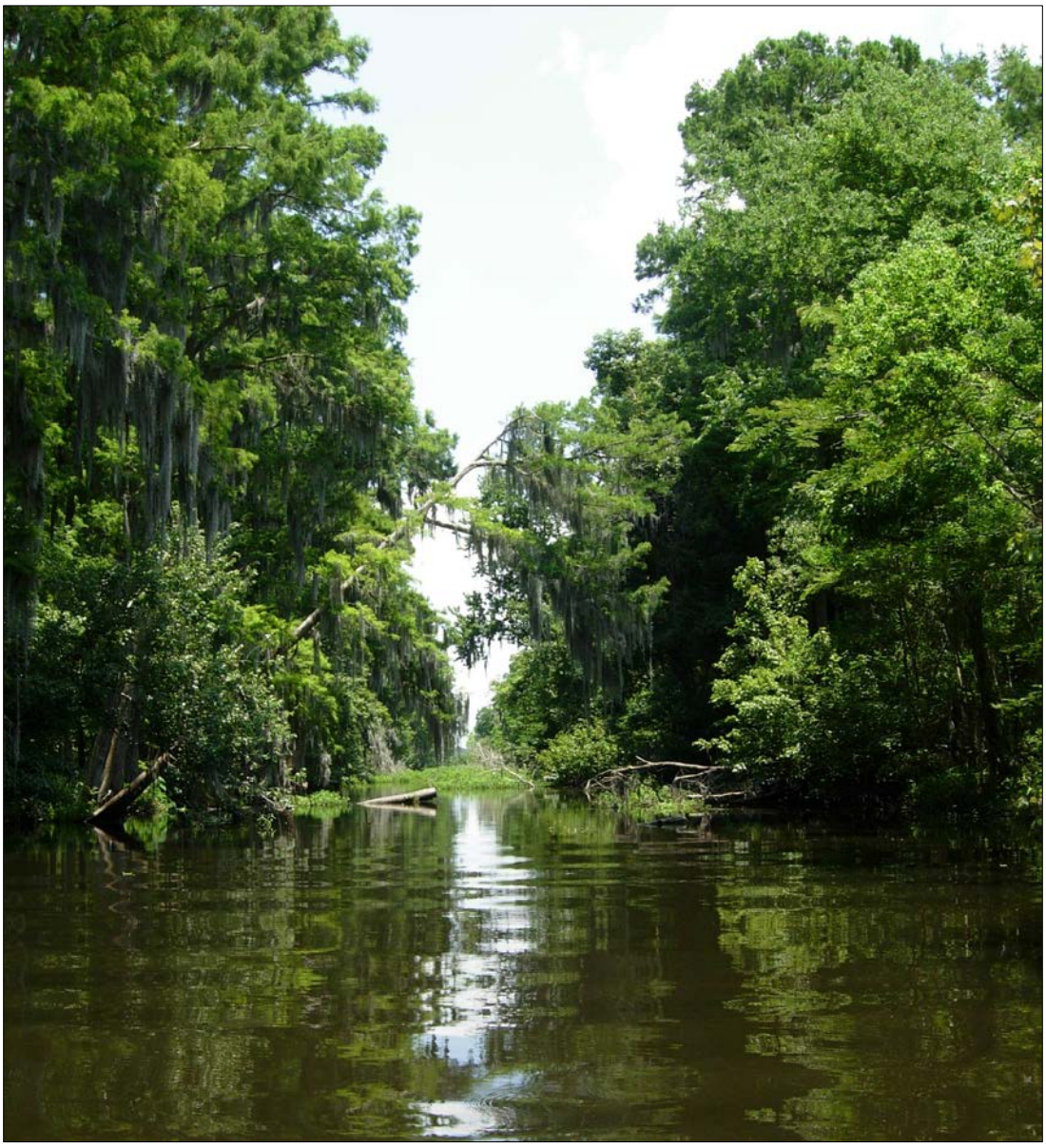
National Park Service
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Natural Resource Stewardship and Science

Gulf Coast Network Water Quality Report

Status of Water Quality of Jean Lafitte National Historical Park and Preserve—Barataria Preserve 2008-2014

Natural Resource Data Series NPS/GULN/NRDS—2015/969



ON THE COVER
Millaudon Canal, May 26, 2010
Photograph by Joe Meiman

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Fort Collins, Colorado

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Acronyms and Abbreviations

°C	degrees Celsius
CFS	(cfs) cubic feet per second
DO	dissolved oxygen
DPFD	Davis Pond Freshwater Diversion Project
GULN	Gulf Coast Network
km	kilometer
LDL	lower detection limit
mg/L	milligrams per liter
mL	milliliter
mm	millimeter
MPN	most-probable number
n	number of measurements
NPS	National Park Service
NPStoret	NPS's water quality depository
NTU	nephelometric turbidity unit
SM	Standard methods for the examination of water and wastewater
SOP	standard operating procedure
SpC	specific conductance
STORET	national water quality database
SU	standard unit (pH)
U.S.C.	United States Code
UDL	Upper Detection Limit
USACE	United States Army Corps of Engineers
µS/cm	microSiemens per centimeter
USEPA	United States Environmental Protection Agency
USGS	United States Geological Survey

Gulf Coast Network Long-Term Water Quality Monitoring

Water quality ranked among the top vital signs and was chosen to be monitored long-term in the eight parks composing the National Park Service's (NPS) Gulf Coast Network (GULN). Water quality monitoring protocols and Standard Operating Procedures (SOPs) are located in the GULN Vital Signs Monitoring Plan (Segura et al. 2007). The report that follows is a park-specific document that describes the status of water quality knowledge, including a description of the monitoring program, sampling sites, parameters tested, results in graphic form (when available), a brief interpretation of the results, and recommendations of parameters to be measured along with long-term sampling locations and frequency.

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

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

Non-conditional synoptic sampling, where samples are taken regardless of flow and weather conditions on fixed calendar dates, is central to this effort. Basic fixed sampling locations are 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.

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

Measureable Objectives

This is a long-term monitoring program. It is not designed to respond to catastrophic or singular water quality events. It is designed to form a comparative database to detect changes in a variety of water quality parameters over time within an individual park or stream. Parks within a particular ranking category may be cross-comparable, but charting changes in water quality within a particular park is the primary statistical objective for the long-term data. Through a series of Vital Signs Workshops and other meetings with park managers, the water quality monitoring program was devised to meet the management objectives of the GULN parks. These measurable objectives are as follows:

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

Brief Hydrologic Introduction to Jean Lafitte National Historical Park and Preserve: Barataria Preserve

It is impossible to look in any direction in the Barataria Preserve and not see either water or a landscape directly resulting from the actions or presence of water. A collection of man-made canals connect forested wetlands, across large expanses of flotant marsh, to vast fresh water lakes, which are in turn joined to the Gulf of Mexico through waterways, including maintained canals, and open marshland. It is important to note that following the start of GULN routine water quality monitoring, Jean Lafitte National Historical Park and Preserve expanded to include some 1,200 hectares of forested wetlands and marsh east of Route 45and bounded by the Intracoastal Waterway to the south and east. This report will focus on the hydrology and water quality in the Barataria Preserve prior to the 2009 expansion.

Threats to Water Quality

The Preserve receives water from three general sources 1) meteorological (direct precipitation or pumped storm water), 2) wind driven (tropical storm surges or strong south winds), and 3) Mississippi River water via the Davis Pond Freshwater Diversion Project (DPFD). The later taps into the West Bank of the Mississippi River and diverts water into Davis Pond and into Lake Cataouatche which forms the western boundary of the Preserve on its way to the Gulf. Thus if DPFD water enters the Preserve it would mean that Jean Lafitte National Historical Park and Preserve (JELA) has the largest watershed of any National Park Service unit—the entire Mississippi River watershed above New Orleans—some 3,163,792 km^2. As the adjacent towns of Westwego and Estelle lie within levees at or slightly below sea level, massive pumping stations are required to prevent flooding. The Preserve is the receiver of urban runoff via ten pump stations draining five developed basins. The Preserve receives annual average precipitation of 143cm, but at times of tropical storms, daily totals can exceed 25 cm. At times the gradient in the Barataria reverses as tropical storms and seasonal southern winds push saline water from the Gulf of Mexico some 60 km to the south deep into the Preserve. Each source of water will be discussed in detail below and in the water quality results section.

Davis Pond Freshwater Diversion

Authorized through the Flood Control Act of 1965 and modifications by the Water Resources Development Acts of 1974, 1986 and 1996, the Davis Pond Freshwater Diversion is a component of the Mississippi Delta Region Project, US Army Corps of Engineers (USACE 1999). The purpose of this diversion structure is to slow the loss of salt marsh habitat and enhance shellfish and finfish production by reducing salinities in the lower Barataria Basin. The resulting structure of four 14’ by 14’ box culverts that tap into the west bank of the Mississippi has the maximum design capacity of 10,650 cfs (Figures 1 and 2). A secondary goal of the Project is to supply the basin with river nutrients and sediment that were historically carried by spring floods; a natural process that has been eliminated by river levees. Construction began in 1997 and the Project became operational in July 2002.



Figure 1. The Davis Pond Freshwater Diversion looking south into the Barataria Basin. Image courtesy of US Army Corps of Engineers.

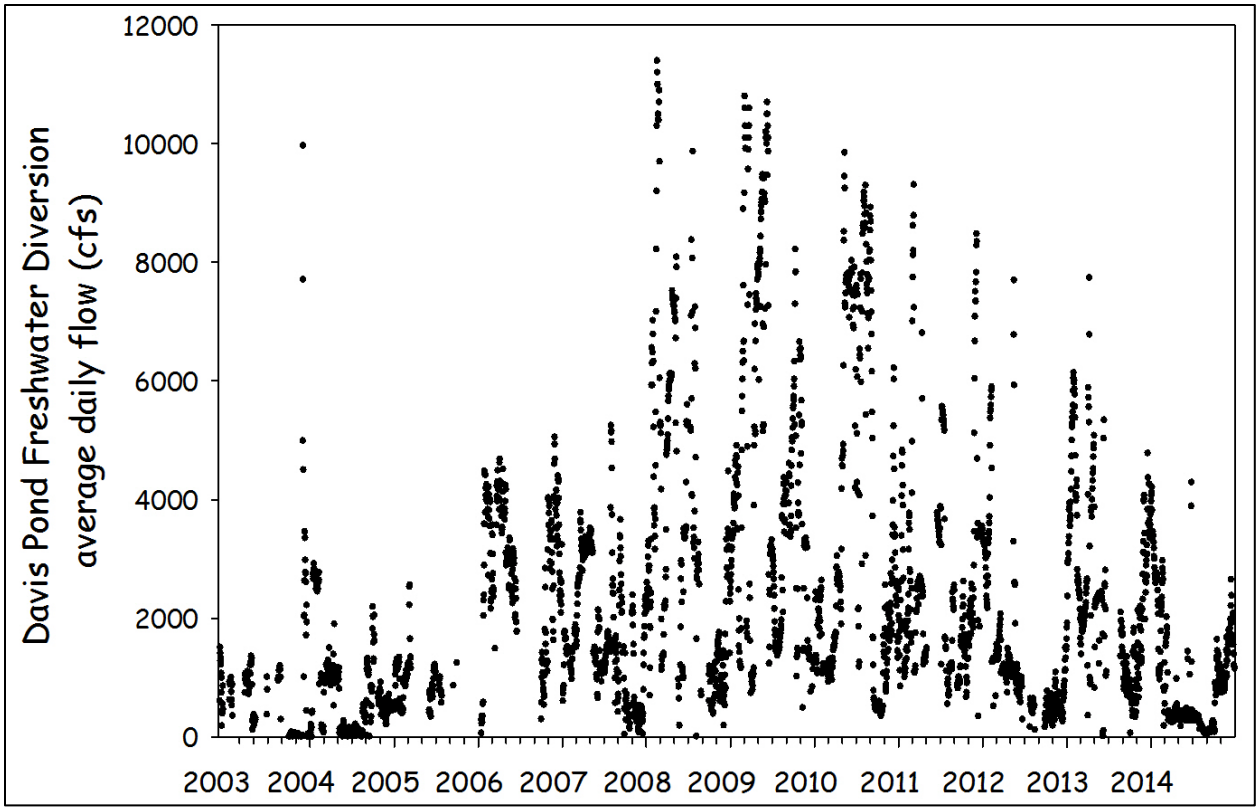


Figure 2. Davis Pond Freshwater Diversion flow; December 5, 2002 through December 31, 2014. The limited flow of the first few years after activation were primarily due to very fresh conditions in the lower basin.

En route to the lower basin water diverted through Davis Pond passes along the western margin of the Barataria Preserve. While this program only monitors a modest list of parameters it is reasonable to assume that any contaminant that passes through the Davis Pond Freshwater Diversion Project could enter the Preserve under specific conditions. While the United States Army Corps of Engineers funded a water quality monitoring program between 1997 and 2007 there is currently no routine water quality monitoring associated with the Project other than continuous monitoring stations to report specific conductivity (salinity) and temperature as it relates to the operation of the Davis Pond Freshwater Diversion Project.

It would be erroneous to assume that all or many releases from the Davis Pond Freshwater Diversion Project actually enter the Preserve. The image of Figure 3 was captured on November 29, 2011 following a period of elevated releases (daily average of 6,000 cfs) from the Davis Pond Freshwater Diversion beginning November 27. While turbid Mississippi River water can be seen pouring into Lake Cataouatche, dark water also recharges the lake from marshes and canals of the Preserve. Only a modest amount of river water can be seen entering Preserve canals at Bayou Bardeaux and Bayou Segnette Waterway. The New Orleans International Airport Station (the nearest weather station with an acceptably complete data record) recorded 4.3 cm of rainfall over the two weeks preceding this image with gentle breeze of 0.4 m/s from the southeast. The interaction of diversion water and the Preserve cannot be automatically assumed, as it is a product of simple hydraulic gradient, which in turn is a result of prevailing wind and rainfall volume. This may be the most important and fundamental relationship to bear in mind when examining the hydrology of the Preserve; as easy as it may be to over-complicate the source of water in the Preserve, it always comes down to gradient, be it caused by wind, riverine discharge or pumps.

Pumping Stations

Jefferson Parish operates pump stations that drain four adjacent basins that discharge directly into the Preserve (Table 1, Figures 3 and 4). Their combined maximum pumping volume is 9,364 cfs (USACE 2009). When all pumps are operating at capacity, which typically occurs three or four times each year for a few hours (personal communication, Clinton Hotard, Jefferson Parish Department of Environmental Affairs) their combined flow into the Preserve is nearly equal the 10,650 cfs maximum design capacity of the Davis Pond Freshwater Diversion. Parish canals have been recipients of an assortment of contaminants that comprise general urban runoff. There are additional pump stations on the southern margin that have limited effect on the Preserve.

To make a general estimate of annual contribution to the Preserve from the pumps we know the average annual precipitation at the adjacent Audubon weather station is 143 cm. We know that Jefferson Parish pumps service 7,150 Ha. If only one tenth of this volume results as runoff and reaches the pumps, a total annual average of approximately 7.5 million cubic meters is pumped into the Preserve.

Table 1. Jefferson Parish pumping stations that discharge directly into the Preserve. Runoff from a total of 17,668 acres (7,150 ha) of adjacent land is pumped into the Barataria Preserve.

Basin Number/Name	Basin Area (Acres)	Pumping Station	Pump Station Capacity (cfs)
8 Ames	4,041.97	New Ames	3,314
		Oak Cove	68
		Mount Kennedy	262
10 Bayou Segnette	1,816.76	Westwego No.1	300
		Westwego No.2	936
		Westminster	1,248
11 Avondale	5,170.03	Bayou Segnette	936
		New Bayou Segnette	1,200
9 Westwego	6,639.50	Cataouatche No.1	500
		Cataouatche No.2	600
Total*	**17,668.26**		**9,364**

*These figures are for pumping stations discharging into the Barataria Preserve prior to the 2009 expansion and do not include stations such as Old Estelle which discharges into the new area of the Preserve.

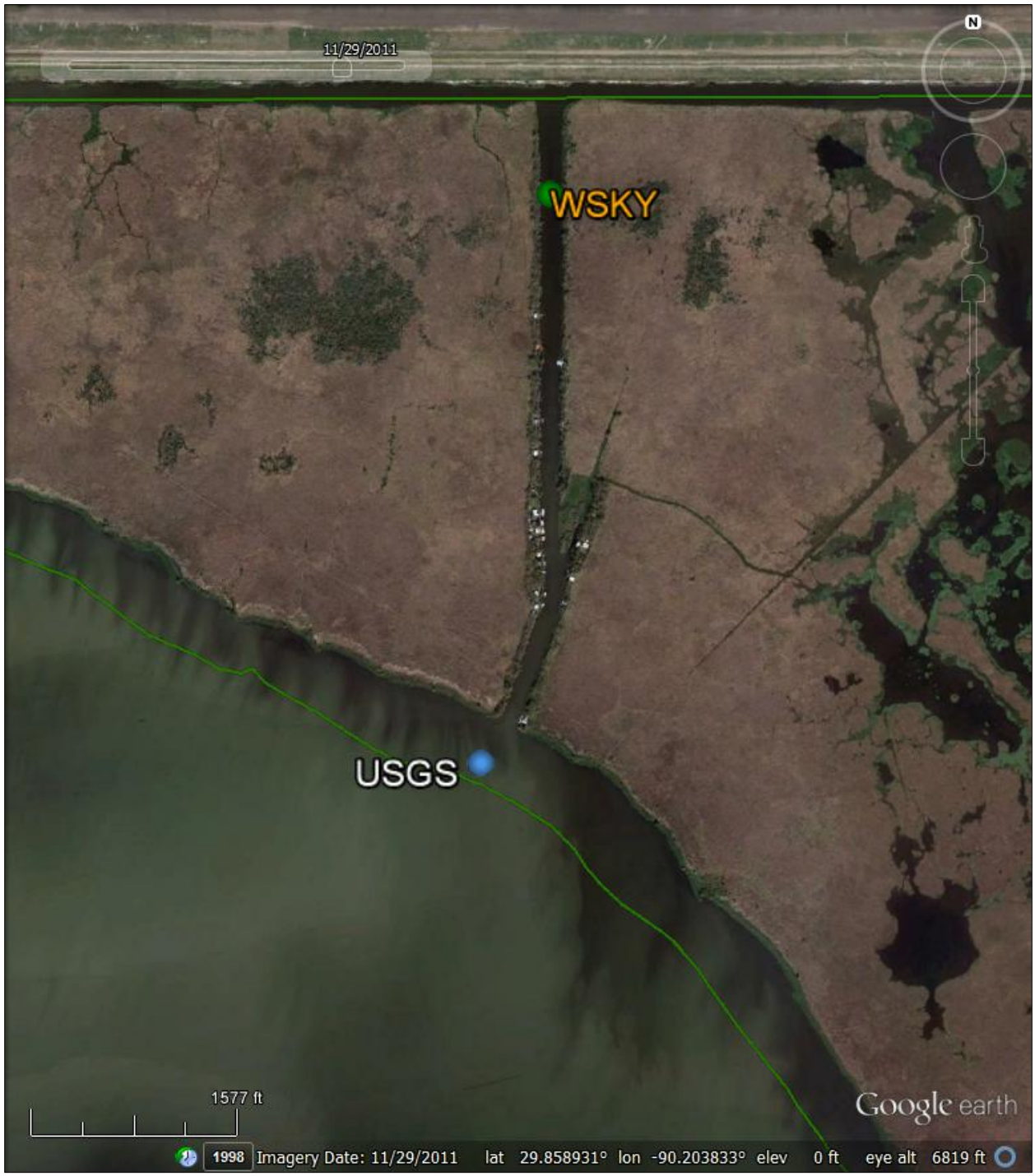


Figure 3. The northeastern margin of Lake Cataouatche as seen on November 29, 2011. USGS station 2951190901217 is located at the southern end of Whiskey Canal, and GULN water quality station WSKY on its northern end. Note the dark marsh waters discharging into the turbid lake water. The daily average flow from Davis Pond from November 27–29, 2011 was 6,000 cfs, or 60% of its upper design flow limit.

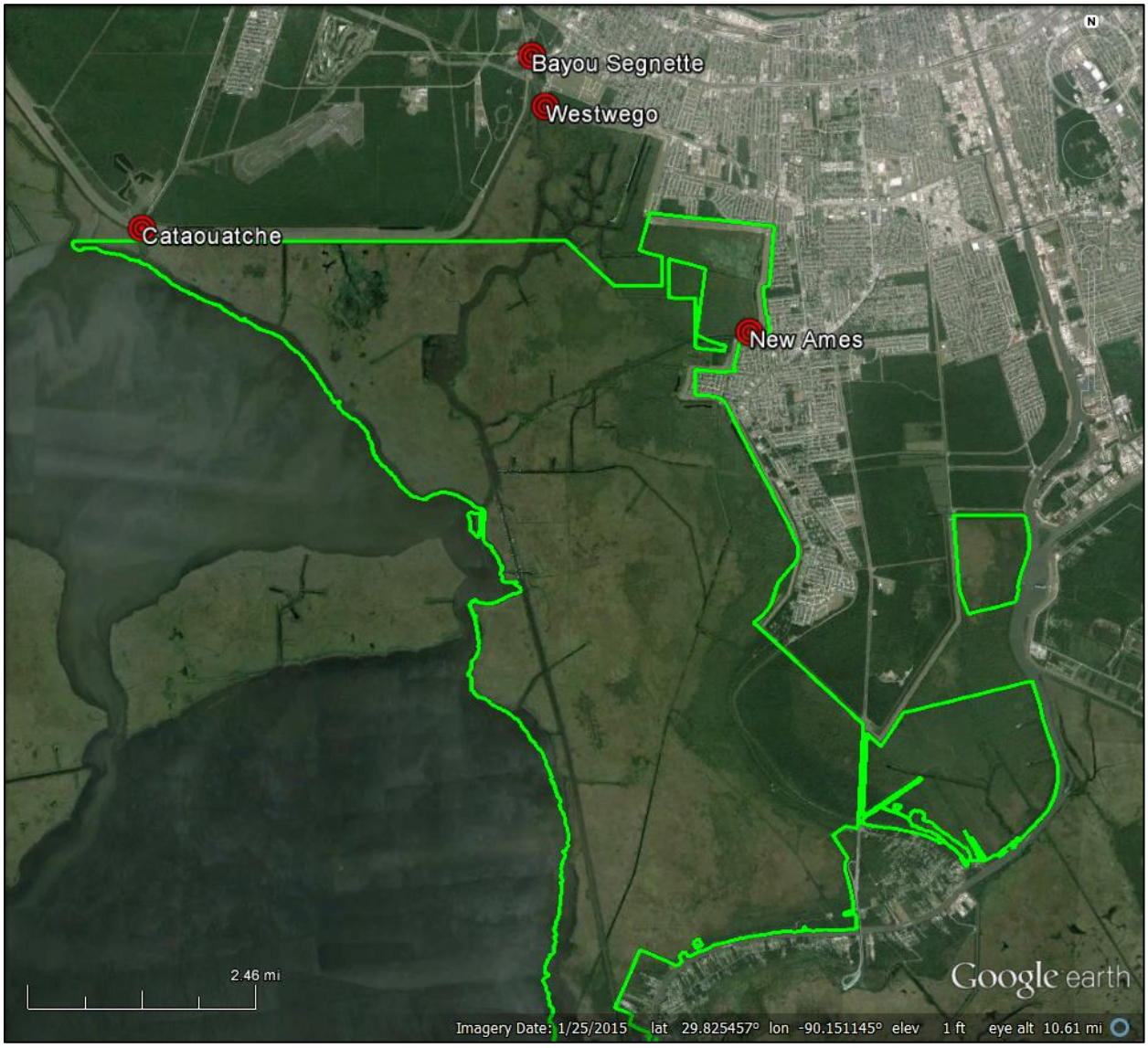


Figure 4. Four main pump stations discharge directly into the Preserve.

Saline Water Intrusions

Tropical storms push tremendous volumes of salt water 60 km from the Gulf of Mexico into the Barataria Basin and ultimately into the canals of the Preserve. Doses of salt water kill non-tolerant vegetation and increases native amphibian mortality and recruitment (Robert Woodman, GULN Ecologist, personal communications). While such intrusions are natural, their frequency, duration and intensity have increased due to the loss of coastal wetlands. Trend analysis from 1985 to 2012 shows a wetland loss (freshwater and non-freshwater marshes and forested and scrub-shrub wetlands) of 43 km^2 per year (Couvillion et al. 2011). The cause of wetland loss is likely a combination of several anthropogenic and natural factors ranging from alterations in drainage, relative sea level rise (including high rates of subsidence, and tectonic action), and introduction of exotic mammals. The National Oceanic and Atmospheric Administration (NOAA) measured a 9.03 mm/year relative sea level rise at Grand Isle, 50 km south of the Preserve on the edge of the Barataria Basin (NOAA 2015). Penland and Ramsey (1990) attribute the relative rise largely to sediment compaction. While agreeing to the rate of relative sea level rise, Dokka (2006) argues that tectonism accounts for between half and three quarters of deltaic subsidence rather than compaction of near surface sediments. Day, et al. 2000 demonstrates a positive correlation between artificial canals and wetland loss in the Barataria Basin. The nutria (*Myocastor coypus*), an exotic rodent from South America was first reported in coastal Louisiana in 1937, can add to the burden of stressed wetland plant communities. These non-native semi-aquatic herbivores can devastate marsh vegetation opening it to erosion and decay. Nutria infestation became such an issue that the Nutria Eradication and Control Act of 2003 became Public Law 108-16.

Waters of the Barataria Preserve may experience periods of elevated salinities in the absence of tropical storms. Prior to the completion of the Davis Pond Freshwater Diversion, saline events were caused by extended droughts. Beginning in 2000 and continuing for nearly one year, southern Louisiana experienced an extreme drought. Without freshwater to push south into the Gulf, saline waters, at times aided by winds from the south, pushed far north into the basin (Figure 5).

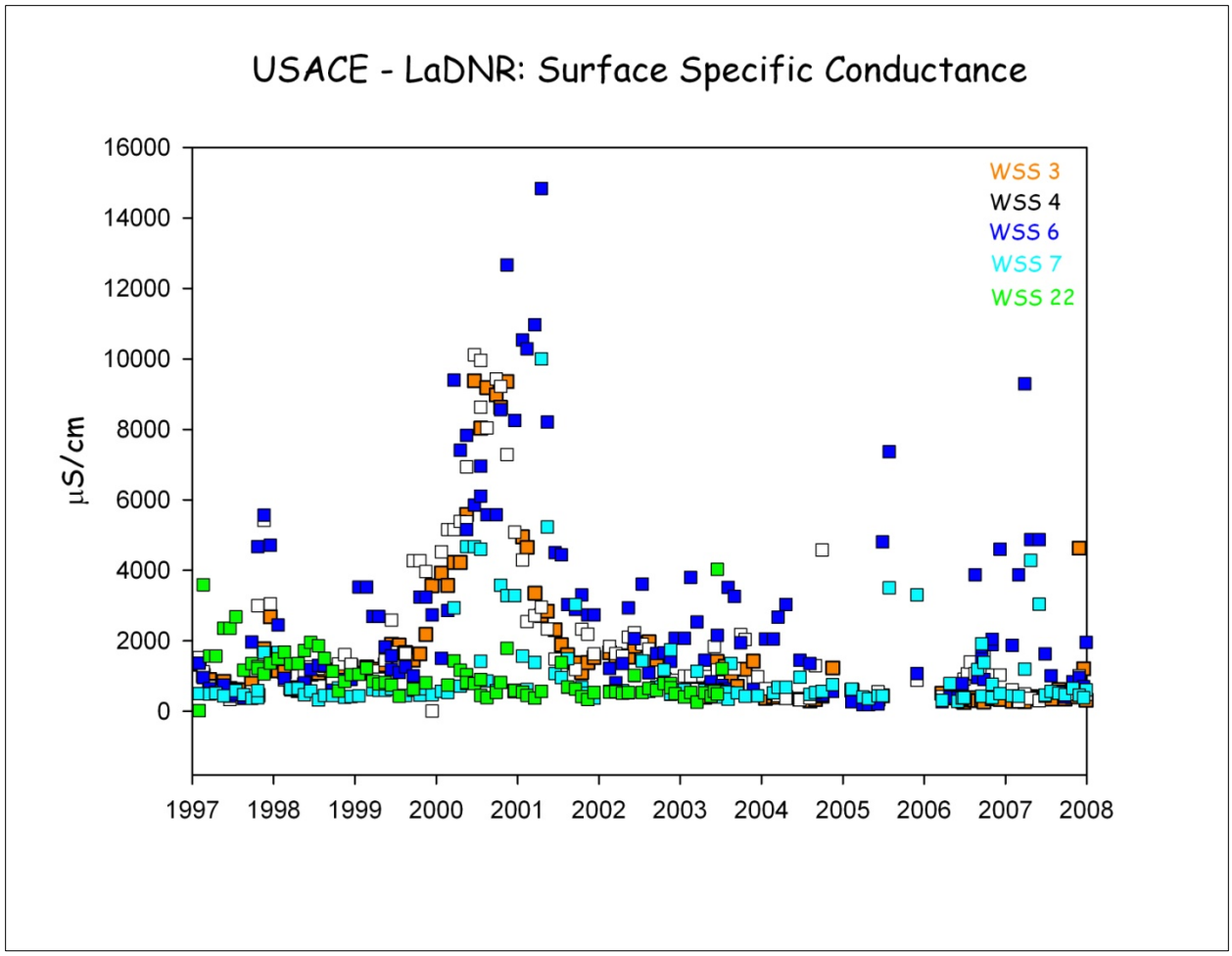


Figure 5. Results for the USACE monitoring program. These five sites represent those of the program's 22 sites proximal to the Preserve. Elevated salinities are seen pushing into the northern portions of Lake Cataouatche (WSS3) but not at Bayou Segnette Waterway (WSS22).

Autogenic Modifications

The hydrology of the Preserve is severely altered by numerous canals, including several historic canals, such as portions of the Millaudon and Kenta canals that predate the civil war (personal communication, Dusty Pate, NPS JELA 2012). Canals affect hydrology and the dependent vegetative community; canals provide hydraulic communication of the Preserve wetlands to the lower Barataria Basin, and associated spoil banks curtail sheet-flow causing both increased local flooding and desiccation of adjacent marshes. Beginning in 2001 the park has pulled down spoil banks on either side of 8.7 km of selected canal segments with 25.8 km remaining (Figure 6). While changes to the existing artificial hydrology are not known, these banks that were covered with exotic plants were removed, extending the viewshed deep into the flotant marsh.

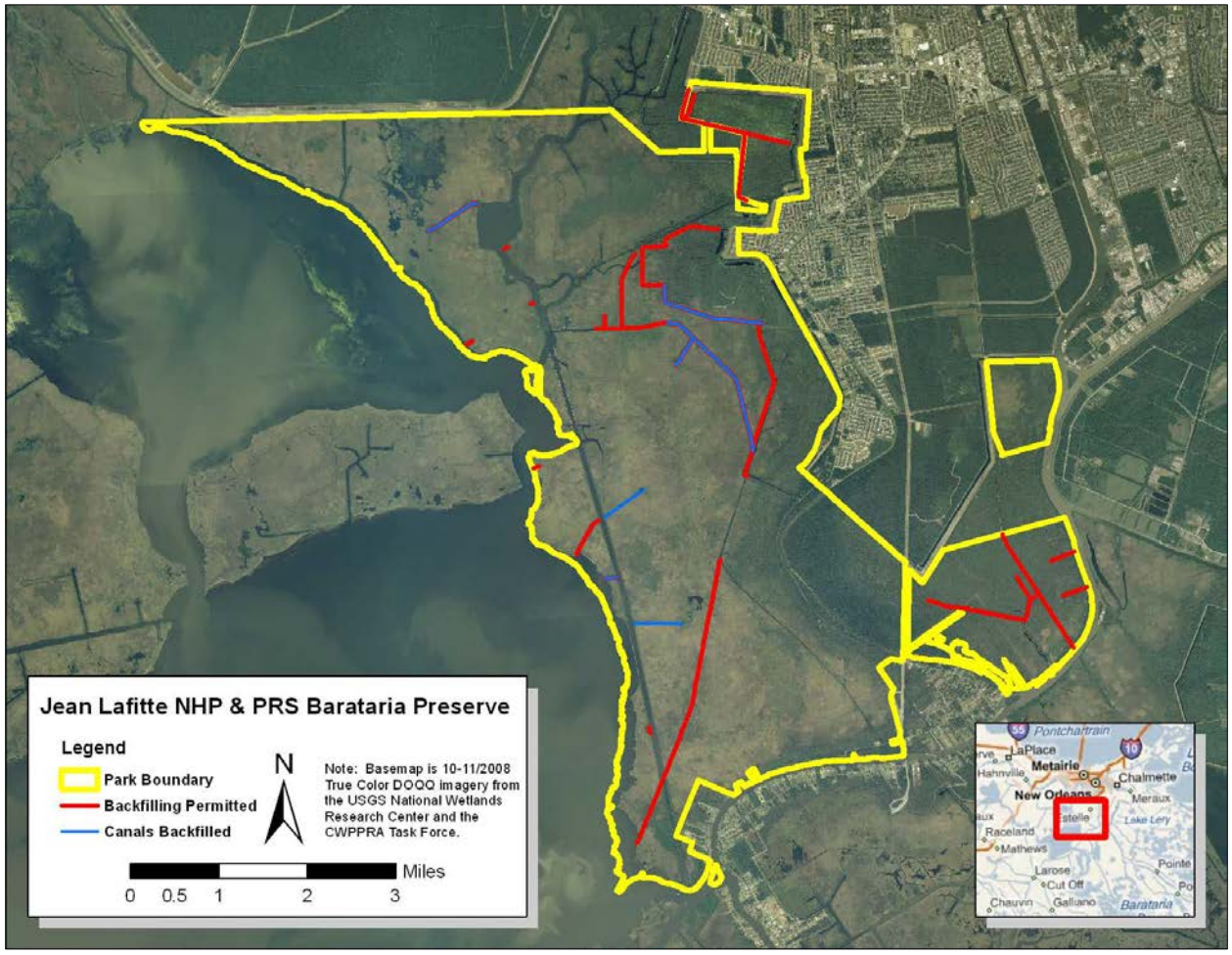


Figure 6. Non-historic canals, dikes and borrow canals under reclamation as of 2010.

While the Preserve is moving towards reclaiming non-historic canals and restoring a more natural hydrologic function, larger navigation canals, such as the Bayou Segnette Waterway (dredged by the United States Army Corps of Engineers typically every 20 years) are maintained. Recent dredging operations have experimented with beneficial uses of spoil, pumping into adjacent swamp sites.

The United States Army Corps of Engineers contracted annual aquatic vegetation control with herbicides. The chemicals 2,4-dichlorophen-oxyacetic acid and diquat dibromide (and occasionally, although not in concordance with the permit, glyphosate) are sprayed to control common *Salvinia* and water hyacinth to keep canals open for visitor navigation. This program operated from 2001 through 2011 (Table 2). Jean Lafitte National Historical Park and Preserve reports that the Louisiana Department of Wildlife and Fisheries has operated an herbicide spraying program in the Preserve since 2012 but details are unavailable. Nearly 2,000 ha were treated (including retreated canals) by this program. Records did not provide enough detail to estimate the mass of active ingredients applied.

Table 2. Herbicide application at JELA waterways 2001–2011 (JELA files, 2012). Some acreage may be larger than actual application on park waters as the contract treatment extended beyond the park boundary. Information on specific treatment date and area exists for 2009–2011 only.

Date Treated	Canal Treated	Hectares Treated	Herbicide
2001	Unknown	40.5	Diquat
		20.3	2,4-D
2002	Unknown	109.4	Diquat
		20.3	2,4-D
2003	Unknown	60.8	Diquat
		8.1	Glyphosate
		20.3	2,4-D
2004	Unknown	131.6	Diquat
2005	Unknown	97.2	Diquat
		40.5	2,4-D
2006	Unknown	89.1	2,4-D
2007	Unknown	101.3	Diquat
		190.4	2,4-D
2008	Unknown	60.8	Diquat
		192.4	Glyphosate
07-22-2009	Bayou Segnette Millaudon Canal Lower Kenta Canal Upper Tarpaper Canal	153.9	2,4-D
08-09-2009	Bayou Segnette Waggaman Canal Upper Tarpaper Canal Lower Tarpaper Canal Lower Millaudon Canal	202.5	2,4-D
10-15-2009	Kenta Canal	40.5	Diquat
05-12-2010	Bayou des Familles	12.2	2,4-D
08-05-2010	Bayou des Familles	12.2	Diquat
08-10-2010	Waggaman Canal Upper Bayou Segnette Upper Kenta Canal Lower Kenta Canal Pipeline Canal	60.8	2,4-D
11-06-2010	Bayou Segnette Waggaman Canal Whiskey Canal Upper Tarpaper Lower Millaudon Canal	151.9	2,4-D
04-20-2011	Bayou des Familles	12.2	Diquat
05-14-2011	Kenta Canal Millaudon Canal Upper Tarpaper Canal Lower Tarpaper Canal Pipeline Canal Parallel Canal Ross Canal	70.9	2,4-D
05-15-2011	Bayou des Familles	12.2	2,D
06-02-2011	Upper Tarpaper Canal Lower Tarpaper Canal Lower Kenta Canal Upper Kenta Canal Parallel Canal Pipeline Canal Ross Canal Millaudon Canal	70.9	2,4-D

Recreational Use and Aquatic Life

The park does keep records of visitor use in the Preserve; it would be nearly impossible to track this accurately as a great deal of park access does not originate from controlled access points such as trail heads and boat/canoe launches, but rather from the myriad of canals, bayous and trenasses extending into adjacent state and private land. The park does promote front country use (maintained trails and boardwalks), and maintains three canoe launches (Twin Canals, Lower Kenta Canal and Bayou des Familles), though many of the waterways they serve are often closed by vegetative growth. Privately owned camps, typically small permanent structures built upon canal dredge spoils, are found in the northwestern portion of the Preserve (Figure 7). There are dozens of camps within the Preserve which provide owners and guests immediate access to the Preserve and nearby Lakes Cataouatche and Salvador. Although swimming in the interior waterways of the Preserve is rare, there is swimming during the warmer months at the camps. Boating and fishing, both secondary contract recreational activities occur year-round.



Figure 7. Fishing camps line the dredge spoil banks along Bayou Segnette north of Bayou Bardeaux. Photograph by Joe Meiman, September 19, 2010.

Existing Water Quality Information

The utility of a database is contingent upon data quality (including collection, analysis, and data management, entry and metadata), spatial relevancy (samples collected in the most strategic locations), temporal continuity (samples collected over a period of time that allow study) and parametric relevancy (parameters that address water quality issues chosen). In short, was the sampling program designed and executed in such a way that it provides park management with information needed to make informed resource decisions?

Unlike many park service units where little water quality data are available, it is difficult to digest the volumes of information in and proximal to the Preserve. In 1994 the National Park Service inventoried USEPA STORET and found 40 industrial dischargers, 10 drinking water intakes, and six active or inactive USGS and USACE gauging stations (NPS 1994). The results of the STORET retrieval for the study area yielded 126,979 observations for 364 separate water quality parameters collected by five federal, state, and local government agencies at 120 water quality stations (NPS 1994). This inventory, while impressive in sheer volume, is of limited use to the park manager as it drew from a buffer of three to five kilometers around an area that includes the Barataria Preserve, the park headquarters in the French Quarter and the Chalmette Battlefield and National Cemetery; including the west and east banks of the Mississippi River from Bridge City to downstream of Chalmette including downtown New Orleans, Gretna, Harvey, Belle Chase and the Callander Field Naval Air Station that do not affect the waters of the Preserve.

Water quality studies that focus on the Barataria Preserve are numerous, albeit of short-duration, with narrow objectives. The National Park Service did not conduct a regular water quality monitoring program until the GULN began routine monitoring in July 2008. There have been two recently completed and three continuing routine sampling efforts at the Preserve; Jefferson Parish Department of Environmental Affairs Stormwater Permit Monitoring sampled at pump stations, and the USACE Davis Pond Freshwater Operation Monitoring have been completed while the Louisiana Department of Environmental Quality Ambient Surface Water Quality Program, the Coastwide Reference Monitoring System (CRMS) and the GULN long-term water quality program continue (Figure 8).

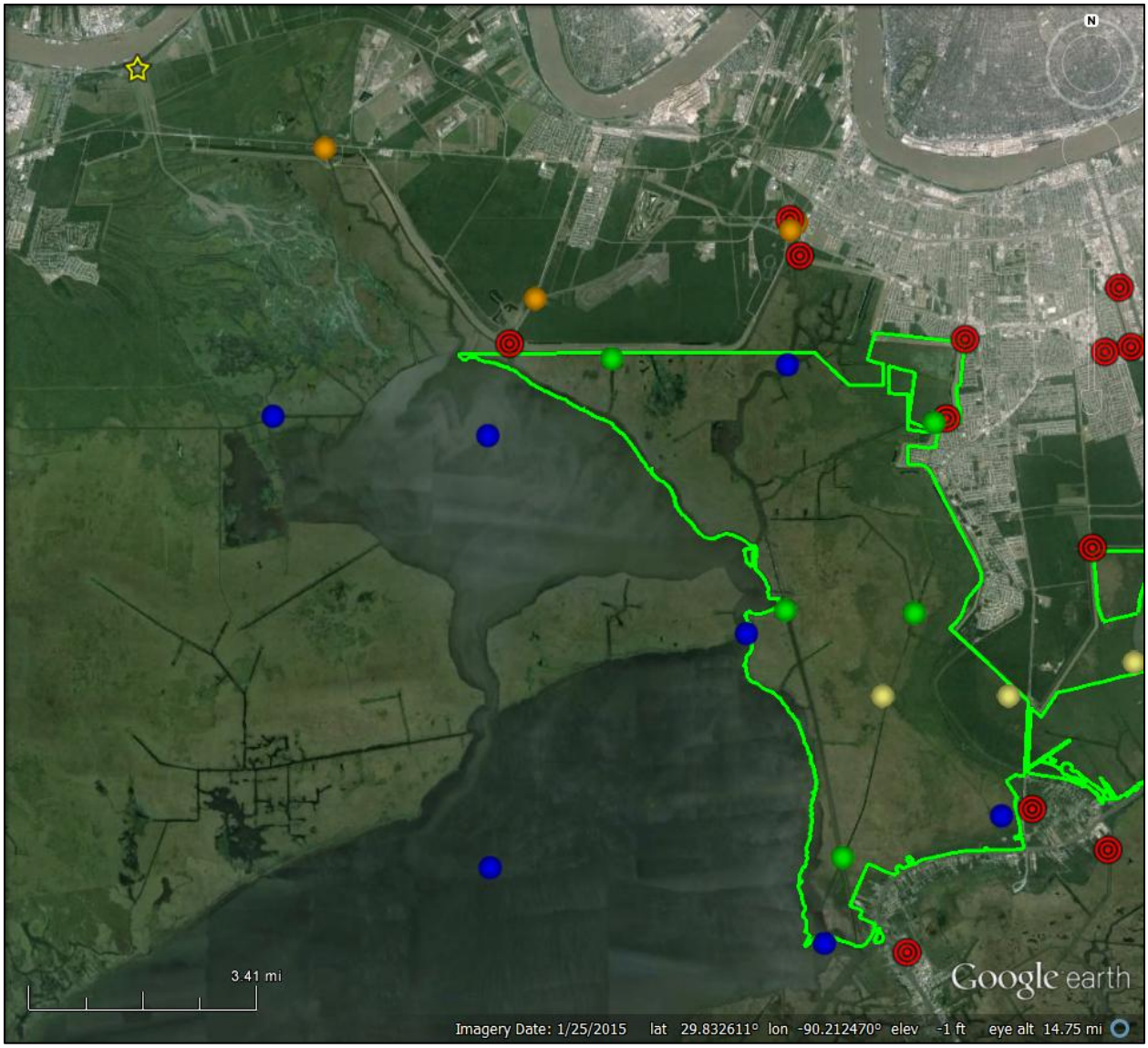


Figure 8. Past and present water quality monitoring sites proximal to JELA relative to the Davis Pond Freshwater Diversion (yellow star) and Jefferson Parish pump stations (red targets). Yellow dots are CRMS (2007–present), blue dots, USACE DPFD sites (1997–2007), orange dots, Louisiana Ambient Surface Water Quality Program (2000–present) and green dots representing GULN long-term stations (2008–present).

A water quality monitoring program was implemented as early as 1983 at 12 west bank parish pumps stations by the Jefferson Parish Department of Environmental Affairs. Samples were taken from the canal side of the pump stations for *Escherichia coli*, fecal streptococcus, nitrite, nitrate, total Kjeldahl nitrogen (biologically accessible nitrogen), chemical oxygen demand, total phosphorous, oil and grease, arsenic, cadmium, chromium, copper, mercury, nickel, lead and zinc. The program was discontinued in March 2011 due to funding reduction and changes in stormwater permit requirements (personal communication, Jefferson Parish Department of Environmental Affairs 2012).

The United States Army Corps of Engineers, in order to evaluate the water quality of the Barataria Basin related to the operation of the Davis Pond Freshwater Diversion, contracted a sampling program over a ten year period, five years before and five years after the Project went on line in 2002. These data are perhaps the best of those existing to influence the development of the GULN program. Twenty two stations were established for monthly synoptic sampling for a host of physio-chemical parameters including nutrients and metals. The limiting factor for these data for our use is spatial relevance as only five stations were set in or proximal to the Preserve. Core nutrient parameters were chosen for the GULN water quality program based on this 10-year effort.

The State of Louisiana conducts sampling proximal to the park as part of its ambient surface water quality monitoring program. The program samples nearly 600 sites statewide through a rotation, sampling approximately 100 sites in any given month. Six sites proximal to the Preserve were sampled semi-annually beginning in 1991 through the present. These data may be useful for a more detailed water quality assessment but with many data gaps, sporadic sampling schedule and a poorly accessible database the extraction and examination of these data is difficult and beyond the scope of this report.

As a result of the 1990 Coastal Wetlands Planning, Protection and Restoration Act (CWPPRA), funds were made available for short- and long-term restoration projects of coastal wetlands in Louisiana. A component of CWPPRA is the establishment of a monitoring system, the Coastwide Reference Monitoring System (CRMS) to evaluate the effectiveness of restoration projects. Three CRMS stations were established in the Preserve; CRMS0184 established in 2006, CRMS0184 in 2006, and CRMS0234 in 2008. These sites sample temperature, specific conductance, salinity and stage and marsh elevation every hour. These stations, while providing hourly data for a limited suite of parameters, were not designed to adequately describe water quality at the Preserve.

Other water quality-related studies have been initiated in the Preserve over the past few decades. From 1981 through 1991 the USGS conducted water quality monitoring but provided no analysis or discussion of results. The National Park Service (Baron and Newkirk 1992) examined these data to ask: 1) what are the water quality conditions in the Barataria Preserve over this decade? 2) Are there water quality trends over this period? and 3) Was the sampling frequency (variable depending on specific sampling interest) sufficient to provide useful information to park managers? Questions regarding the integrity of the data were not addressed. The USGS program was extremely fragmented (temporarily and parametrically) and not designed with park questions in mind. The USGS data were unable to answer these basic questions and if the park wished to know the quality of its water a monitoring program must be directly tied to management questions (Baron and Newkirk 1992).

More recently Christopher Swarzenski of the USGS has conducted various monitoring efforts focused on pore water, surface water, and sediment quality of the Preserve. Swarzenski (2004) conducted a resurvey of surface water and bottom material sites of the USGS 1981–1982 monitoring sites (a portion of the above described dataset). Little additional information was gained and neither study cites collection or analytical methods, which are critical in resurveys.

GULN Sampling Sites

After examination of existing data and interviews with park staff five stations were chosen for the GULN long-term water quality monitoring program representative of water quality threats to the Preserve; freshwater from the Davis Pond Diversion, surges of saline waters from the Gulf of Mexico, and stormwater pumped over the levees from adjacent urban lands (Figures 9–14).



Figure 9. GULN long-term monitoring stations at JELA

Bayou Bardeaux (BARD): Bayou Bardeaux is located on the edge of Bayou Segnette Waterway and the east pass between Lakes Cataouatche and Salvador (Figure 10). Depending on winds, freshwater inflow and tides water may be dominated by Bayou Segnette Waterway or the lakes. There are several private camps proximal to this site.



Figure 10. Bayou Bardeaux looking northward. Note camps on canal spoil banks in the background. Photograph by Joe Meiman, May 26, 2010.

Pipeline Canal (LPIP): Pipeline Canal is sampled near the intersection of Bayou Segnette Waterway (Figure 11). This is the closest GULN site to the Gulf Intracoastal Waterway, approximately 2 km south on Bayou Segnette Waterway.



Figure 11. Pipeline Canal looking northward at the intersection of Segnette Waterway. Photograph by Joe Meiman, May 26, 2010.

Millaudon Canal (MILL): Millaudon Canal, unlike other GULN sites penetrates into the hardwood wetland forest (Figure 12). The canal is typically sampled within 200 m of the New Ames Pump Station; on occasion the canal cannot be traversed due to treefall, when it is sampled as near as possible.



Figure 12. New Ames Pump Station at the upstream terminus of Millaudon Canal. Photograph by Joe Meiman, September 19, 2006.

Tarpaper Canal (TARP): Tarpaper Canal is the most isolated canal sampled by the GULN (Figure 13). Often site access is difficult because of thick growths of aquatic vegetation. The dredge spoil banks of Tarpaper Canal north of the sampling site were reduced by the park in 2010 yielding views into the flotant marsh to the west.



Figure 13. Tarpaper Canal looking north. Photograph by Joe Meiman, May 26, 2010.

Whiskey Canal (WSKY): Whiskey Canal is the closest site to Lake Cataouatche and the waters diverted through Davis Pond 11 km to the northwest (Figure 14). Whiskey Canal, sampled within the Preserve a few meters south of the intersection of Waggaman, or Outer Cataouatche Canal, which receives water from the Highway 90 (Cataouatche) Pump Station 2.5 km to the west.



Figure 14. Waggaman Canal looking north from Whiskey Canal. The hurricane protection levee in the background has been recently reinforced. Photograph by Joe Meiman, May 26, 2010.

Stream Designated Uses and Water Quality Standards

Pursuant to the Clean Water Act, states must classify their waters into specific categories, or designated uses. A designated use reflects the highest use or activity for that segment (i.e., drinking water supply, recreation, or fish and wildlife use). The U.S. Environmental Protection Agency (USEPA), in addition to mandating these rankings, directs the states to develop water quality criteria that support each designated use. Louisiana Title 33, Part IX, Subpart 1, §1111 lists seven different use categories. The only water in the Preserve that has been assigned designated uses by the state is Bayou Segnette Waterway; Fish and Wildlife Propagation, Primary Contact Recreation, and Secondary Contact Recreation. Title 33, Part IX, Subpart 1, §1111 states "Designated uses assigned to a subsegment apply to all water bodies (listed water body and tributaries/distributaries of the listed water body) contained in that subsegment unless unique chemical, physical, and/or biological conditions preclude such uses." Therefore all waters within the Preserve examined in this report have the same designated uses as Bayou Segnette Waterway.

Each designated use category has specific water quality standards. As the waters of the Preserve have three designated uses, the most stringent standard is applicable in evaluating water quality. Table 3 includes all routine monitoring parameters measured in the GULN program. As shown, the state does not have criteria for some of these parameters.

Table 3. Water quality criteria for parameters routinely measured by the GULN at JELA.

Calcium	No state standard
Dissolved Oxygen	December 1 through February 28; > 5.0 mg/L March 1 through November 30; > 2.3 mg/L
E. coli	<298 MPN/100 mL*
Magnesium	No state standard
Nitrate	No state standard
Nitrite	No state standard
pH	>6.0, < 8.5 SU
Phosphorous	No state standard
Specific Conductance	No state standard
Turbidity	No state standard
Water Temperature	<32^{o}C

It must be noted that the state conducted an ecoregional Use Attainability Analysis (UAA) to describe the water quality and biological characteristics of reference water bodies which portray the natural conditions in the Barataria and Terrebonne Basins, and to assign the appropriate designated uses and/or dissolved oxygen criteria. Physical descriptions, water quality, and biological characteristics of reference or least-impacted water bodies in these basins, which lie in the Coastal Deltaic Plains and Lower Mississippi River Alluvial Plains ecoregions, were documented in the Barataria-Terrebonne Use Attainability Analysis completed by LDEQ in 2008 (State of Louisiana 2010). The UAA determined that the seasonal occurrence of low dissolved oxygen in the Barataria Basin reflects a natural condition. This determination does not change the water quality standard, but acknowledges that low dissolved oxygen may reflect a natural condition.

Parameters for Water Quality Monitoring

Parameters were chosen after examination of existing data. Monthly non-conditional synoptic sampling (sampling on a fixed monthly date regardless of flow condition) commenced on July 31, 2008. Initially, the GULN continued the parameters of the 10-year USACE Davis Pond water quality survey. After 15 months the data were evaluated and it was determined that a streamlined list could provide more cost-effective water quality monitoring; chloride, hardness, mercury, arsenic, barium, cadmium, chromium, copper, lead, nickel, selenium, zinc, sulfate, total Kjeldahl nitrogen and ammonia were dropped after September 2009. Most of these parameters were routinely below detection limits so the cost of analysis far outweighed the usefulness of the data. Nitrate and phosphate were selected over total Kjeldahl nitrogen and ammonia because they are better indicators of high nutrient conditions that may lead to eutrophication. To enhance a USGS water quality study, calcium and magnesium were added in November 2010. These parameters will be dropped after FY15 as we have determined the relationship between calcium and magnesium ratios and water source.

The Gulf Coast Network adopted USGS protocols for all field measures, including sample collection and transport. These protocols can be found in USGS (variously dated) Techniques of Water-resources Investigations Book 9.

Field Measures

Dissolved Oxygen

Accurate data on concentrations of dissolved oxygen (DO) in water are essential for documenting changes to the environment caused by natural phenomena and human activities. Sources of DO in water include atmospheric reaeration and photosynthetic activities of aquatic plants. Many chemical and biological reactions depend directly or indirectly on the amount of oxygen present. Dissolved oxygen is necessary in aquatic systems for the survival and growth of many aquatic organisms. The Network uses an amperometric method in which DO concentration is determined with a temperature-compensating, galvanic, membrane-type sensor and measured in milligrams per liter (mg/L; Lewis 2006).

pH

The pH of an aqueous solution is controlled by interrelated chemical reactions that produce or consume hydrogen ions. Water pH is a useful index of the status of equilibrium reactions in which water participates. The pH of water directly affects physiological functions of plants and animals, and is therefore an important indicator of the health of a water system. The pH is measured using the electrometric measurement method via a hydrogen ion electrode and reported in standard units (SU; Ritz and Collins 2008).

Specific Conductance

Electrical conductance (SpC) is a measure of the capacity of water (or other media) to conduct an electrical current (the inverse of resistance). SpC is a quick and reliable estimation of the dissolved solids in the water, but there is no universal linear relation between total dissolved substances and

specific conductance. A dip-cell electrode sensor is used and SpC measured in microSiemens per centimeter (μS/cm; Radtke et al. 2005).

Turbidity

Turbidity measures the scattering effect that suspended solids have on light, with higher amounts of suspended solids resulting in greater turbidity measurements. Primary contributors to turbidity include clay, silt, finely divided organic and inorganic matter, soluble colored organic compounds, plankton, and microscopic organisms. The measurement cannot be correlated directly to milligrams per liter of TSS. Measurements were made in the field with a nephelometer using SM 2130-B and reported in nephelometric turbidity units (Anderson 2005).

Water Temperature

Measurements of water and air temperatures at the field site are essential. Determinations of dissolved oxygen concentrations, specific conductance, pH, rate and equilibria of chemical reactions, biological activity, and fluid properties rely on accurate temperature measurements. Accurate water and air temperature data are essential to document thermal alterations to the environment caused by natural phenomena and human activities. Water temperature was measured in degrees Celsius (°C) using a thermistor thermometer, which is an electrical device made of a solid semiconductor with a large temperature coefficient of resistivity. An electrical signal processor (meter) converts changes in resistance to a readout calibrated in temperature units (Wilde 2006).

Laboratory Measures

The Gulf Coast Network has adapted the USGS protocol for the collection water samples (USGS 2006) and uses only laboratories that are certified by the National Laboratory Accreditation Conference. An accredited laboratory was used for each of the following parameters except *Escherichia coli* which are determined in the GULN lab:

Calcium and Magnesium

Calcium and magnesium are divalent cations essential to most aquatic life. Calcium and magnesium are monitored in order to determine the general source of water, i.e., marine or riverine. Swarzenski (2004) notes that calcium to magnesium ratios in the Mississippi River are typically 3:1 and attributes ratios approaching 1:1 to be rainwater or marine water influenced (C. Swarzenski, personal communication 2012). Calcium and magnesium are analyzed by USEPA method 200.7.

Escherichia coli

Escherichia coli (*E. coli*) is a naturally occurring bacteria found in the intestines and feces of warm-blooded animals. While not generally a human pathogen (a substance that causes harm to people), some strains of *E. coli*, 0157:H7 for example, have been linked to illness from contaminated foods. As *E. coli* may be associated with pathogens, they are considered an indicator species, and thus used as a measure of water quality. *E. coli* bacteria enter a stream or river by point source (direct contribution at specific points) and non-point source (runoff over a broad area). Point sources include failing septic systems, inadequate waste water treatment facilities, and confined livestock operations. Non-point sources include surface runoff from livestock pastures, land application of manure, and wildlife. *E. coli* was measured using SM 9223-B.

Nitrate and Nitrite as N

The most common form of nitrogen is N_2, but it is not useable by most biota, which primarily utilizes nitrogen as nitrate (NO_3), nitrite (NO_2), or ammonia (NH_3) in freshwaters, in large part depending on the amount of dissolved oxygen. While nitrate alone is not particularly toxic to aquatic life (except in extremely high concentrations), moderate levels of nitrogen can lead to eutrophication, habitat loss, and depressed dissolved oxygen. Nitrate and nitrite were analyzed to provide a total nitrogen value using SM 4500-NO_3-E and SM 4500-NO_2 –B, respectively.

Phosphorous, Total

Phosphorous in the form of orthophosphates is found in natural waters and, in low concentrations, is essential for aquatic life. While not toxic to humans except in extremely high concentrations, excess phosphates can cause eutrophication, leading to excessive aquatic plant growth. Excessive aquatic plants can cause low DO via respiration or through decomposition after the plants die. Excessive DO depletion may cause fish kills. Phosphate was reported as total phosphorous-P and analyzed with method SM4500-P E.

Water Quality Status

Water quality has been sampled by monthly sampling of the above from July 2008 to the present. These data have spanned the reasonable flow continuum (sampling has been conducted during normal, drought, high pumping periods, post tropical storm and strong south wind events), and a general picture of water quality status is beginning to emerge. The dataset for the Preserve is rich with a number of short-term investigations spread through the Barataria Basin as well as populated with long-term records at a few key locations. For example, during the first 14 months the Gulf Coast Network monitored a wider suite of ionic parameters to coincide with the concluding USACE ten year monitoring program. The USACE and GULN data were analyzed and it was determined that an abbreviated list could provide the most cost-effective long-term parameter set. This report focuses on data collected through the GULN Water Quality Monitoring Program supplemented with important data from other sources for specific discussion. Statistical results of initial GULN-sampled USACE parameters are included in statistical summaries.

Monthly Sample Results

The Gulf Coast Network collects synoptic water quality samples and makes *in situ* measurements monthly on every fourth Wednesday. Samples are returned to the GULN office for *Escherichia coli* analysis and a certified laboratory for ionic/nutrient analysis. Notice that there are “missing” data points on some of the graphs presented below. These missing points are not included in final results as, although sampled and analyzed, their concentrations were below method quantification limits. Table 4 is a brief collective statistical summary of monthly results for all five sites. Each of the five sites has 75 sample events, however because of rare equipment or analytical failure actual sample populations may be slightly less. Table 5 examines each site per parameter with an assigned state water quality standard. All standards used are specified by the state of Louisiana for the Bayou Segnette Waterway and associated waterways.

Table 4. Statistical summary of JELA quarterly sample results, July 2008 through December 2014. Substitutes for censored data are: "Not Detected" = 0.5 x the detection limit, "Present>Quantification Limit"=1.1 x Upper Quantification Limit, "Present<Quantification Limit"=0.5 x Lower Quantification Limit.

Parameter	Units	N	Censored*	Min	Max	Mean	Median	Std Dev
Arsenic	µg/L	75	70	2.0	20.8	2.5	2.0	2.5
Barium	µg/L	75	7	5.0	322	96.7	71	62.6
Cadmium	µg/L	75	75	1.0	1.0	1.0	1.0	0
Calcium	mg/L	248	0	11.1	107	37.5	34.7	16.8
Chloride	mg/L	75	1	25	3,060	338	92	539
Chromium	µg/L	75	74	2.0	5.05	2.03	2.0	0.4
Copper	µg/L	75	67	1.0	12.9	1.90	1.0	2.8
DO	mg/L	385	1	0	16.6	5.6	5.6	3.2
*E. coli***	MPN/100 mL	385	34	1	2,662	210	31.8	540
Hardness $Ca^{+}Mg$	mg/L $CaCO_3$	75	6	65.1	1,080	221	139	179
Lead	µg/L	75	74	0.5	1.66	0.5	0.5	0.1
Magnesium	mg/L	248	0	5.4	120	20.6	16.3	14.1
Mercury	µg/L	75	75	---	---	---	---	---
Nickel	µg/L	75	70	5	21.1	5.7	5.0	2.6
Nitrate	mg/L as N	385	198	0.01	0.9	0.07	0.1	.2
Nitrite	mg/L as N	385	261	0.01	2.29	0.1	0.01	0.2
Nitrogen Ammonia	mg/L	75	67	0.1	20.2	0.5	0.1	2.4
Nitrogen Total Kjeldahl	mg/L	75	6	0.06	4.2	1.2	1.1	0.8
pH	SU	385	0	5.65	9.12	7.28	7.23	0.6
Phosphorous	mg/L	385	100	0.03	1.1	0.2	0.1	0.1
Selenium	µg/L	75	70	3.0	6.8	3.3	3.0	0.9
SpC	µS/cm	385	0	207	9,250	970.8	617	1,023
Sulfate	mg/L	75	4	2.5	586	64.5	37.2	84.9
Turbidity	NTU	385	10	1.21	227	21.7	14.9	42.6
Temperature	°C	385	0	6.6	34.1	23.1	24	6.4
Zinc	µg/L	75	73	3.0	10.2	3.2	3.0	1.0

*Censored data include samples that were below quantification limits or were otherwise not reported due to rare equipment or sample error. Not reported data do not affect results.

**17 samples were not reported due to equipment/sample error; four samples were below the lower quantification limit of <1, and 11 samples exceeded the quantification upper limit of 2419.6. For simple descriptive statistics these samples are assigned 0 and 2402 MPN/100mL, respectively.

Table 5. Water Quality Standards Analysis per site for JELA, July 2008 through December 2014. This table represents only parameters that have been assigned water quality standards by the state of Louisiana.

		BARD			LPIP			MILL			TARP			WSKY		
Parameter	**Standard**	*N*	*Ex*	*%*	*N*	*Ex*	*%*	*N*	*Ex*	*%*	*N*	*Ex*	*%*	*N*	*Ex*	*%*
Arsenic	339.8 μg/L	14	0	0	15	0	0	15	0	0	13	0	0	14	0	0
Cadmium	H. Dep.*	14	0	0	14	0	0	14	0	0	13	0	0	14	0	0
Chloride	600 mg/L	15	3	20	15	4	27	15	1	7	14	4	29	15	2	13
Chromium	H. Dep.*	14	0	0	14	0	0	14	0	0	13	0	0	14	0	0
Copper	H. Dep.*	14	0	0	14	0	0	14	0	0	13	0	0	14	0	0
Dissolved Oxygen	Date Dep.**	77	5	6	77	19	25	77	12	16	77	41	53	78	3	4
E. coli	<298 MPN/ 100 mL	77	2	6	77	3	4	77	13	20	77	5	7	78	7	10
Mercury	.204 μg/L	14	0	0	15	0	0	15	0	0	14	0	0	14	0	0
pH	<9 SU	77	2	3	77	0	0	77	0	0	77	0	0	78	0	0
pH	>6 SU	77	0	0	77	0	0	67	0	0	77	0	0	78	1	1
Sulfate	100 mg/L	15	3	20	15	3	20	15	1	7	14	3	21	15	2	13
Temperature	<23°C	77	0	0	77	1	1	77	2	3	77	1	1	78	3	4
Zinc	H. Dep.*	14	0	0	14	0	0	14	0	0	13	0	0	14	0	0

*Hardness Dependent: Generally as hardness increases metal toxicity decreases. Each hardness dependent metal was calculated with the USEPA calculation and compared to the Louisiana standard.

**Date Dependent: December 1 through February 28; > 5.0 mg/L

March 1 through November 30; > 2.3 mg/L

Calcium and Magnesium

While there are no assigned state water quality standards for either divalent cations, the ratio of their concentrations can be used to determine provenance of surface water. Swarzenski (2004) states "Calcium:magnesium ratios are typically about 1:1 or less in water not affected by Mississippi River water. Ratios of the same inorganic ions in Mississippi River water generally are closer to 3:1." The premise being that by using calcium:magnesium (Ca:Mg) ratios one could determine which parts of the Barataria were affected by releases of the Davis Pond Freshwater Diversion. This relationship may be a bit more complicated when calcium: magnesium ratios are examined across all five monitoring sites back-dropped by that of rain water (Figure 15). For example, Millaudon Canal is the most isolated of all five sites, directly adjacent to the New Ames pumping station with a discharge capacity of 3,314 cfs, consistently approximates a 3:1 ratio. It is unlikely that outflow from the Davis Pond Project is affecting water chemistry at the outfall of a pumping station. The 3:1 ratio may be generally indicative of freshwater runoff (riverine or urban) rather than an exclusively reserved to Mississippi River water. It should be noted that the Ca:Mg found at the National Atmospheric Deposition Program (NADP) station in New Iberia, LA can fall anywhere between 1:1 and 3:1, albeit usually in much lower concentrations.

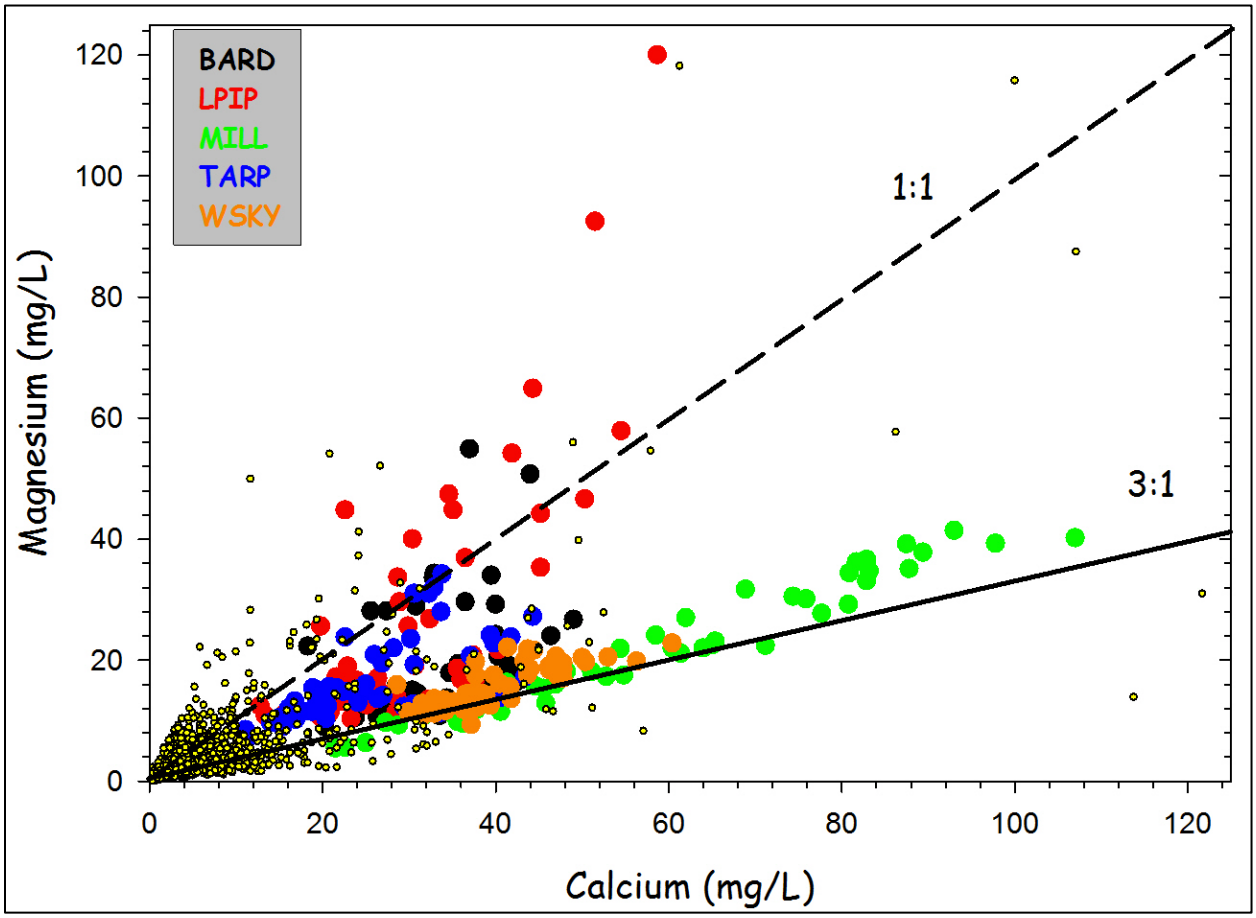


Figure 15. Calcium versus magnesium at the five long-term stations at JELA 2008–2014 (N=248). Solid line is along a 3:1 slope while the dashed line is a 1:1 slope. Precipitation chemistry from New Iberia is shown as yellow symbols (2008–2013).

Dissolved Oxygen

While the state dissolved oxygen standard of 2.3 mg/L is lower during the warmer months (March through November) than the 5.0 mg/L lower limit during the remainder of the year, oxygen levels at Jean Lafitte National Historic Park and Preserve commonly fall below the standards. There may be several reasons, some natural, if one accepts the fact that most of the waterways of the Preserve are not natural in the first place. In general dissolved oxygen levels are lower in the summer months; warmer water cannot hold as much oxygen as colder water. When aquatic plants die, oxygen is consumed in their decay. Plants die in the Preserve for a number of reasons: some are annuals, others are intentionally killed with herbicides, and others die following surges of saline waters from tropical storms or strong southern winds. While the causative agent in aquatic plant death can be discrete (herbicide) or wide-spread (saline water), the end result in a hydraulic system with limited flow-through and aeration is greatly depressed oxygen.

Recall that the state's Use Attainability Analysis (UAA) describes the water quality and biological characteristics of reference water bodies which portray the natural conditions in the Barataria and Terrebonne Basins. The Use Attainability Analysis determined that the seasonal occurrence of low dissolved oxygen in the Barataria Basin reflects a natural condition. This does not change the water quality standard but acknowledges that low dissolved oxygen may reflect a natural condition.

Figures 16 through 20 graph dissolved oxygen for all five sites in the Preserve, but with each graph highlighting a single site. Seasonal state standards are denoted with red hachured boxes. Lines connecting data points are shown to provide visual continuity and not interpolation of data between the points. "N" is the sample population and "SV" is the number of standard violations followed by percentage of violations per sample population in parenthesis.

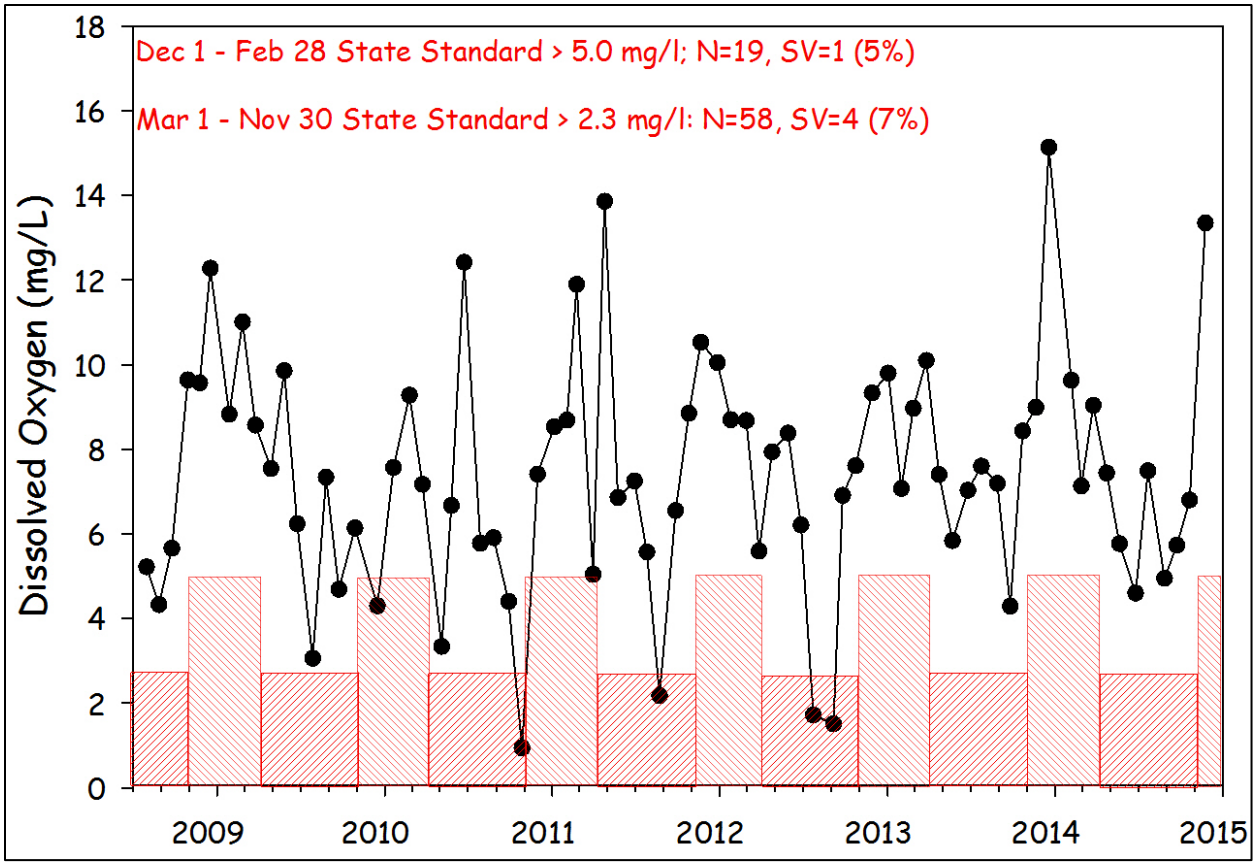


Figure 16. Dissolved oxygen at JELA highlighting Bayou Bardeaux (BARD).

Dissolved oxygen at Bayou Bardeaux is generally above state standards throughout the year. This site is proximal to Lakes Cataouatche and Salvador and is typically well-aerated from winds across these waters and an open hydraulic communication to the lakes.

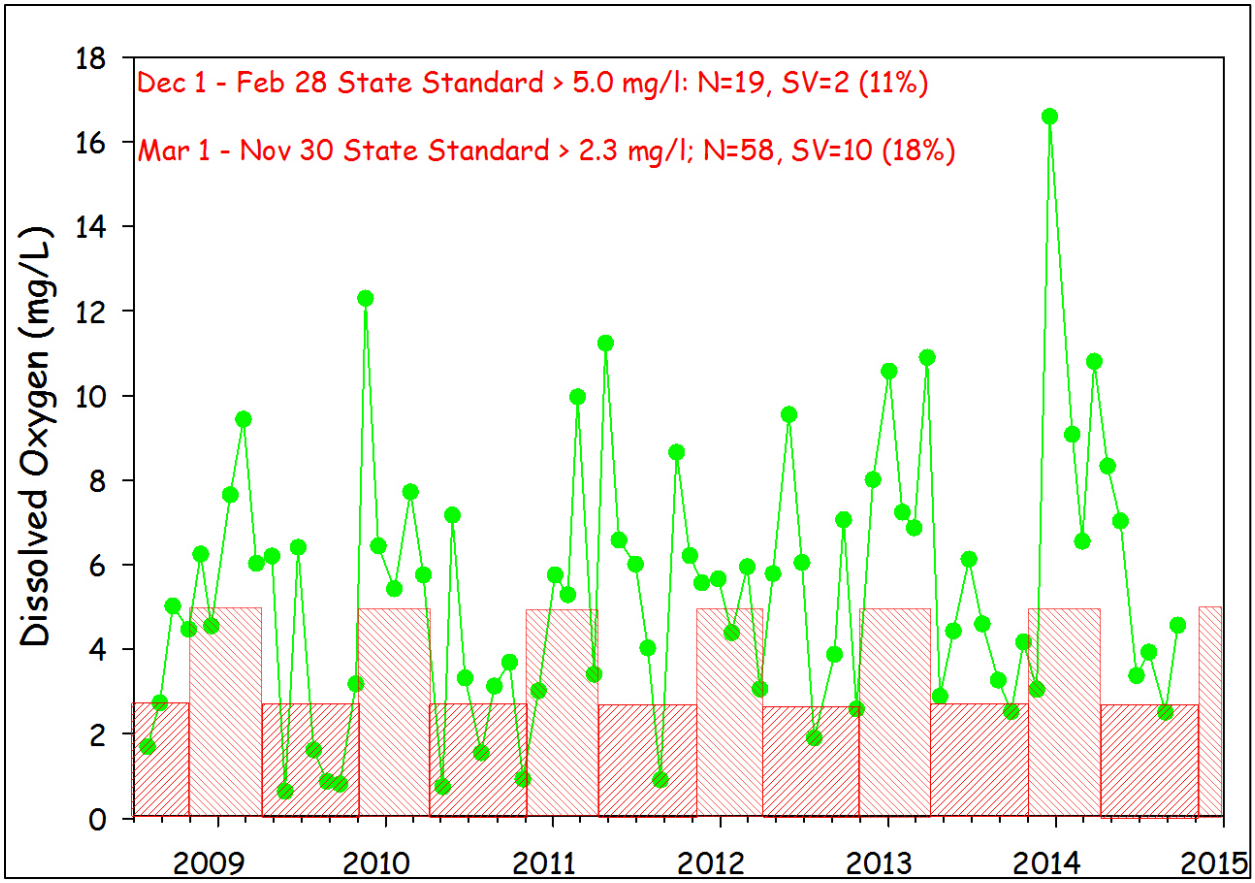


Figure 17. Dissolved oxygen at JELA highlighting Millaudon Canal.

Millaudon Canal essentially begins at the New Ames pumping station. While there is a relation between *Escherichia coli* and pumping activity as will be presented later, there is no apparent correlation with pumping and dissolved oxygen. Oxygen levels tend to be low at the terminus of canals where little or no flow is occurring.

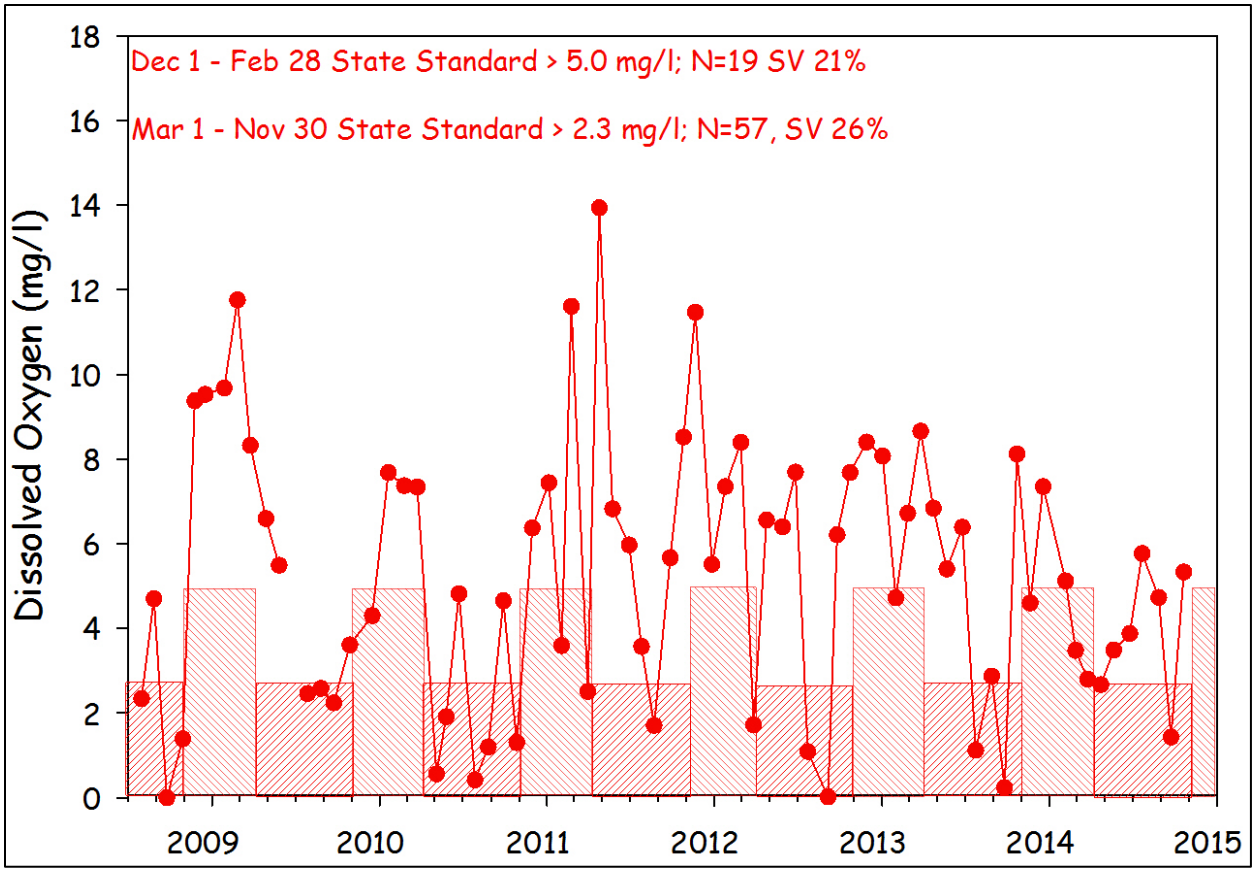


Figure 18. Dissolved oxygen at JELA highlighting Lower Pipeline Canal.

Lower Pipeline Canal is sampled near the intersection with Bayou Segnette. The variability of dissolved oxygen appears to be controlled by communication with the larger Bayou Segnette and nearby Lake Salvador. When there is little or no flow, dissolved oxygen levels typically drop below state standards.

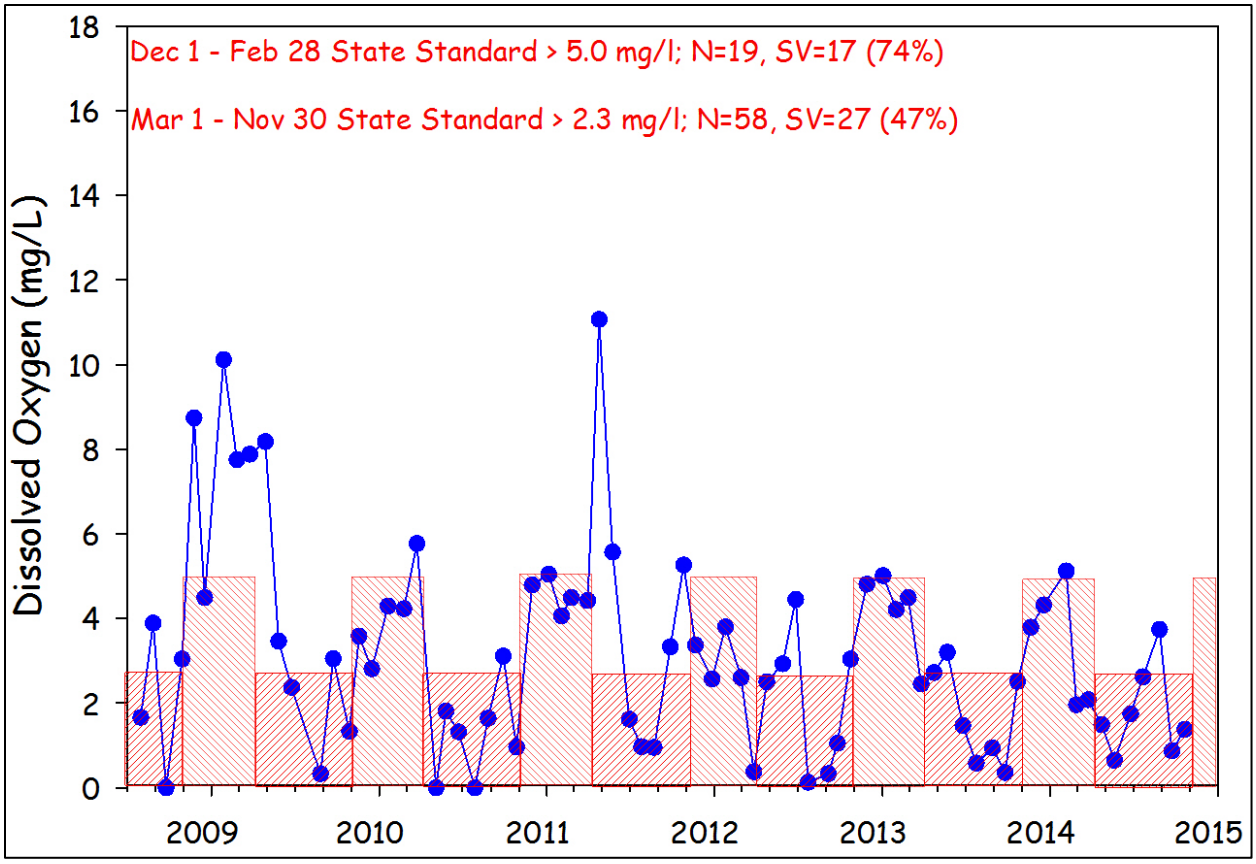


Figure 19. Dissolved oxygen at JELA highlighting Tarpaper Canal.

The Tarpaper Canal site was selected to be representative of a waterway deep in the Preserve. There is extremely limited flow at this site as long-residing waters have very limited interaction with other canals and bayous. Dissolved oxygen is usually below state standards regardless of the season, reflecting the stagnant nature of this site.

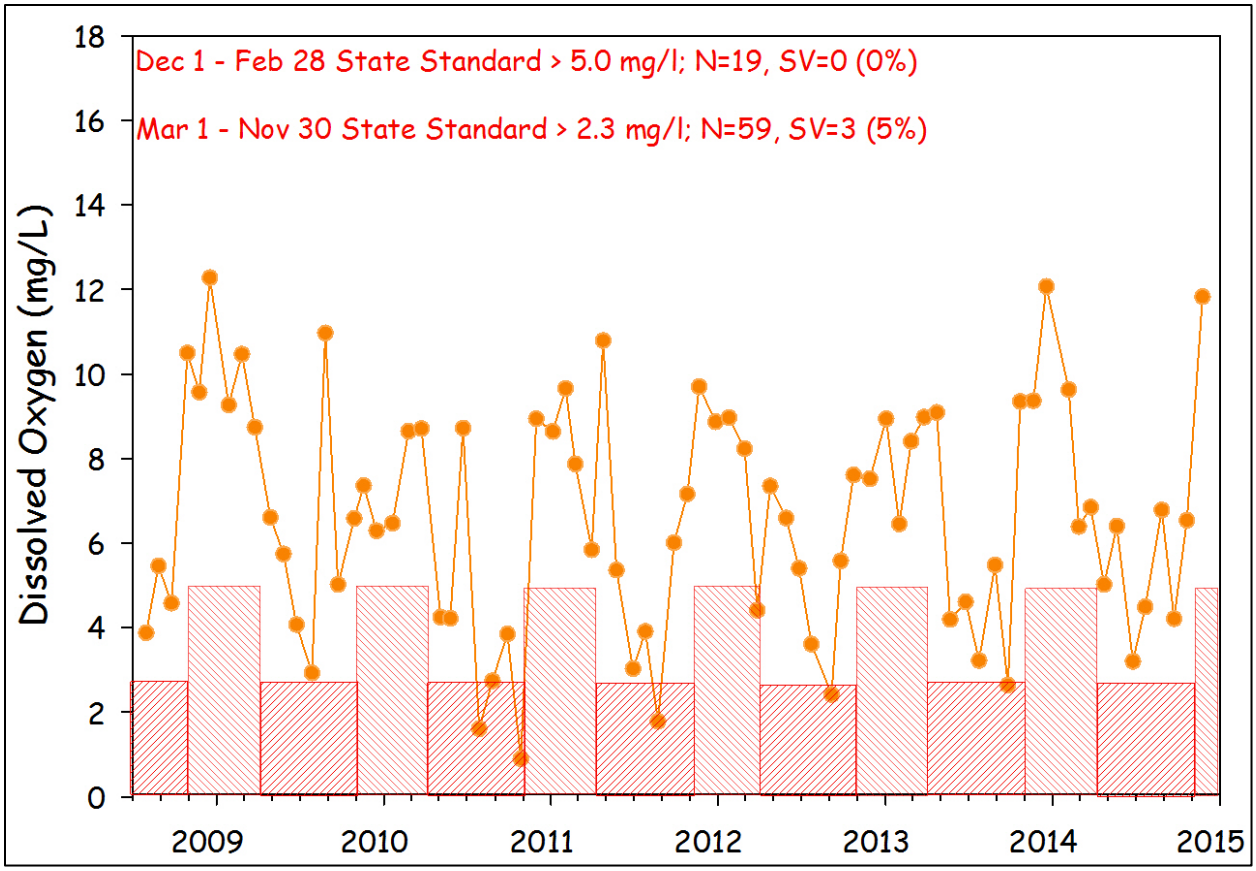


Figure 20. Dissolved oxygen at JELA highlighting Whiskey Canal.

Whiskey Canal is a short waterway connecting the larger Waggaman Canal to the north and Lake Cataouatche to the south. Direct hydraulic communication to the well-aerated lake typically provides ample oxygen to its waters. Standard violations are limited to summer months when there is little exchange occurring.

Escherichia coli

Louisiana uses fecal coliform as its freshwater indicator bacteria and does not have a standard for *Escherichia coli* (*E. coli*). The state designates the waters of the Barataria as "primary contact recreation". As our program is not designed for public health monitoring which requires frequent sampling it is useful to use the USEPA single-standard for *E. coli* of <298 MPN (most-probable number) per 100 mL for primary recreational contact.

Elevated *E. coli* can occasionally be found throughout the Preserve (Figure 21). Most high bacteria counts were found at Millaudon Canal (20% of the samples are above the water quality standard), and to a lesser extent, Whiskey Canal (10% exceeding the limit). As the Millaudon site is directly downstream of the New Ames pumping station it is not surprising to see high bacteria associated with pump activity during and following rainfall events.

There is an interesting apparent correlation between times of precipitation and elevated bacteria, or to be more accurate; a correlation between times of no precipitation and low bacteria. Figure 22 shows the data from Figure 21 but with a backdrop of vertical bars representing weeks prior to a sampling event with less than 0.1 cm of precipitation. Precipitation can be thought of as a surrogate for pumping data (Jefferson Parish could not provide pump discharge information). Precipitation means pump activation. With two exceptions (Whiskey Canal on May 26, 2010 and Millaudon Canal on February 5, 2014) no site was above the 298 MPN/100 mL standard on sampling events following a week of no precipitation. While it would be a more difficult case to state that the *E. coli* is high when pumps are operational, it is easy to see the relationship that *E. coli* is low when the pumps are not operational.

While it is easy to imagine pumped water impacting canals immediately downstream of a pumping station there are occasions when *E. coli* becomes elevated deep within the Preserve at Tarpaper Canal (TARP). The combined capacity of all pumps that discharge into the Preserve is over 9,000 cfs. Later, evidence of brackish water being pushed far into the interior canals will be presented. It appears that the interior canals can be directly impacted by conditions exterior to the Preserve.

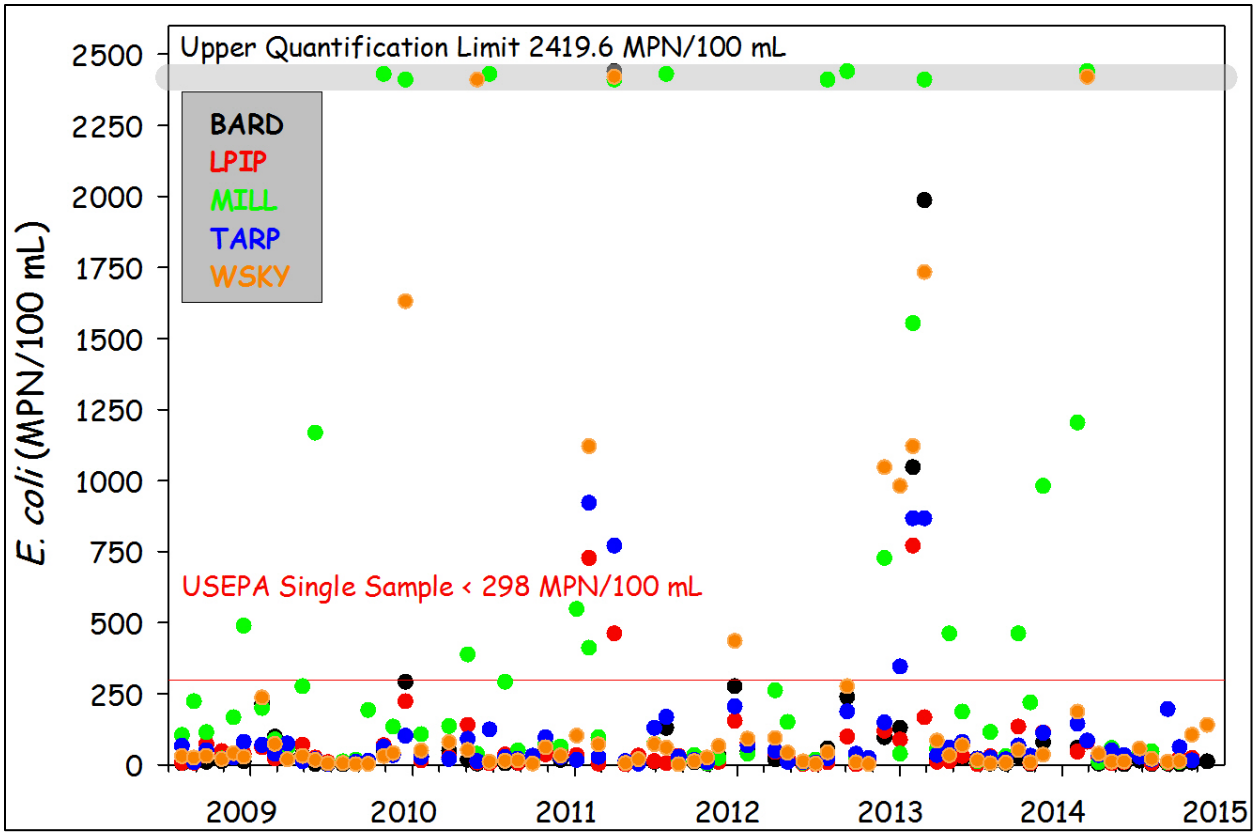


Figure 21. *Escherichia coli* commonly exceed the USEPA single sample limit of 298 MPN/100 mL for primary recreational contact.

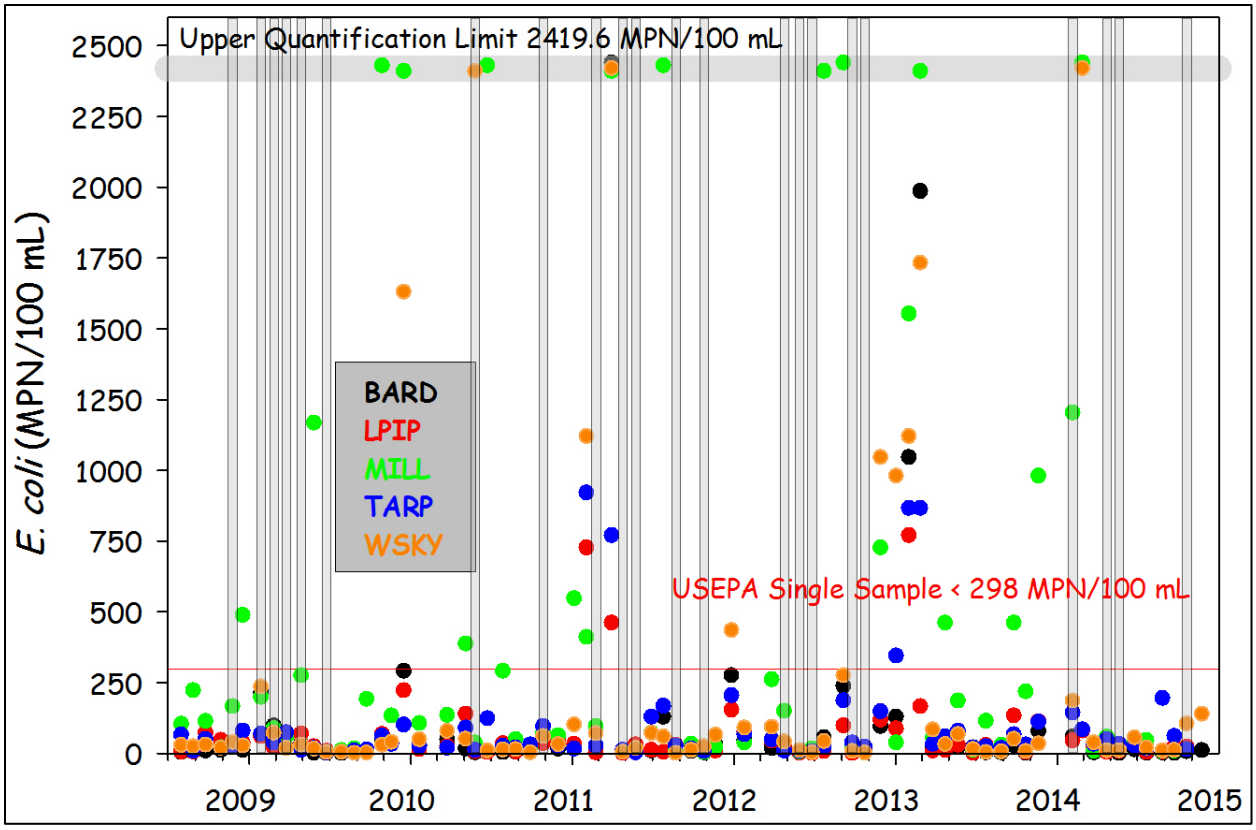


Figure 22. *Escherichia coli* shown with total precipitation the week prior to sampling. Each gray vertical bar represents a week prior to a sampling event with less than 0.1 cm of precipitation.

Nitrate

There is no state standard for nitrate in Louisiana. Sources of nitrate include waste water, agricultural runoff (animal waste and fertilizer) and decomposition of plant material. Nitrate levels in the Preserve are low, rarely exceeding 0.5 mg/L (Figure 23). To put these numbers in perspective, the USEPA standard from drinking water is < 45 mg/L as NO_3. The NADP station in New Iberia Louisiana (160 km to the west-northwest) recorded an average of about 0.7 mg/L in rainfall between 2008 and 2014. The average value found in water samples in the Preserve for the same time period is also 0.7 mg/L.

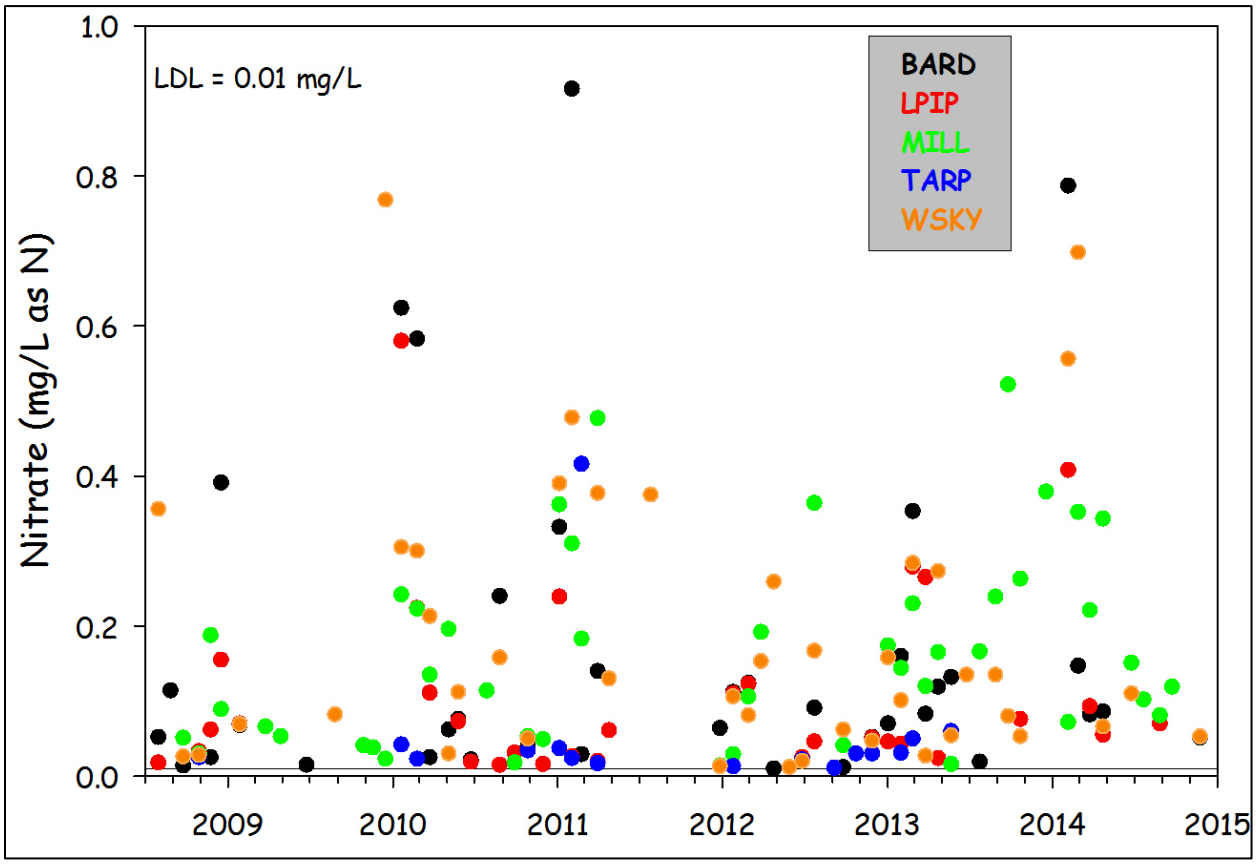


Figure 23. Nitrate as N at JELA. Average values found in Preserve waters are 0.7 mg/L, the same as found in precipitation samples taken in New Iberia.

Nitrite

There is no state standard for nitrite in Louisiana. Nitrite typically originates as the reduced form of nitrate. Natural denitrification may occur in conditions of low dissolved oxygen. Nitrogen, either in the form of nitrate or nitrite, is a very mobile ion, is in high demand, and is typically quickly consumed by plants. There is no ready explanation for the outliers (above 1 mg/L) however there is reason to believe they may reflect real conditions as in such cases where the duplicate QA/QC samples happened to coincide with abnormally high values, the QA/QC samples were also high (Figure 24).

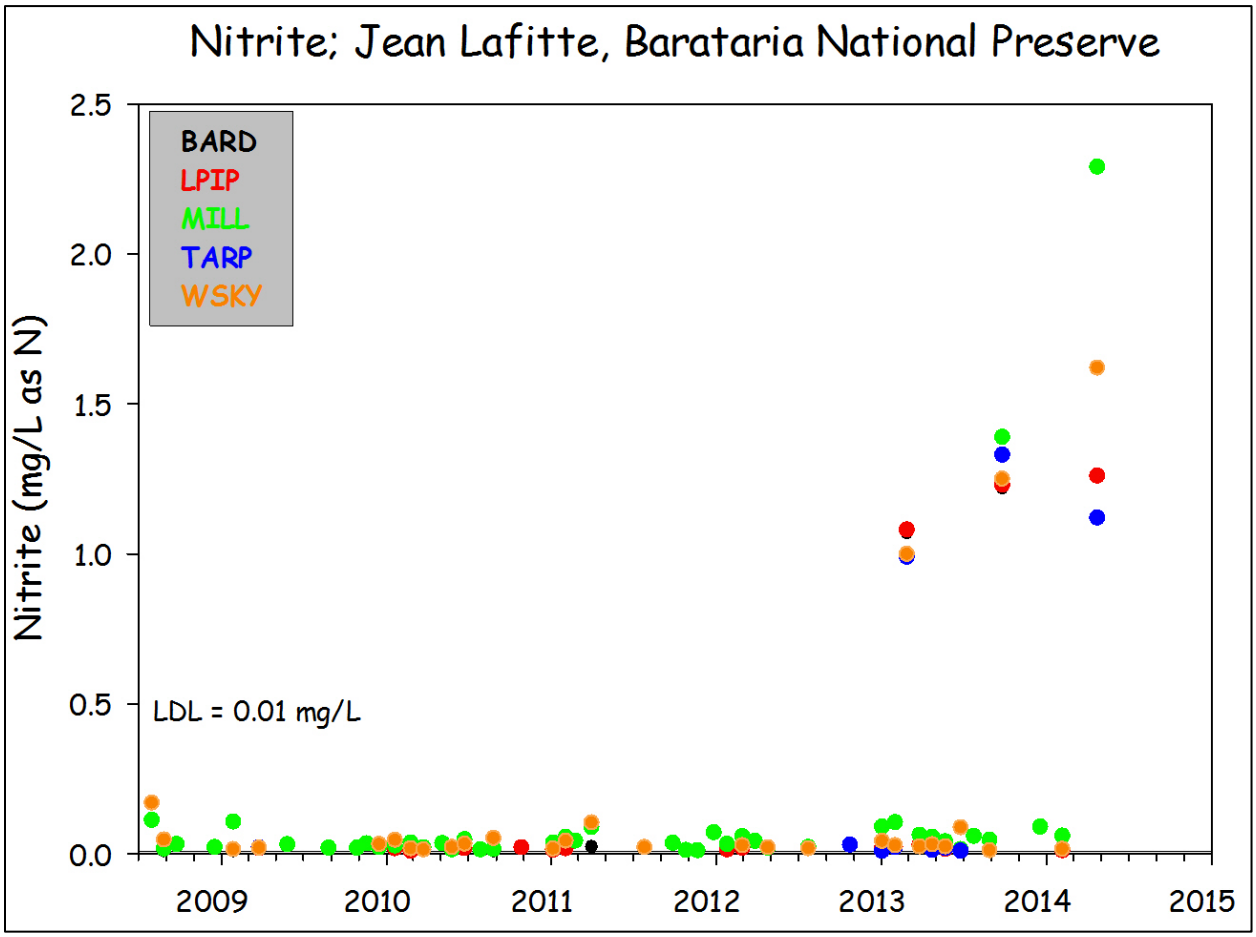


Figure 24. Nitrite as N at JELA. “Missing” data are samples below lower detection limit of 0.01 mg/L.

pH

The pH standard for the Barataria is set between 6.0 and 8.5 SU by Louisiana. Water of the Preserve generally falls within this band with an occasional sample falling above the upper limit and rarely below the lower standard (Figure 25). It is possible that the cause of the increased pH is a product of photosynthesis of algae. If photosynthesis consumes more CO_2 than can be atmospherically in-gassed into the canals, plants will begin to use other dissolved carbonates such as H_2CO_3, HCO_3^- and CO_3^{-2}. The end result is the production of hydroxyl ions which raise the pH. Note the interior Tarpaper Canal had the least amount of variability, typically the lowest of the five sites.

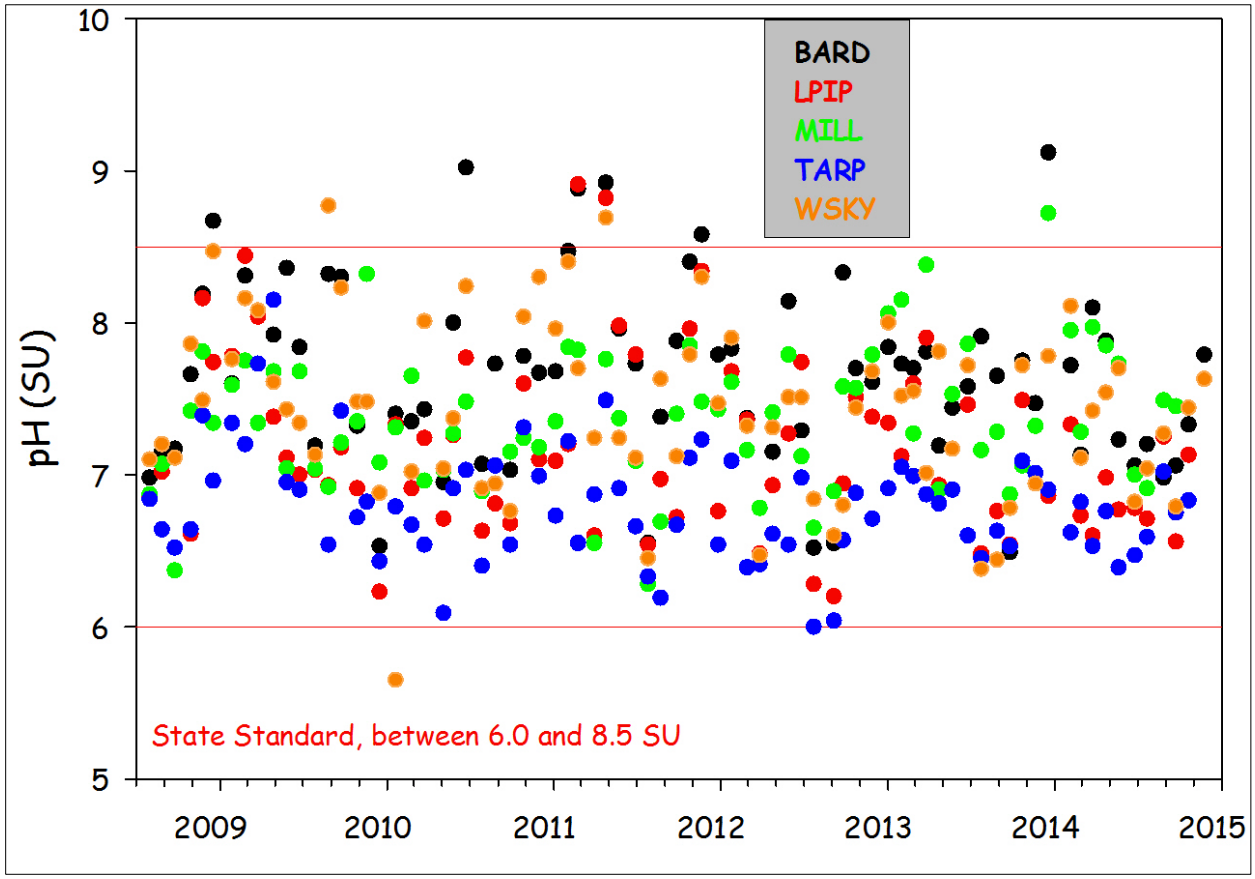


Figure 25. pH at JELA. pH is sometimes elevated above the 8.5 SU upper limit in the summer time when algal production is highest.

Phosphorous

There is no state standard for phosphorous in Louisiana. Phosphorous, like nitrate, is typically derived from wastewater (sewage plants, urban runoff) and agricultural runoff (animal waste, fertilizer). While essential to plant life, too much phosphorous may hasten eutrophication of a water body. Similar to *E. coli*, lower phosphorous levels coincide with sampling dates following a week of precipitation less than 0.1 cm (Figure 26). The only sample above 0.2 mg/L was a value of 0.41 mg/L at Millaudon Canal on June 26, 2012.

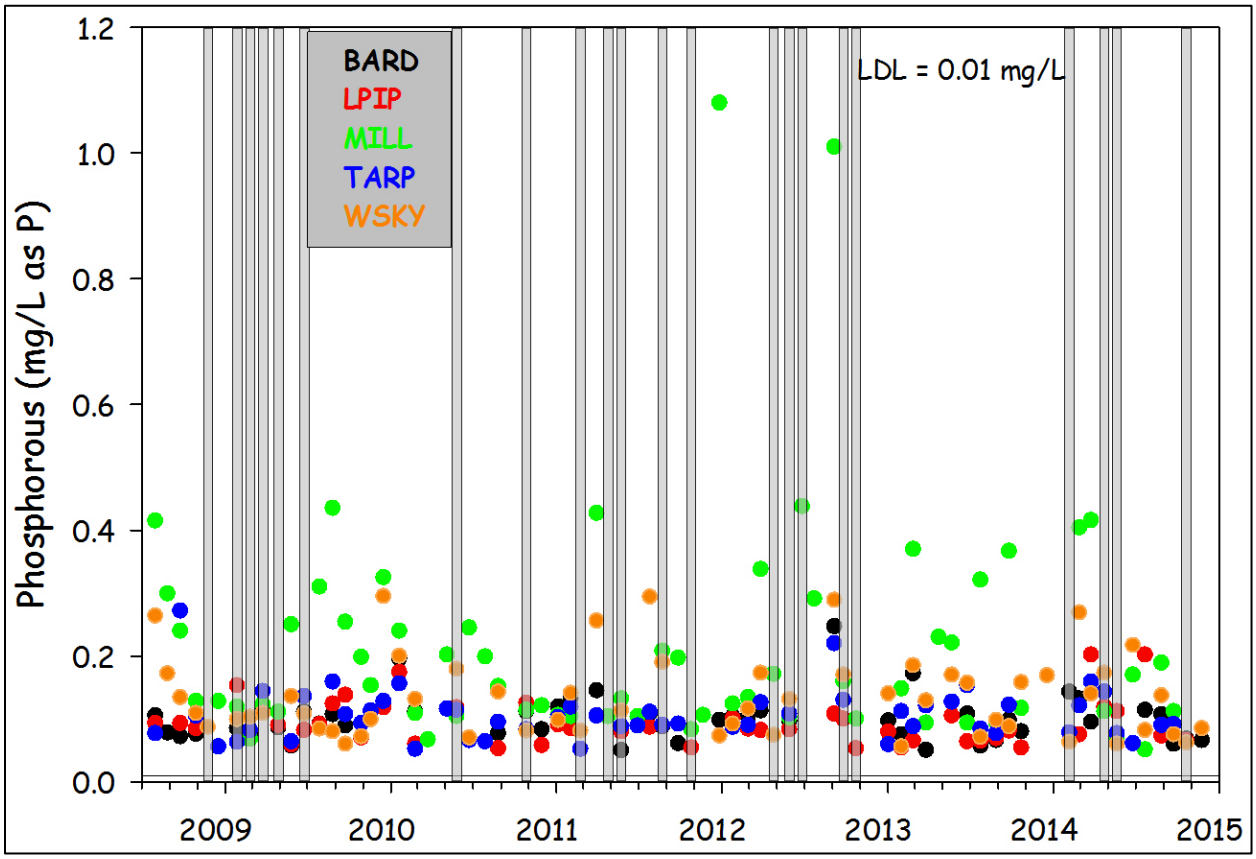


Figure 26. Phosphorous at JELA. Like E. coli, phosphorus is lowest at times when there has been little or no precipitation prior to sampling (when pumps are not active).

Specific Conductivity

There is no state standard for specific conductivity (SpC) in Louisiana. SpC is an electrical determination of the concentration of dissolved ions at 25°C. For example marine water will have a much higher SpC than freshwater due to the high amount of dissolved ions such as chloride and sodium. The effect of Hurricane Gustav is readily apparent in the fall of 2008 as saline water was pushed deep into the Barataria (Figure 27). Notice that even the interior Tarpaper Canal had elevated SpC for five months from Gustav. Tropical storms are not the only cause of high SpC events. Most winter months show an increase in SpC as strong southern winds associated with approaching frontal boundaries blow brackish water into the canals from Lake Salvador. Of course, Lower Pipeline Canal and Bayou Bardeaux are most easily affected as they are proximal to Lake Salvador but sustained winds can also increase SpC in the interior canals. The relationship between elevated SpC and southern winds is derived by direct measurement and observation.

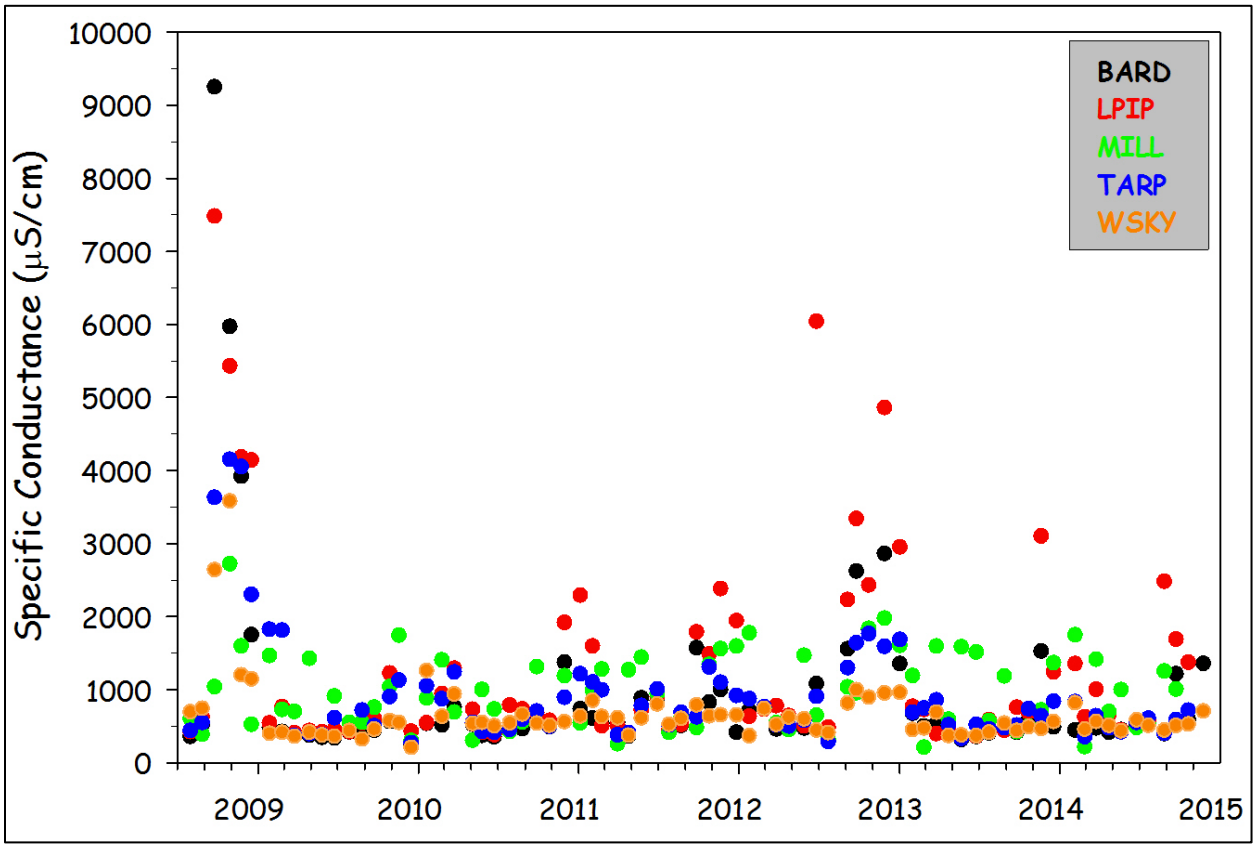


Figure 27. Monthly specific conductance values JELA, July 2008 through December 2014.

As mentioned in the introduction the sources of water in the Barataria Preserve are from 1) direct meteoric precipitation or pumped storm water primarily composed urban runoff as a product of the precipitation, 2) surges of saline water from the south from strong wind or tropical storms, and 3) Mississippi River water via the Davis Pond Freshwater Diversion. While it would take a separate study to determine the actual contributions of these (and possible other sources), we can examine the data to at least define relative influence on the water quality of the Preserve. Figure 27 shows the

magnitude, frequency and extent of influence from tropical systems and strong south winds. We can draw similar relationships of the results of rainfall and *E. coli* in Figure 22. The question of whether water from Davis Pond Freshwater Diversion contributed to the Preserve is a bit more complicated but no less compelling as the other two water sources.

Figure 28 is a limited Y-axis presentation of data of Figure 27 but with the addition of the daily mean SpC records from USGS stations at Davis Pond and at the edge of Lake Cataouatche near the GULN Whiskey Canal site. Predictably the USGS and GULN sites proximal to Whiskey Canal have very similar SpC values. SpC at Davis Pond are typically higher than that found at the Lake Cataouatche site as the lake also derives water from adjacent marshes and direct precipitation, except when strong south winds or storms push brackish water into the lakes and canals.

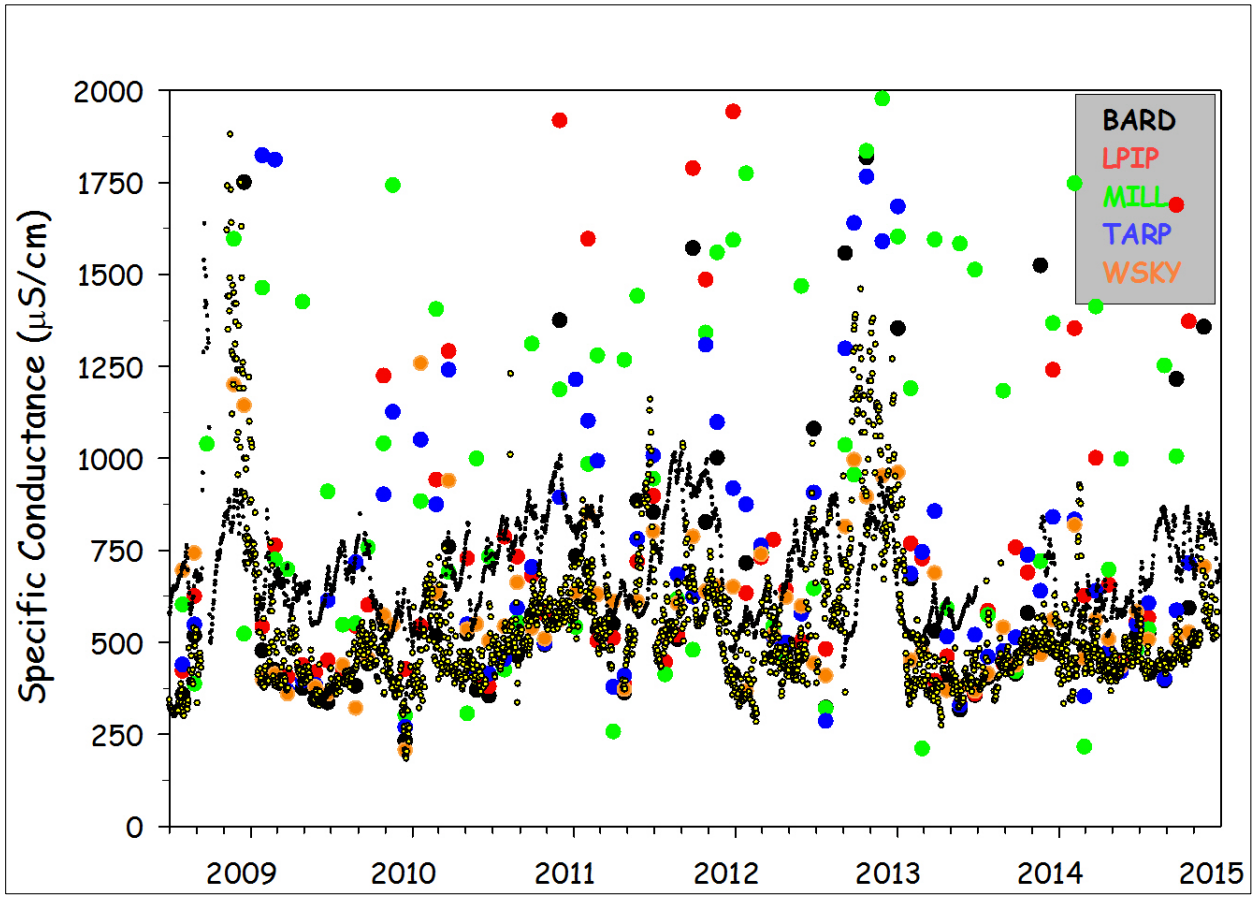


Figure 28. Monthly GULN data and daily mean USGS specific conductance data from the gauging station at the Davis Pond structure (295501090190400) in small black dots and the USGS site on the edge of Lake Cataouatche near Whiskey Canal (2951190901217) in small yellow dots.

Davis Pond Freshwater Diversion is operated to maintain salinities south of the Preserve while maintaining productive oyster harvesting area, thus varying discharge a great deal over the course of the year. If DPFD waters are entering the Preserve its presence should be seen in converging SpC values during periods of high flow. Figure 29 shows the relative percent differences (RPD) between mean daily SpC at Davis Pond and GULN data on common sampling dates; the lower the RPD, the more similar the compared values. The vertical gray bars indicate sample dates when discharge from

Davis Pond was above 4,000 cfs. Data were compared at various flow ranges but it is simpler to exclusively examine the higher flow events when the likelihood of effecting Preserve waters is the highest. It is important to realize the relationship between SpC at one site to another is a bit more complicated in that SpC is a composite measure of all dissolved ions. That is, waters with entirely different chemistries can have identical SpC, thus low RPD values would be of pure coincidence. The highest RPDs are coincidental with the introduction of brackish waters from the south during tropical storms or strong sustained southern winds. Thirteen different times the flow from DPFD was higher than 4,000 cfs during GULN sampling activities. One can see that the RPD values were quite low during these high flow events, with the exceptions of the interior Tarpaper and Millaudon Canals.

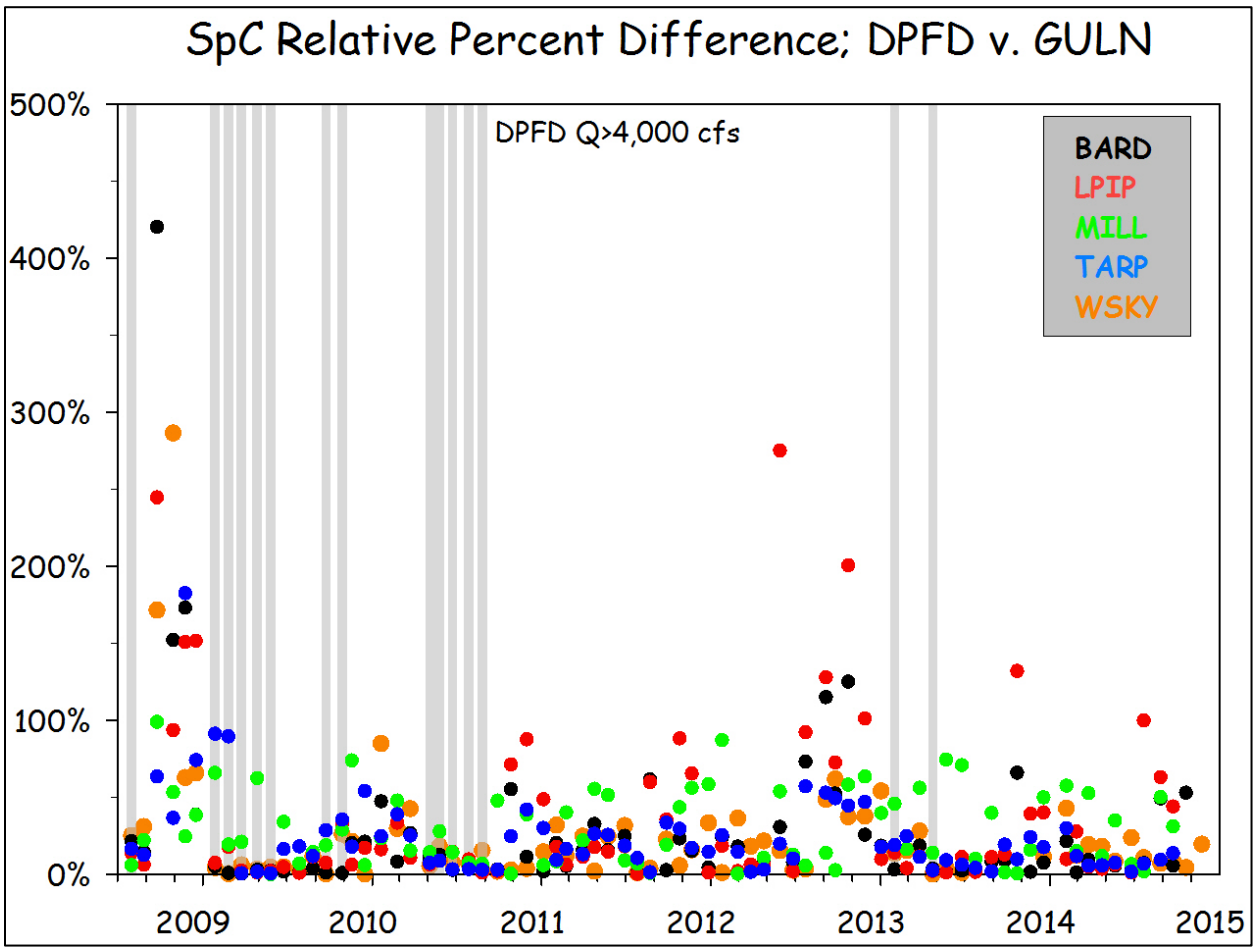


Figure 29. Relative percent differences between SpC at Davis Pond Freshwater Diversion and GULN water quality sites. Gray vertical bars indicate times when discharge from DPFD was above 4,000 cfs.

Figure 30 simplifies this dataset as only RPDs were calculated between DPFD and the GULN Whiskey Canal site. While RPD values are very low during high discharge times they are also very low at low and moderate discharge. Either DPFD is having a great influence on the water found at Whiskey Canal or any similarity between SpC is coincidental.

It is easy to see on the image taken November 29, 2011 (Figure 4) that dark water is draining out of the canals and marshes of the Preserve and into Lake Cataouatche, and turbid by flows from DPFD which was discharging a daily average of 6,000 cfs from November 27–29. Under these conditions water from DPFD, operating at 60% design capacity does not appear to enter the Preserve.

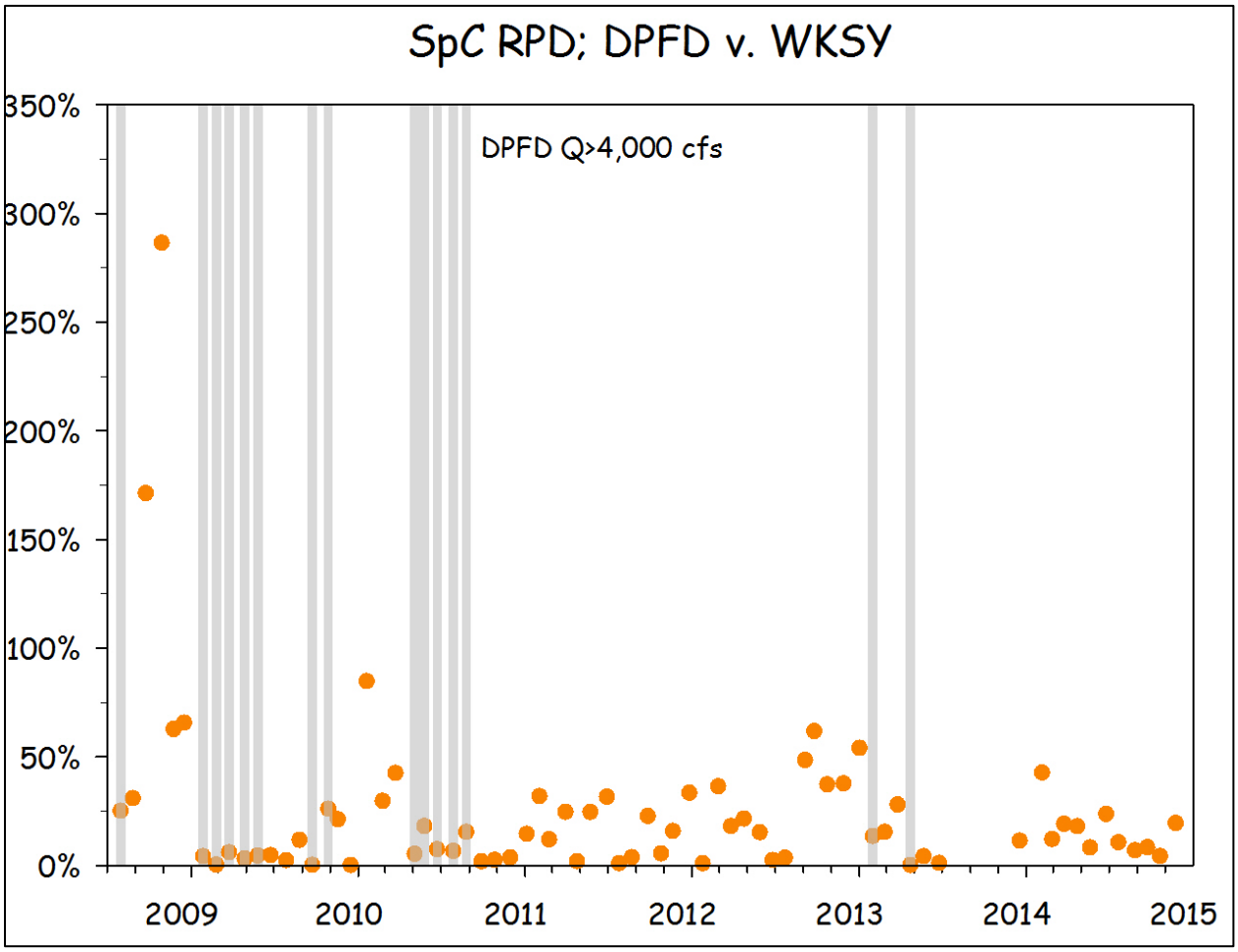


Figure 30. Relative percent differences between SpC at Davis Pond Freshwater Diversion and GULN's Whiskey Canal water quality site. Gray vertical bars indicate times when discharge from DPFD was above 4,000 cfs.

As a final examination of the assumption that similar SpC values (low RPD) equate to similar waters, Figure 31 shows RPD between SpC at Davis Pond and the Lake Cataouatche site and between Davis Pond and a station at Markland Dam on the Ohio River near Warsaw Kentucky. One can see over the period of common dates the SpC at Davis Pond is more similar to that of the Ohio River 2170 km upstream at Markland Dam than to the Lake Cataouatche station 15 km downstream. Based on this analysis, there is no compelling evidence that water released from the Davis Pond Freshwater Diversion Project is significantly affecting water in the canals of Barataria Preserve. This is an important issue that warrants additional research to confirm these results.

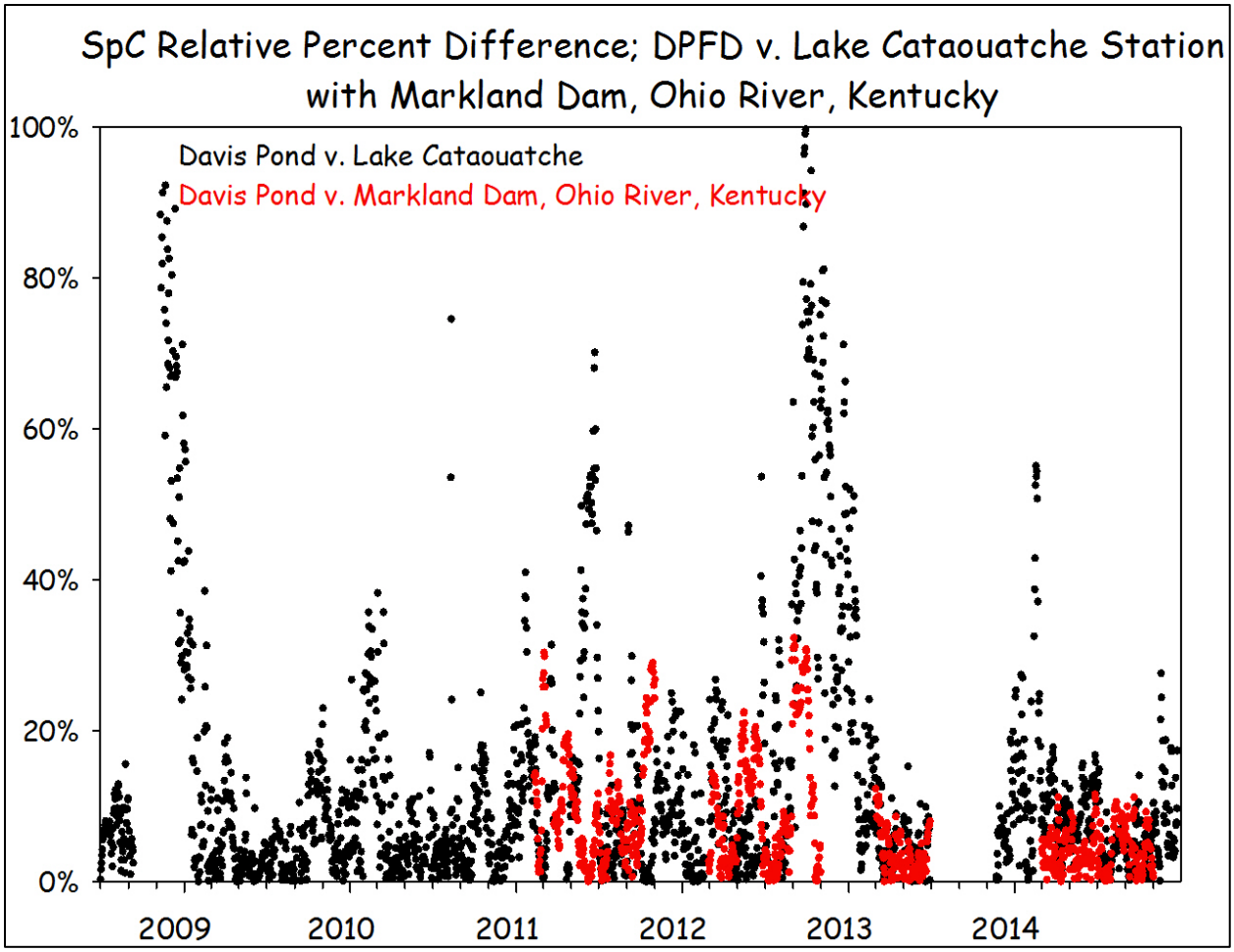


Figure 31. SpC relative percent differences between Davis Pond Freshwater Diversion (DPFD) and Lake Cataouatche station and that of DPFD and Markland Dam, Ohio River, Kentucky.

Turbidity

There is no state standard for turbidity (SpC) in Louisiana. Turbidity can be used as general approximation of the amount of suspended solids in the water, however waters with exact amounts of suspended sediments may have vastly different turbidities as particle size, shape and color all effect transmission and scattering of light. Many states adopted a turbidity standard of "not to exceed 50 Nephelometric Turbidity Units (NTU) above background". To put the Preserve in context, there are only a few occasions where turbidity exceeds this limit (Figure 32). Aside from a few acute events (Tarpaper Canal on 6-24-2010 was high due to the NPS reducing adjacent canal spoil banks, and both Millaudon and Whiskey Canals elevated accompanying strong flow pumping stations) the Preserve generally sees an increase in turbidity in the winter months, likely associated with periods of stronger winds keeping particles in suspension.

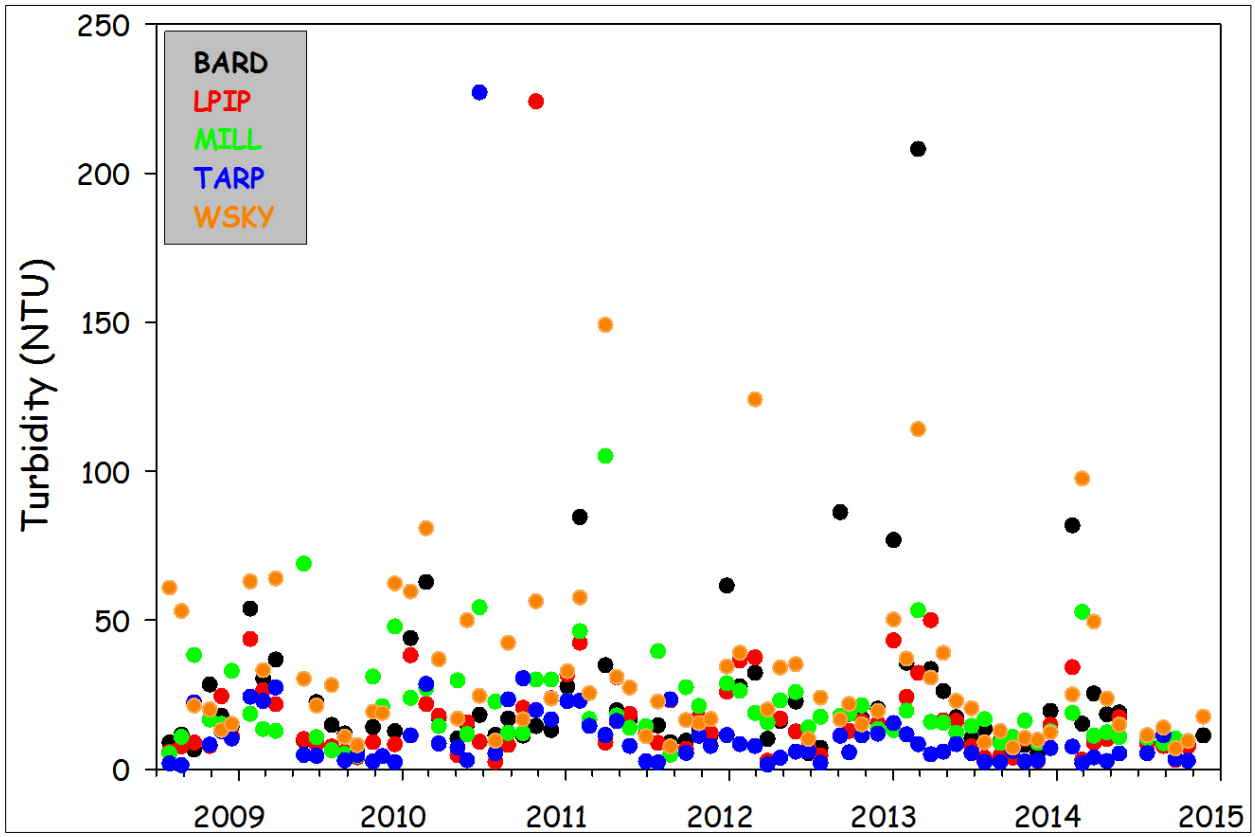


Figure 32. Turbidity at JELA. Turbidity increases each winter in likely response to strong winds.

Water Temperature

According to state water quality standard for the Barataria water should remain below 32°C. Occasionally, during the peak of summer, a sample may be above this limit; at least one exceedance has been recorded at each GULN station. Temperatures at Whiskey Canal had a slightly larger range than the other sites (Figure 33).

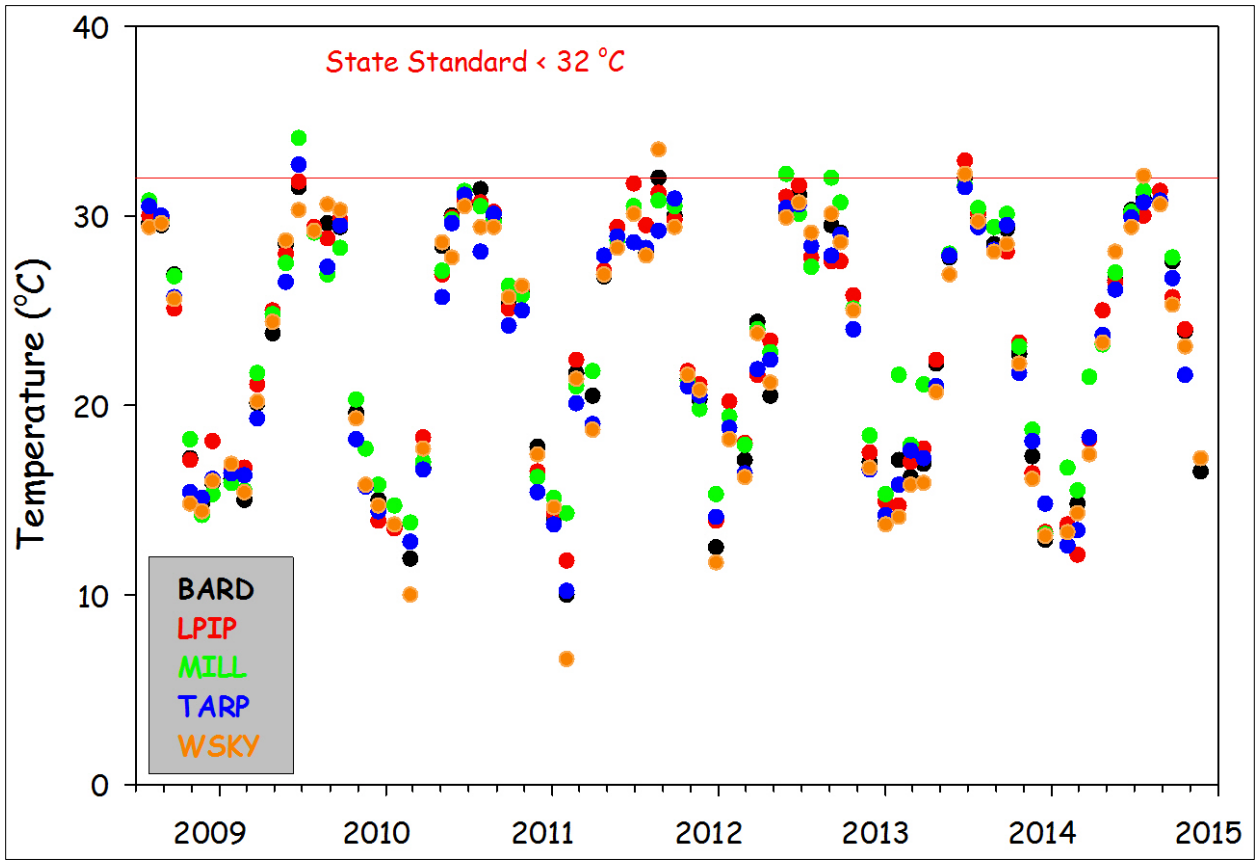


Figure 33. Water temperature at JELA. An occasional exceedance of the 32°C standard is seen at all five sites.

Summary

Few park units in the National Park System have a more altered hydrology that Jean Lafitte National Historic Park and Preserve. Many of the waterways within the marsh are man-made. These canals criss-cross the marsh and swamp bound to the east by hardwood ridges, to the north by a levee and west by large freshwater lakes. The Preserve receives water from three general sources that can be ranked on volume, frequency, and areal extent of affected waters within the Preserve; 1) meteorological, direct and via pump stations (large volume, high frequency, large area), 2) wind and tide driven (large volume, infrequent, large area), and 3) Mississippi River water via the Davis Pond Freshwater Diversion Project (low volume, infrequent, limited area).

Water quality in the Barataria Preserve is a product of natural forces working through a variety of local and regional modifications. Water quality should be viewed in light of this highly altered landscape, as the impact from natural events is influenced by man's activity; loss of marshlands to the south, restricting natural flood processes, cutting canals through a marsh, introduction of millions cubic meters of pump water per year into those canals.

Caution should be used if one were to assume that waters with a Ca:Mg ratio of 3:1 are derived from riverine sources. Our data show that the same ratio is prevalent in not only pump water but also rainwater. Furthermore, there is no evidence in our current dataset that a large amount of river water is entering the canals of the Preserve. More detailed analysis of existing data may confirm this interpretation or lead to a needed research question.

Data show when sampling dates are preceded by at least one week of dry weather, thus no surface runoff, *Escherichia coli* levels in the Preserve are low, presumably when Jefferson Parish pumps are not active. Conversely *E. coli* frequently exceeds the USEPA primary recreational contact limits if precipitation occurred within the week prior to sampling, presumably during or following recent pump operation. Nutrients in the Preserve are typically low. Nitrate levels approach that found in precipitation. Phosphorous levels show the same relationship between precipitation (and presumably pump operation) and *E. coli*. This is especially demonstrated at Millaudon Canal.

Dissolved oxygen commonly falls below the state standard of 5.0 mg/L (December through February) and 2.3 mg/L (March through November). With the single exception of Whiskey Canal's winter period, all sites in all seasons had violations of the dissolved oxygen standard. While these depressed levels are commonly found during the warmer, calmer months in the interior of the Preserve, they can occur throughout the year at any location. Low dissolved oxygen is a product of oxygen consumption during the decay of aquatic organic material, limited aeration and warm water.

The Barataria Preserve is part of an unraveling landscape. Rates of relative sea level rise are among the highest in the world. Coastal wetlands are being lost at an unprecedented rate. Natural disturbances will likely increase in frequency, duration and intensity as the land subsides and protective wetlands are lost. The Gulf Coast Network will continue to document water quality of the Preserve as part of its long-term monitoring program.

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