination reveals that these two protocols are extremely similar, with primary differences in target waters and parameters. The USGS is actually a collaborative partner in the Texas CRP.

Both rationales are constructed to produce long-term water quality records to answer the monitoring objectives restated from earlier in this document:

- Determine if concentrations of selected parameters (key nutrients, bacteria, and key physical characteristics) are changing monotonically over time and estimate rates of change.
- Determine if the park is meeting the designated use water quality requirements through annual reports.
- Provide a water quality backdrop to compare changes in the aquatic biologic communities (where applicable).
- Provide data to determine pollutant sources (non-point source contaminants versus point-sources).
- Determine impacts to water quality by in-park activities within selected watersheds.
- Determine the basic effects of atmospheric contaminants (acid precipitation).

3.2.1 NPS Water Quality Monitoring

Developed primarily from protocols of the USGS, the NPS program relies upon fixed-site, synoptic, non-conditional sampling strategies. The Basic Fixed-Site sampling is designed to provide an integrated assessment of the spatial and temporal distribution of general water-quality conditions and the transport of major inorganic constituents of stream water in relation to hydrologic conditions and major pollution sources (USGS Circular 1112). Data from Basic Fixed-Site sampling are the primary source of information for meeting water-column assessment objectives for temperature, specific conductance, dissolved oxygen, pH, major ions and metals, nutrients, and organic carbon. Site selection and sampling strategy for Basic Fixed-Sites are based on balancing needs and priorities for assessing water-column conditions, ecological characteristics, program logistics and budget.

The fixed monthly, bi-monthly (six times per year), or quarterly (based upon Water Resources Ranking and existing water quality programs) sample set provides comparative statistics for the selected sites and parameters under variable flow conditions. Similar to the NAWQA, topical surveys are included in the program to further elucidate anomalies found during the synoptic sampling. For example, if synoptic sampling revealed high concentrations of E. coli bacteria, a topical study would be

developed to examine possible source areas of animal waste through additional sampling stations. Since there is little existing data relative to the water quality of the Natchez Trace Parkway, a water quality inventory encompassing a wider array of parameters will occur during the first year.

Diel Variance

In order to determine diel variability, 24-hour measurements of field water quality parameters will be conducted at BITH, SAAN and VICK for each site each year. Due to the excessive number of sites at NATR, an annual rotation of sites will be selected for diel recording. Multi-parameter probes will be utilized for documentation of diel variability. In addition, each site will be sampled in the same order for each round. This will allow that each sample will be taken at about the same time of day for each round. The following parameters and annual sampling schedule will be used by NPS staff for the Natchez Trace Parkway and Vicksburg Military Park.

Natchez Trace Parkway

Since there are little existing data relative to the water quality of the Natchez Trace parkway, a water quality inventory encompassing a wider array of parameters will occur during the first year. Such an inventory will yield a subset of parameters to be measured long-term without fear that important analytes are missed. All NPS water quality monitoring procedures and activities will be conducted under the QA-QC protocols detailed in Appendix A.

Sampling entity: NPS staff

Field Parameters (Bi-monthly):
Temperature
pH
Specific conductivity
Dissolved oxygen
Flow
Turbidity
Weather/physical observations

Laboratory Parameters (Bi-monthly):
E. Coli
Nitrate
Total phosphate
Sulfate
Acid neutralizing capacity

Vicksburg National Military Park

Thanks to the work of Dr. Eric Dibble (Mississippi State University) much is known about the water quality of the park. Water resources of the park are more ancillary in nature and management objectives less prominent than other parks. No rare species or recreation occur and water resources are not part of the interpretative message.

Sampling entity: NPS staff

Field Parameters (Quarterly):
Temperature
pH
Specific conductivity
Dissolved oxygen
Flow
Turbidity
Weather/physical observations

3.2.2 Clean Rivers Program Water Quality Monitoring

The following protocols established by the TCEQ's Surface Water Quality Monitoring (SWQM), the Clean Rivers Program can be found in detail the TCEQ Surface Water Quality Monitoring Procedures Manual (RG-415). This document establishes protocols relevant to site selection, temporal and spatial considerations and level of monitoring effort. All GULN water quality monitoring sites were selected under these protocols and will fall under the CRP "Fixed Station" monitoring design. This traditional type of monitoring – identical to that used by the LNVA and SARA CRP monitoring efforts – is conducted on high-profile water bodies that rely on a minimum of quarterly field measurements, indicator bacteria, conventional parameters, and a suite of metals.

The following parameters and annual sampling schedule will be used by the Lower Neches Valley Authority for the Big Thicket National Preserve and the San Antonio River Authority for the San Antonio Missions National Historical Park. While the parameter list and sampling frequency of these programs are not the same, they are both within the protocols of the CRP and both identical to existing routine monitoring schedules and parameters. This assures data generated for the GULN program will be directly correlative to the overall sampling efforts of the CRP. Individual Authority Quality Assurance Programs are found in Appendices B and C.

Big Thicket National Preserve
Six sites will be added to the routine water quality monitoring program of the Lower Neches Valley River Authority. These sites will receive the same sampling schedule, parameter list and analysis as the existing sites under this Clean Rivers Program water quality effort.

Sampling entity: Lower Neches Valley Authority

Field Parameters (quarterly):
Temperature
pH
Specific conductivity

Total dissolved solids
Dissolved oxygen
Secchi depth
Total water depth
Weather/physical observations

Conventional parameters (quarterly):
Alkalinity
Total hardness
Chloride
Sulfate
Total phosphates
Turbidity
Nitrate/nitrite
Ammonia-nitrogen
Total suspended solids

Bacteria (quarterly):
E. coli

Metals, dissolved (bi-annual):
Aluminum
Arsenic
Cadmium
Chromium
Copper
Lead
Barium
Nickel
Silver
Zinc

Metals, total (bi-annual):
Selenium
Mercury

San Antonio Missions National Historical Park
Two sites will be added to the routine water quality monitoring program of the San Antonio River Authority. These sites will receive the same sampling schedule, parameter list and analysis as the existing sites under this Clean Rivers Program water quality effort.

Sampling entity: San Antonio River Authority

Field Parameters (quarterly):
Temperature

pH
Specific conductivity
Total dissolved solids
Dissolved oxygen
Secchi depth
Flow
Weather/physical observations

Conventional parameters (quarterly):
Nitrogen (NH3, NO3, NO2, Total Kjeldahl nitrogen)
Total phosphorous
Total organic carbon
Chloride
Sulfate
Total suspended solids

Bacteria (quarterly):
E. coli

3.2.3 Sampling Schedule

Exact dates of bi-monthly (BM, every other month) and quarterly samples (Q, every three months) are to be determined but will fall within a one-week period common to each park. Each park listed below includes all sampling stations plus one QA/QC duplicate sample per round. A typical annual schedule follows:

Sampling Entities: GULN, LNVA, SARA.

Sample	Park	Field Office	#samples	#samples/year
Q	BITH	LNVA	7	28
BM	NATR	GULN	21	126
Q	SAAN	SARA	3	12
Q	VICK	GULN	4	16
				182

Samples per field office/year: GULN: 142, LNVA: 28, SARA: 12
Estimated field days/year: GULN: 28, LNVA: 4, SARA: 4

3.3 Water Quality Standards and Designated Uses

As discussed below, each water body sampled within the GULN has either been assigned a designated use by the state, or, by using the same ranking criteria, by this author (Table 3.1). The USEPA, besides mandating these rankings, also directed the states to develop water quality standards for each designated use. We can use these water quality standards as a minimum to track water quality trends in GULN parks. By adapting the states'

standards, we can also track park water quality trends within the states, regions, or watersheds.

Although it would be convenient to list all water quality standards for each designated use for each state in this document, transcribing these lists would be very time and space consuming. Instead, specific state documents that contain both designated use classifications and water quality standards will be listed below.

Alabama: Alabama Department of Environmental Management; Water Division – Water Quality Program, Chapter 335-6-10.

Mississippi: Mississippi Commission on Environmental Quality regulation WPC-2: Water Quality Criteria for Intrastate, Interstate and Coastal Waters.

Tennessee: Rules 1200-4-3-01, Tennessee Department of Environment and Conservation.

Texas: Chapter 307: Texas Surface Water Quality Standards 307.1-307.10

Table 3.1 Designated Use determinations for waterbodies in GULN parks. Those sites designated by the author appear in red italic font.

Park	Site ID	Stream	State	Designated Use
BITH	MCMC	Menard Creek	TX	*Aquatic Life* *Contact Recreation*
BITH	BSVC	Big Sandy Creek	TX	Aquatic Life (high) Contact Recreation Public Water Supply
BITH	KTVC	Village Creek @ Kirby Nature Trail	TX	Aquatic Life (high) Contact Recreation Public Water Supply
BITH	TCTC	Turkey Creek	TX	Aquatic Life (high) Contact Recreation Public Water Supply
BITH	MBBC	Beech Creek	TX	Aquatic Life (high) Contact Recreation Public Water Supply
BITH	SPVC	Village Creek @ State Park	TX	Aquatic Life (high) Contact Recreation Public Water Supply
BITH	10581*	Neches River at FM 1013	TX	Aquatic Life (high) Contact Recreation Public Water Supply
BITH	15543*	Neches River near Lakeview	TX	Aquatic Life (high) Contact Recreation Public Water Supply
BITH	15346*	Little Pine Island Bayou at FM 326	TX	Aquatic Life (high) Contact Recreation Public Water Supply
BITH	10607*	Pine Island Bayou at Old Sour Lake Road	TX	Aquatic Life (high) Contact Recreation Public Water Supply
BITH	15367*	Pine Island Bayou at SH 105	TX	Aquatic Life (high) Contact Recreation Public Water Supply
BITH	10599*	Pine Island Bayou at LNVA Neches 1st lift	TX	Aquatic Life (high) Contact Recreation Public Water Supply
BITH	10602*	Pine Island Bayou at US 69	TX	Aquatic Life (high) Contact Recreation Public Water Supply
BITH	15353*	Big Sandy Creek on the Alabama Coushatta Reservation	TX	Aquatic Life (high) Contact Recreation Public Water Supply
BITH	15356*	Turkey Creek at FM 1013	TX	Aquatic Life (high) Contact Recreation Public Water Supply

Park	Site ID	Stream	State	Designated Use
BITH	13625*	Village Creek at FM 418	TX	Aquatic Life (high) Contact Recreation Public Water Supply
BITH	15349*	Hickory Creek at US 69	TX	Aquatic Life (high) Contact Recreation Public Water Supply
BITH	15355*	Beech Creek at FM 1943	TX	Aquatic Life (high) Contact Recreation Public Water Supply
BITH	13622*	Cypress Creek at US 69	TX	Aquatic Life (high) Contact Recreation Public Water Supply
NATR	GCGC	Garrison Creek	TN	*Fish and Aquatic Life Recreation*
NATR	BBBB	Burns Branch	TN	*Fish and Aquatic Life Recreation*
NATR	JFJF	Jackson Falls	TN	*Fish and Aquatic Life Recreation*
NATR	FHFH	Fall Hollow	TN	*Fish and Aquatic Life Recreation*
NATR	LSLS	Little Swan Creek	TN	*Fish and Aquatic Life Recreation*
NATR	MFBR	Metal Ford Buffalo River	TN	Fish and Aquatic Life Recreation
NATR	JBJB	Jacks Branch	TN	*Fish and Aquatic Life Recreation*
NATR	GBGB	Glenrock Branch	TN	*Fish and Aquatic Life Recreation*
NATR	SBSB	Sweetwater Branch	TN	*Fish and Aquatic Life Recreation*
NATR	CCCC	Cypress Creek	TN	*Fish and Aquatic Life Recreation*
NATR	RSCC	Colbert Creek	AL	*Fish and Wildlife*
NATR	BSBS	Buzzards Roost Spring	AL	*Fish and Wildlife*
NATR	BCBC	Bear Creek	AL	*Fish and Wildlife*
NATR	JCJC	Jourdan Creek	MS	Fish and Wildlife
NATR	MBMB	Middle Bywy Creek	MS	Fish and Wildlife
NATR	LBLB	Little Bywy Creek	MS	Fish and Wildlife
NATR	HCHC	Hurricane Creek	MS	Fish and Wildlife
NATR	RSLS	Little Sand Creek	MS	Fish and Wildlife
NATR	MIMI	Mud Island Creek	MS	Fish and Wildlife
NATR	NFCC	North Fork Coles Creek	MS	Fish and Wildlife

Park	Site ID	Stream	State	Designated Use
SAAN	17066*	San Antonio River	TX	Aquatic Life (high) Contact Recreation
SAAN	12897*	San Antonio River	TX	Aquatic Life (high) Contact Recreation
SAAN	PCPC	Piedras Creek	TX	*Aquatic Life*
SAAN	AEAE	Acequia de Espada	TX	*Aquatic Life*
SAAN	12883*	San Antonio River	TX	Aquatic Life (high) Contact Recreation
VICK	UPMS	Mint Spring Creek	MS	Fish and Wildlife
VICK	UAGB	Glass Bayou	MS	Fish and Wildlife
VICK	UASC	Stouts Creek	MS	Fish and Wildlife

*Denotes sites currently sampled by the LNVA and SARA routing water quality programs.

Chapter 4 Budget

This budget section should be considered a reasonable estimate of startup and annual costs of the GULN Inland Parks Water Quality Monitoring Program. This budget does not reflect NPS personnel costs, including program direction, field sampling, or data management.

In-house NPS Water Quality Monitoring (NATR and VICK)

Startup Costs	
Multi-parameter sensor (2)	12,000
IDEXX E. coli and total coliform equipment	3,200
pH/SpC meters (4)	2,400
Dissolved oxygen meters (4)	2,600
Turbidity meters (2)	1,400
Velocity meters (2)	4,200
Digital titrator (1)	800
Sample bottles	500
Miscellaneous hardware	500
Regents	500
Total	28,100

Contract Water Quality Monitoring (BITH and SAAN)

No startup costs or equipment will be needed for sampling at BITH and SAAN, as all work will be performed under contract.

Annual Costs	
SARA contract	6,000
LNVA contract	29,000
NATR WQ inventory lab analysis (first 2 years)	3,000
IDEXX supplies	2,500
Replacement probes	1,500
Replacement meters	1,300
Sample shipping	1,000
Sample bottles	500
Miscellaneous hardware	500
Regents	500
Total	47,800

Chapter 5 Literature Cited

Dibble, E.D. 2004. A Long-term (1995-2003) Biological Assessment and Inventory of the Streams in Vicksburg National Military Park; draft. Mississippi State University, 35 p.

Gonzalez, M., and E. Moran. 2005. An inventory of fish species within the San Antonio Missions National Historical Park, San Antonio River Authority. 68 p.

Hays, T.M. 2004. Inventory of the bird, fish and mammal species at Palo Alto NationalHistoric Site; Accipter Biological Consultants, 46 p.

Howells, R. G. 1997. Status of freshwater mussels (Bivalvia: Unionidae) of the BigThicket region of Eastern Texas. Texas Journal of Science, v. 49(3), supplement: 21-34, 34 p.

Johnson, C.E., and B. Phillips. 1999. Fishes and mussels of the Bear Creek drainage Mississippi. Auburn University, 11 p.

Moring, J. B. 2003. Baseline assessment of fish communities, benthic macroinvertebrate communities, and stream habitat and land use, Big Thicket National Preserve, Texas, 1999-2001. U.S. Geological Survey, Water-Resources Investigations Report 03-4270, 40 p.

Moss, K., and M. VanMouwerik. 1998. Mining and power generation along the Natchez Trace Parkway. Natural Resource Year in review – 1998, National Park Service, p. 2.

National Park Service .1995. Baseline water quality data inventory and analysis, Big Thicket National Preserve. Technical Report NPS/NRWRD/NRTR-95-39, 485 p.

National Park Service. 1999. Baseline water quality data inventory and analysis, San Antonio Missions National Historical Park. Technical Report NPS/NRWRD/NRTR-99/222, 1999 p.

National Park Service. 2000. Baseline water quality data inventory and analysis, Palo Alto National Historic Site. Technical Report NPS/NRWRD/NRTR-99/239, 469 p.

McColluogh, J.D. 1947. A preliminary survey of the invertebrate fauna of Big Thicket National Preserve. National Park Service, 18 p.

Parks, H. B., V. L. Corey, et al. 1954. Biological survey of the East Texas Big Thicket area. publisher unknown, 51 p.

Paxton, C.J., D.A. Etnier, J.T. Baxter, and M.H. Doosey. 2000. Fishes of the Tennessee portion of the Natchez Trace Parkway. University of Tennessee, 56 p.

Suttkus, R.D., and G.H. Clemmer. 1979. The fishes of Big Thicket National Preserve. Tulane University and Mississippi State University, 234 p.

Ross, S.T. .1994. Natchez Trace fish inventory. University of Southern Mississippi, 54 p.

State of Texas .2006. http://www.tpwd.state.tx.us/publications/nonpwdpubs/water_issues/rivers/navigation/riddell/index.phtml

Texas Commission on Environmental Quality (RG-145) Surface Water Quality Monitoring Procedures, Volume 1. 198 p.

United States Geological Survey (Circular 1112) Design of the National Water-Quality Assessment Program, http://pubs.usgs.gov/circ/circ1112/

Appendix A
Field Quality Assurance Quality Control

Quality Assurance and Quality Control – the routine steps and protocols needed to produce reliable data – begins before the first sample is taken and ends when the data are verified, validated, and entered into NPStoret. Separate QA/QC documents are appended to the "Water Quality Monitoring Program for the Inland Parks of the Gulf Coast Network" that deal with laboratory and data issues. Furthermore, additional QA/QC topics are addressed in the Plan's "Protocol Narrative" and associated "Standard Operating Procedures". The following text will describe field measures that will be taken to assure that the highest possible data will result. At risk of redundancy of topics discussed in the SOPs (water quality protocol narrative section of this document), several key field QA/QC elements will be presented below.

Central to QA/QC, both field and laboratory, is accounting for precision, accuracy, and bias. The USEPA defines precision as "a measure of mutual agreement among individual measurements of the same property". Bias is defined as "the systematic or persistent distortion of a measurement process which causes errors in one direction." While accuracy can be defined as "the degree of agreement between an observed value and an accepted reference value." Accuracy includes a combination of random error (precision) and systematic error (bias) and the term is used when these two types of errors can't be separated. Although it would be hubristic to assume one can fully control all aspects affecting precision, accuracy and bias, by careful use of basic QA/QC measures, one can successfully account for these key elements.

Field Probe Calibration

Prior to taking the first sample the sampler is required to calibrate all field sensors against a referenced standard. Calibrating probes to standards is a measure of accuracy. Each probe has an "accuracy" claimed by the manufacturer. This is typically reported as +/- a reporting unit or percentage. This is not to be confused with resolution, which refers to discernable differences from one step to the next. It is essential that the sampler documents the probe accuracy and resolution, as they will define the significant figures data reporting.

Temperature

For economy and ease of use, the liquid-in-glass thermometer is recommended for field use. A pocket-sized thermometer protected by a plastic or metal case is recommended. Mercury filled thermometers should be avoided since breakage may occur in the stream and the spilled mercury may be toxic. To eliminate the problem of column separation, it is best to use a thermometer with gas-filled capillary.

Most thermometers shipped from the manufacturer are not highly accurate. Before each new thermometer is issued for field use, it should be checked for accuracy. This is done by comparing the field thermometer to a precise instrument such as an ASTM calibration thermometer at three points. The comparison is usually made in a water bath to eliminate erratic readings. Any thermometer found to be off by more than 0.5^{o}C should be rejected.

Temperature measurements should be made directly in the stream if possible. The following steps should be taken when making temperature measurements:

1. Check thermometer for liquid-column separation.
2. Immerse bulb into source.
3. Allow the reading to stabilize.
4. Read temperature with bulb immersed (removing the bulb from water can result in an erroneous temperature reading due to rapid thermometer response to changing conditions).
5. If temperature cannot be measured in the source, collect (at a minimum) an 8-ounce (500 mL) bottle or beaker of water and measure the temperature immediately. Shield the sample from the sun and wind while measuring.
6. Return thermometer to protective case.

Note: Temperature of the sample is required for accurate calibration of the instrumentation for dissolved oxygen, pH and conductivity. Temperatures should be recorded with results of these analyses. Air temperatures can be collected on-site, and provide useful information for site characterization as well.

pH

It is important that maintenance and calibration be provided for all pH meters. If the pH meter is properly maintained and calibrated, field values may be more valid than lab values due to changes in pH with time and temperature fluctuation.

Calibrate meter and electrode according to manufacturer's instructions using three buffer solutions (for example 4.01, 7.00 and 10.01). To avoid contamination of buffers, calibration and meter checks should be conducted in buffer solution in separate containers, such as small disposable paper cups. Buffer solutions should be discarded after use. Often in parks only occasional pH measurements are made, therefore it is critical to calibrate the instrument before each measurement. When frequent measurements are made, the meter calibration should be checked at least twice a day. If the meter is drifting appreciably it will need to be recalibrated more frequently - or it may need new electrodes. If in-situ measurement is not possible, a water sample should be collected and analyzed immediately for pH. This sample is then discarded.

Measurement of Sample pH

1. Place electrode into sample (split sample that is discarded after measurement).
2. Measure temperature.
3. Turn function switch to "measure" or equivalent
4. Allow meter readout to stabilize (this may take several minutes if the solution is poorly buffered).
5. Record pH to nearest 0.1 pH unit.
6. Cover electrode with protective cap of electrode storage solution.

Specific Conductance

Specific conductance is dependent upon water temperature, and by convention, values are adjusted to 25^{o}C (standard temperature and pressure). Basically all modern conductivity instruments have a temperature compensation mechanism that automatically adjusts readings to the 25 degree standard. The GULN will use only temperature compensated sensors.

It also is advisable to check a field instrument's automatic calibration mechanism periodically. This may be done by warming and cooling a single water sample in the laboratory, above and below 25 degrees, and observing the instrument's ability to correct its reading back to the 25-degree value. In most solutions an increase of 1^{o}C will increase conductance by approximately 2 percent.

Specific conductance electrodes should be rinsed occasionally in a hydrogen peroxide solution or a weak acid solution (5 percent) to prevent debris and algae from accumulating. Maintenance and calibration of conductance meters should follow manufacturer's instructions.

Calibration and Measurement of Specific Conductance

The GULN will use automatic temperature compensated meters for all specific conductance measurements.

1. Check battery
2. Calibrate as per manufacture’s instructions using a traceable standard of 447 μS/m.
3. Read conductance according to manufacturer's instructions.
4. Record sample measurement
5. Remove probe from sample and rinse thoroughly with deionized or distilled water.

Dissolved oxygen

Dissolved oxygen (DO) should be measured in-situ or in the field, as concentrations may show a large change in a short time if the sample is not adequately preserved. Dissolved oxygen concentrations may be determined directly with a DO meter.

Calibration and Measurement of Dissolved Oxygen

Dissolved oxygen meters can be used to measure dissolved oxygen concentrations in-situ, in the field. The procedure is as follows:

1. Calibrate the instrument as per manufacture’s instructions. Meters currently used by the GULN are easily calibrated in water-saturated air. Make sure that the current barometric pressure (uncorrected, absolute pressure) is entered into the meter setup menu. Recalibration and pressure entry should be done prior to a DO measurement at each monitoring site.

2. Place the probe in the solution to be measured and agitate the probe. Let the probe come to temperature and measurement stabilize before recording values.
3. If measurements are in waters with low turbulence, gently stir the probe in the water, without inducing aeration.

Report both the concentration (mg/L) and the percent saturation (%) for each sample. This is done as the saturation (partial pressure) of any dissolved gas in a liquid is dependent on the temperature of the liquid.

Duplicate Samples

The general discussion above focused on accuracy – the agreement or calibration of a sensor to a traceable standard. In order to account for precision and bias, duplicate samples will be routinely taken during all water quality collection events.

For each sampling event (where an event is defined as sampling occurring during one field day) one site – pre-assigned by random number selection at the beginning of the fiscal year by GULN Hydrologist – will undergo duplicate sampling. All parameters, both field and laboratory, will be duplicated. In the case of field parameters, the sensors will be used to measure as described in SOPs 3, 4, and 5 ("Collection of Field Data," "Field Measures," and "Sample Collection, Preservation, and Transportation," respectively. QA/QC readings will be taken in exactly the same manner – sensors removed from the sample, turned off, and the measurement repeated. Time between the collection of the "regular" sample and the QA/QC duplicate sample will be kept at a minimum – typically less than 10 minutes – to assure the same conditions, or nearly the same as possible, are sampled. Each sample extraction, probe placement, equilibration times, etc, component will be duplicated when taking the QA/QC duplicate sample.

The duplicate QA/QC samples will be labeled as "QAQC" in the four-digit site code and noted in the field book as the QA/QC sample. All preservation, storage, and transportation protocols will be followed QA/QC samples.

The sampler will record the in situ measures for the QA/QC sample and compare each reading to that of the "regular" sample. Each reading must have a relative percent difference (RPD) of no greater than 10%. Calculation for the RPD is as follows:

$$RPD = (S1-S2)/((S1+S2)/2)*100$$

Where: S1 = value of sample one
S2 = value of QA/QC sample

The sampling will be repeated until the RPD score is 10% or less.

In the case where a sample is extracted for laboratory analysis, the sampler will follow SOP 5. In addition, to assure that the same and its QA/QC duplicate will be as close to identical as possible (at this point it is not feasible to use a cone or churn splitter) the sampler will collect bottle pairs at the same time, side-by side.

Much discussion has been given to QA/QC sampling schedules. In order to remove sampler bias, a random-number transform was performed at each park. The results that will be used for the first complete year of sampling is as follows. In this exercise the sample number was set equal to the number of sampling sites at a given park, the number of iterations was equal to the number of park visits per year. Each iteration was done “with replacement” – that is, all sites were “returned to the hat” prior to each iteration. The same randomization method will be used prior to each sampling year.

Appendix B
Clean Rivers Program Quality Assurance Project Plan
Lower Neches Valley Authority

Appendix C
Texas Clean Rivers Program Surface Water Monitoring Program for the San Antonio River Basin
Quality Assurance Project Plan