ENVIRONMENTAL ASSESSMENT

Pascagoula River Drought Resiliency Project

George and Jackson Counties, Mississippi

August 25, 2015

Prepared For:

Pat Harrison Waterway District
George County Board of Supervisors,
&
Jackson County Board of Supervisors

Submitted by

Pickering Firm, Inc.
2001 Airport Road, Suite 201
Flowood, Mississippi

PASCAGOULA RIVER DROUGHT RESILIENCY PROJECT

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   2. Project Submission (Submitted-November 21, 2012)
   3. EPA Region 4 Response (January 29, 2013)
B. Recommended Project Area Maps

C. Wetlands/Biological Technical Report, Pickering Firm, Inc. (February 2015)
D. Cultural Resources Investigation Research for the Proposed Southeast Mississippi Water Supply Lakes Project, George and Jackson Counties, Mississippi, Brockington and Associates (2015)
E. Hazardous and Toxic Materials Report, Environmental Data Resources, Inc.
    1. Upper Lake
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F. Pascagoula River Minimum Flow Supply Lake Option Analysis. Pote, J.W., C.L. Wax and M.L. Tagert. Department of Agricultural and Biological Engineering, Mississippi State University (2014)
G. Utilizing Impounded Waters in George County to Decrease the Incidence of Low in the Pascagoula River, Phase 2. Pote, J.W., C.L. Wax and M.L. Tagert, Department of Agricultural and Biological Engineering, Mississippi State University (April 8, 2015).
H. Geo-Hydrology Theoretical George County Lake, Schmitz, D.W., A. Lenz and C. Ladner. Department of Geosciences, Mississippi State University (2013).
I. Geo-Hydrologic Analysis George County Lake Project Phase II, Schmitz, D.W., C. Killian and J. Foote. Department of Geosciences, Mississippi State University (2015)
J. Utilizing Impounded Waters to Enhance Habitat for Endangered Species of the Pascagoula River. Dr. J.W. Pote, C.L. Wax and A.C. Linhoss, Department of Agricultural and Biological Engineering, Mississippi State University (April 8, 2015)
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PASCAGOULA RIVER DROUGHT RESILIENCY PROJECT

EXECUTIVE SUMMARY

This Environmental Assessment provides additional information and analysis to support the Joint Application and Notification. Stream flow in the Pascagoula River is critical to the ecology, environment and economy of southeast Mississippi. The Mississippi Commission on Environmental Quality set a minimum stream flow of 917 cubic feet per second (CFS) for the Pascagoula River at the US Geological Survey Merrill stream gage to protect these consumptive (economic) and non-consumptive (environmental, ecological) water uses. The gage is immediately downstream of the confluence of the Leaf and Chickasawhay Rivers where the Pascagoula River begins. Low flows could also threaten the viability of any restoration projects in the Pascagoula River watershed or those planned off the mouth of the Pascagoula River proposed in response to the 2010 Deep Water Horizon oil spill.

During the historic drought in the 2000 water year (October 1, 1999 through September 30, 2000), the Pascagoula River's minimum daily discharge at the Merrill gage was 649 CFS, about 8% less than the previous recorded daily low flow of 704 CFS recorded on October 21, 1936 (Turnipseed 2001). Subsequently, the Pascagoula River's flows have fallen below 917 CFS at the Merrill gage in 2007, 2010 and 2011. The cause(s) of this trend toward more frequent low flow events is not clearly understood. However, climate variability studies predict that the Pascagoula Basin will face more frequent, severe and prolonged droughts in the future with corresponding threats to the Pascagoula River's minimum stream flows.

Conventional wisdom speculates that low flows could result from upstream dams or water withdrawals, channelization, or the loss of floodplain function and/or wetlands. Alternatively, a 2015 report, *Connectivity of Streams & Wetlands to Downstream Waters* offers a more scientific basis to understand hydrologic changes and low flows (USEPA 2015). Briefly, the report recognizes that river flows are controlled by a continuum of surface and subsurface hierarchical factors that connect river basins and river networks longitudinally (upstream/downstream) and laterally (floodplain/wetlands). The regional climate interacts with river-basin terrain, topography and geology that binds natural flows and flow paths.

This document presents a detailed hierarchical systems approach to analyze hydrologic flows in the Pascagoula River, watershed and basin. The discussions on the project location and environmental setting in Sections 1.1 and 2.2 invalidates the popular sentiment on anthropomorphic causes of low flows. There are already existing dams on the Pascagoula River's tributaries, but it is recognized as the largest undammed river in the continental U.S. The Pascagoula's basin covers approximately, 9,600 square miles with roughly 1,563 square miles (more than 16%), including almost the entire river's riparian zone, being conserved or managed by federal or state agencies. The basin's land use/land cover is approximately 2% of urban with 72% forested and 21% in agricultural use. There are no especially large surface water or ground water withdrawals permitted in the basin. Furthermore, during the 2000 drought, flow augmentation from Okatibbee Reservoir in the basin's extreme headwaters was unable to keep the River flowing above 917 CFS at the Merrill gage.

Accordingly, a more detailed basin-scale projection of climate variability and surface and sub-surface geo-hydrologic analysis was undertaken to identify the basin's hydrologic infrastructure that bounds natural flow paths and flows. This enhanced data collection and analysis is concentrated in sections 2.2 and 4.1 but shows up throughout the report and the appended supporting studies. Finally, the data and analysis was used to ensure that the recommended

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public project was sited and sized as the least environmentally damaging practicable alternative for long-term drought resiliency in the Pascagoula River. The recommended project provides a two-pronged drought resiliency approach: 1) restore the watershed's natural sub-surface water table to minimize the frequency, severity and duration of low flow events; and 2) store sufficient surface water supplies to quickly and efficiently augment river flows when necessary. The recommended reservoirs will also provide additional public recreational opportunities. Maintaining the Pascagoula River's natural hydrologic flows in light of broadly accepted projections of increased drought severity, frequency and duration is critical to the region's environmental, ecological and economic resilience and sustainability.

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ACRONYMS AND ABBREVIATIONS

AF	Acre Feet
AMSL	Above Mean Sea Level
APE	Area of Potential Effect
BFI	Base Flow Index
BGS	Below Ground Surface
BLH	Bottomland Hardwood
CFR	Code of Federal Regulations
CFS	Cubic Feet per Second
CWA	Clean Water Act
COE	U.S. Army Corps of Engineers
DOE	U.S. Department of Energy
DMR	Mississippi Department of Marine Resources
ESA	Endangered Species Act
EA	Environmental Assessment
EDA	Environmental Data Resources, Inc.
EIS	Environmental Impact Statement
EPA	Environmental Protection Agency
ESA	Environmental Site Assessment
EO	Executive Order
FAC	Facultative
FACU	Facultative Upland
FACW	Facultative Wetland
FEMA	Federal Emergency Management Agency
GIS	Geographical Information System
GPS	Global Positioning System
HGM	Hydrogeomorphic
HUC	Hydrologic Unit Code
IFMP	Instream Flow Incremental Methodology Process
JCPA	Jackson County Port Authority
JCUA	Jackson County Utility Authority
LEDPA	Least environmentally damaging practicable alternative
LOMR	Letter of Map Revision
MDAH	Mississippi Department of Archives and History
MDEQ	Mississippi Department of Environmental Quality
MDMR	Mississippi Department of Marine Resources
MGD	Million Gallons per Day
mg/L	milligram/liter
MSL	Mean Sea Level
MSU	Mississippi State University
MWF&P	Mississippi Department of Wildlife, Fisheries and Parks
MYA	Million Years Ago
NEPA	National Environmental Policy Act
NERR	National Estuarine Research Reserve
NHPA	National Historic Preservation Act
NRCS	Natural Resources Conservation Service
NRHP	National Register of Historic Places
NWI	National Wetland Inventory
O&M	Operation and Maintenance
OBL	Obligate

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PHWD	Pat Harrison Waterway District
PFI	Pickering Firm Inc.
POTW	Publicly Owned Treatment Works
REEFS	Regional Oyster Restoration, Enhancement and Expansion for Sustainability
RM	River Mile
ROD	Record of Decision
SEIS	Supplemental Environmental Impact Statement
SPF	Slash Pine Flatwood
SPR	Strategic Petroleum Reserve
SSSF	Small Stream Swamp Forest
SMPDD	Southern Mississippi Planning and Development District
T&E	Threatened and Endangered
TMDL	Total Maximum Daily Load
USFWS	U.S. Fish and Wildlife Service
USGS	U.S. Geological Survey
UPL	Upland
WET	Wetland
WQS	Water Quality Standard

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1. INTRODUCTION

This Environmental Assessment provides data and analysis to support the Pascagoula River Drought Resiliency Project Clean Water Act § 404 permit application. This report augments and expands on the information and analysis provided in the Southeast Mississippi Regional Water Supply Project Application prepared per the Environmental Protection Agency (EPA) Region 4's Guidelines on Water Efficiency Measures for Water Supply Projects in the Southeast United States, issued on June 21, 2010 (Appendix A). To the extent possible, this document quantifies the projected impact of more frequent, severe and prolonged droughts on the Pascagoula River's flows and evaluates alternatives to arrive at a least environmentally damaging preferred drought resiliency project. The technical documents prepared by the Pickering Firm, Inc. (PFI) and their consultants are appended to this report and provide extensive data and data analysis. This Introduction 1) identifies the proposed project location in the context of the Pascagoula basin, watershed and river, 2) introduces the recommended project's two proposed lakes on Big and Little Cedar Creeks, 3) summarizes the Project's history, 4) presents the Project's Statement of Purpose and Need, and finally 5) states the Project's legal authority.

1.1. Project Location

As per the EPA Region 4 Guidelines (2010), the project's location is nested within a watershed framework. The project itself is located in the Big Cedar Creek sub-watershed in south George and north Jackson Counties, Mississippi. The Project's location and size was dictated by the Pascagoula River, its watershed and basin. The Pascagoula River and its roughly 608 square mile watershed (HUC 03170006) are important to Southeast Mississippi's culture, environment, ecology and economy.

1.1.1. The Pascagoula Basin, River and Watershed

The Pascagoula watershed is one of eight watersheds that comprise the roughly 9,600 square mile Pascagoula Basin (Table 1.1, Figure 1.1). The Pascagoula River is formed by the confluence of the Leaf and Chickasawhay Rivers in north George County and flows approximately 81 miles before discharging into the Mississippi Sound in south Jackson County. The Pascagoula River's headwaters extend more than 250 miles upstream to the Chunky River and Okatibbee Creek in Kemper and Neshoba Counties which flow into the Chickasawhay River. The Leaf River originates in Scott County. Downstream, Red and Black Creeks flow into the Pascagoula River from the west in northern Jackson County. Finally, at river mile 6.8 the Escatawpa River flows into the Pascagoula River in south Jackson County.

Hydrologic Unit Code	Name	Acres	Miles²
03170001	Chunky River/Okatibbee Creek	580,550	912
03170002	Upper Chickasawhay River	884,622	1,471
03170003	Lower Chickasawhay River	425,311	657
03170004	Upper Leaf River	1,121,115	1,744
03170005	Lower Leaf River	1,167,140	1,827
03170006	Pascagoula River	389,393	608
03170007	Black and Red Creeks	811,287	1,292
03170008	Escatawpa River	212,717	1,059
031700	Pascagoula River Basin	6,144,000	9,600

Table 1.1 - Pascagoula Basin Watersheds and Approximate Size

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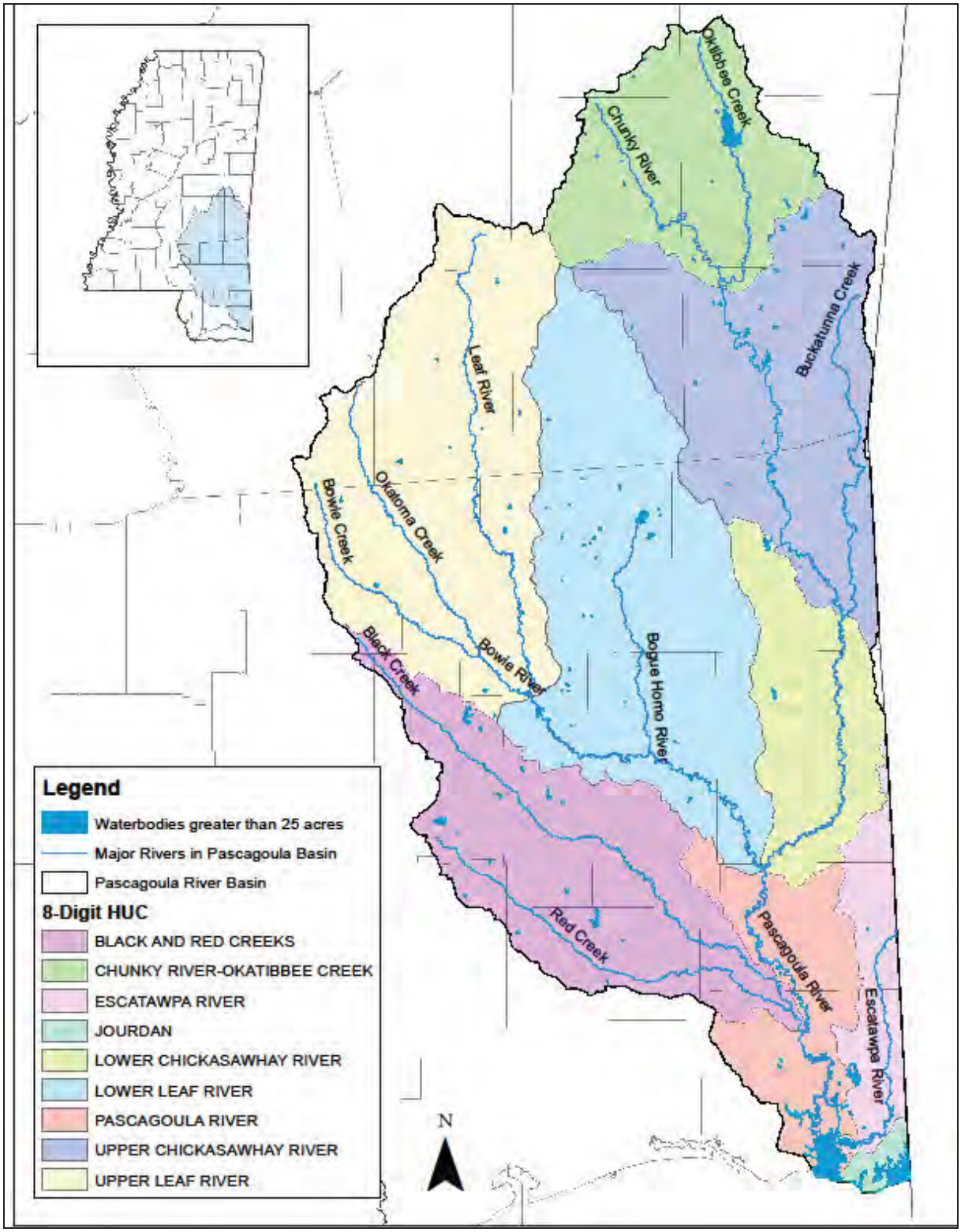

Figure 1.1 - Pascagoula Basin's Rivers and Watersheds

1.1.2. The Pascagoula Basin's Ecological and Environmental Benefits

The Pascagoula River also connects two Level III eco-regions: 1) the Southeastern Plains and 2) the Southern Coastal Plain (Chapman et al., 2004). Ecologically, the river, its riparian zone, wetlands and estuary provide critical habitat for numerous important commercial and recreational fresh water and saltwater fisheries. This includes threatened and endangered species listed under federal or State of Mississippi laws. Examples include Gulf sturgeon (*Acipenser oxyrhynchus desotoi*); Pearl darter (*Percina aurora*); Iron color shiner (*Notropis chalybaeus*); Salt marsh topminnow (*Fundulus jenkinsi*); Gopher Tortoise (*Gopherus Polyphemus*); Alabama Red-bellied Turtle (*Pseudemys alabame nsis*); and Yellow-blotched Sawback Turtle (*Graptemys flavimaculata*). Over 1,000,000 acres of the Pascagoula River Basin are managed to support these natural resources and ecological functions. Federal lands in the Basin include portions of the DeSoto and Bienville National Forests, also the U.S. Fish and Wildlife Service's (USFWS) Sandhill Crane and Grand Bayou National Wildlife Refuges. The US Army Corps of Engineers (COE) manages 11,000 acres adjacent to Okatibbee Reservoir in the basin's headwaters in northwest Lauderdale County and the Mississippi Department of Wildlife, Fisheries and Parks (MDWF&P) leases 6,900 acres of land around the reservoir.

Mississippi agencies also manage considerable acreage designated for conservation and outdoor recreational purposes. The Pat Harrison Waterway District (PHWD) operates a water park, campground and cabins on Okatibbee Reservoir and has campgrounds and recreational facilities on six smaller reservoirs on Pascagoula River tributaries: 1) Archusa, near Quitman in Clarke County, 2) Big Creek, near Laurel in Jones County, 3) Dry Creek, near Mount Olive in Covington County, 4) Flint Creek, near Wiggins in Stone County, 5) Maynor Creek, near Waynesboro in Wayne County and 6) Turkey Creek, near Decatur in Newton County. The MDWF&P's three Wildlife Management Areas cover much of the Pascagoula River's riparian area in George and Jackson Counties: 1) Pascagoula River, 2) Ward Bayou, and 3) Red Creek. The MDWF&P's three other Management Areas in the basin are located on: 1) the Chickasawhay River, 2) the Leaf River, and 3) Mason Creek. The Mississippi Department of Marine Resources (DMR) administers the Grand Bay National Estuarine Research Reserve and three Gulf Ecological Management Sites: 1) Grand Bay Savanna Preserve, 2) Escatawpa River Marsh Preserve, and 3) Pascagoula River Marsh Preserve in the river's estuary. Non-governmental organizations have established sizable preserves and purchased conservation easements throughout the basin. Finally, several for-profit wetland mitigation banks operate or are proposed in the Pascagoula River watershed. Figure 1.2 illustrates many of these areas.

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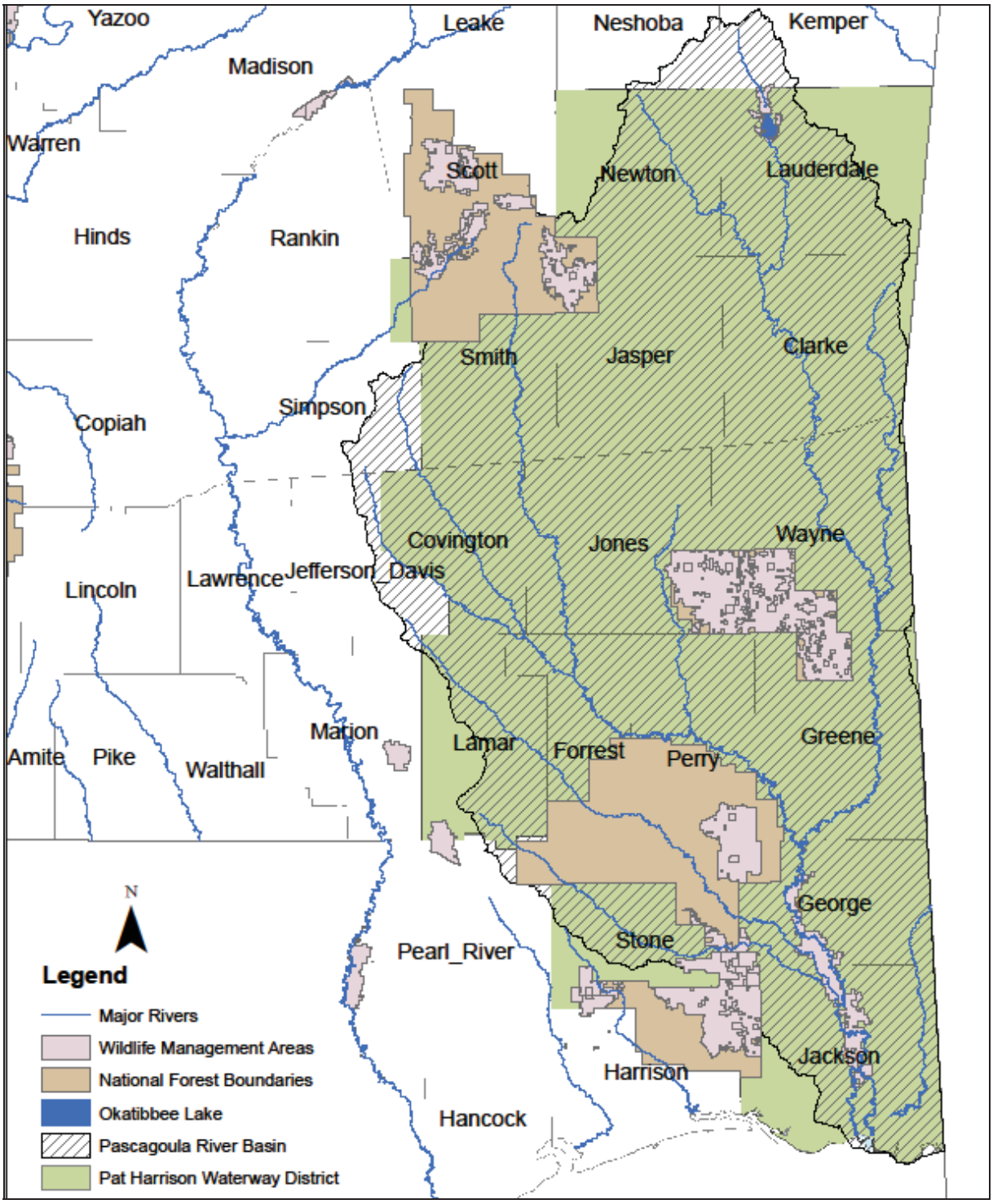

Figure 1.2 - Pascagoula Basin's Public Land

1.1.3. The Pascagoula River's Economic Benefits

Water from the Pascagoula River supports a robust, largely industrial based regional economy. On February 23, 1962, the Jackson County Board of Supervisors obtained a permit from the Mississippi Department of Environmental Quality (MDEQ) to withdraw up to 100 MGD of surface water from the Pascagoula River at Cumbest Bluff in Jackson County (River mile 25.4) (Permit Number 01166). A pipeline transports water approximately 25 miles downstream to the Bayou Casotte Industrial Area, where it is treated and distributed to various industries. In accordance with Mississippi's state water law, this permit was reviewed and reissued on November 12, 1985 (Permit Number MS-SW-00121). On January 9, 1996 the permit was reissued and transferred to the Jackson County Port Authority (JCPA) (MS-SW-00121). The permit remains active and is scheduled for renewal in 2016. Both Mississippi Power Company's Plant Daniel and Chevron's Pascagoula Refinery depend on the JCPA pipeline for water supply. Plant Daniel is a major 2-gigawatt, four-unit power plant, generating about 1 GWe from two coal-fired subcritical drum-type units and 1 GWe from two newer, gas-fired combined-cycle units. The Chevron Cogenerating Plant uses combustion turbines to generate 147,292 kW. The U.S. Energy Information Agency reported in 2013 that the Chevron's Pascagoula Refinery was the Nation's ninth largest refinery. During the summer of 2014, the Jackson County Utility Authority (JCUA) was scheduled to open a one MGD water treatment plant that will use surface water from JCPA's pipeline for potable water supply in northeast Jackson County. Figure 1.3 illustrates the Lower Pascagoula Surface Water Infrastructure.

Figure 1.3 - Lower Pascagoula Surface Water Infrastructure

1.1.4. The Pascagoula River's Baseflow and Minimum Flow

Ecological, environmental and economic functions all require adequate stream flows to thrive or even survive. The Pascagoula River depends on both basin-wide surface water inflows and interactions with groundwater in shallow, unconfined aquifers (e.g. water table) to maintain baseflows during prolonged droughts. Hydrologic fluctuations between high and low flow periods impact riparian wetlands and transitional coastal and estuarine marshes and wetlands. The quantity and quality of surface water inputs into the Pascagoula River varies considerably with seasonal variations in rainfall, soil moisture, evaporation, temperature, etc. Similarly, the river's interaction with the water table varies substantially, even along different river reaches. Depending on localized groundwater levels, a river can either gain or lose water to the water table. In humid climates, such as the Pascagoula watershed, rivers tend to gain water from groundwater unless the water table is lower than the streambed (USEPA, 2015).

The Environmental Protection Agency Region 4, contends that ecologically, the Pascagoula River system has adapted to periods of severe drought. Droughts have occurred throughout the river's history and the Pascagoula's ecology has likely adapted to recover from such events. Thus maintaining low flows may not be necessary to maintain the ecology of the river (EPA Region 4, 2013). Notwithstanding this opinion, Mississippi's legislature sought to accommodate the diverse uses of the State's rivers' by defining minimum stream flow as:

> "the minimum flow for a given stream at a given point thereon as determined and established by the [Mississippi] commission [on Environmental Quality] when reasonably required for the purposes of this chapter. **'Minimum flow' is the average streamflow rate over seven (7) consecutive days that may be expected to be reached as an annual minimum no more frequently than one (1) year in ten (10) years (7Q10)**, or any other streamflow rate that the commission may determine and establish using generally accepted scientific methodologies, considering biological, hydrological and hydraulic factors. In selecting a generally accepted scientific methodology, the commission shall consult with and shall consider recommendations from the [MDWF&P]. **In determining and establishing the minimum streamflow rates, the commission shall give consideration to consumptive and nonconsumptive water uses, including, but not limited to, agricultural, industrial, municipal and domestic uses, assimilative waste capacity, recreation, navigation, fish and wildlife resources and other ecologic values, estuarine resources, aquifer recharge and aesthetics**." ((Miss. Code Ann. § 51-3-3(i)) emphasis added).

The Mississippi Commission on Environmental Quality applied the 7Q10 methodology to set minimum stream flows of 917 cubic feet per second (CFS) for the Pascagoula River the USGS Merrill stream gage immediately below the confluence of the Leaf and Chickasawhay Rivers and 1030 CFS downstream at Cumbest Bluff (USGS 1991, MDEQ 1998). The Pascagoula River's water budget, baseflows and low flows are presented in Section, 2.2; however, it is appropriate to provide an overview of those issues here.

The Pascagoula River suffered a drought of record during the 2000 water year (October 1, 1999 through September 30, 2000). During the drought, the minimum daily discharges at the USGS Merrill stream gage were 649 CFS or 29% less than the 7Q10 and 8% less than the previously recorded minimum flow of 704 CFS set on October 21, 1936 (Turnipseed and Baldwin 2001). Supplemental water releases from Okatibbee Reservoir augmented flows which lessened the drought's downstream impact mainly on Okatibbee Creek and the Chickasawhay River at Enterprise and Leaksville according to USGS's stream gage data. In 2000, supplemental water was released from Okatibbee for a total of 100 days as follows; 1) from Julian Day 195 to 217,

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3,328 acre feet (AF) were released; 2) from Julian Day 233 to 260, 11,110 AF were released; and finally 3) from Julian Day 265 to 316, 18,454 AF were released (Pat Harrison Waterway District 2001). The efficacy of Okatibbee Reservoir water releases to maintain flows diminished notably downstream with the Chickasawhay River at Leakesville falling below its 7Q10 and the Pascagoula River's Merrill stream gage setting a drought of record despite these releases. (Figure 1.4). This downstream water loss is explained more fully in Sections 2.2, 2.3.3 and 4.1. Briefly, minimum daily discharges for nineteen of the Pascagoula River's twenty-one stream gages were lower than their 7Q10s, with sixteen of them being the lowest for the period of record. Three of the Pascagoula River's five gages that did not set new low flow records benefited from flow augmentation from Okatibbee Reservoir (Turnipseed and Baldwin 2001). Subsequently, the Pascagoula River has suffered recurrent periodic droughts in 2007, 2010, and most recently in 2011, during which the river again fell below 917 CFS at the Merrill stream gage. The Okatibbee Reservoir was not used to augment flows during these droughts.

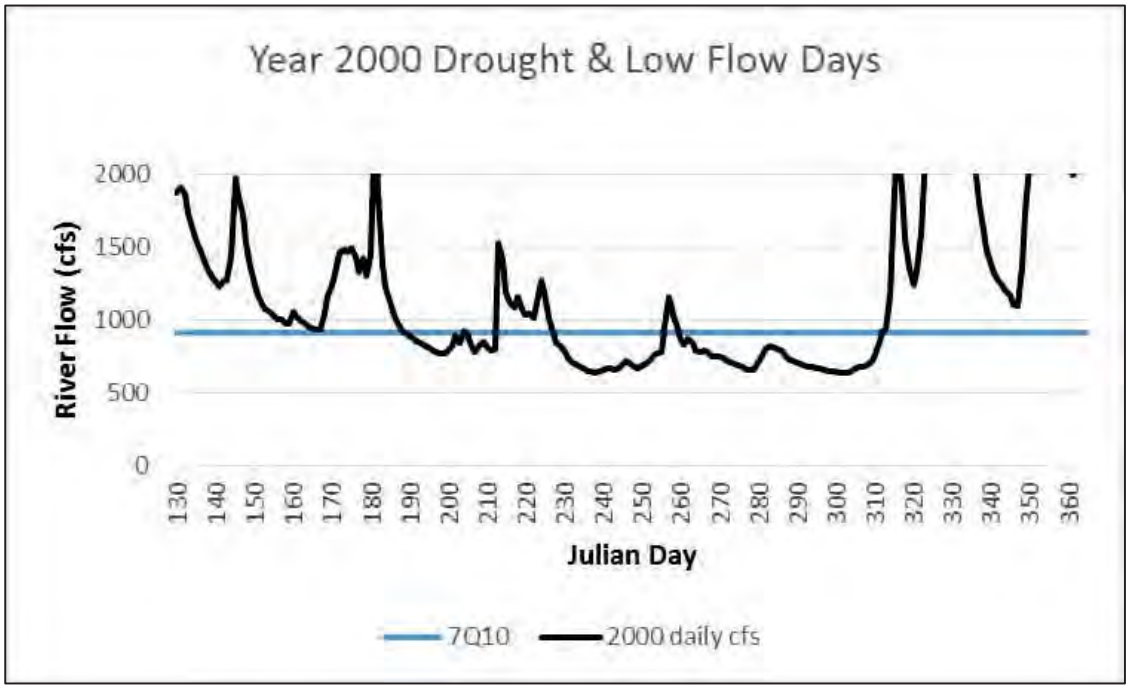

Figure 1.4 – 2000 Low Flow Days at Merrill Stream Gage

1.2. Recommended Project

The Recommended Project consists of two impoundments on Big and Little Cedar Creeks in south George and north Jackson Counties which provides a two-pronged drought resiliency approach (Figure 1.5). First, the lakes provide extensive subsurface which will not evaporate like surface water and will help to naturally maintain the Pascagoula River's baseflow during droughts. Secondly, at full pool, the two lakes will provide 51,638 AF of water storage that will be available for immediate release when the Pascagoula River falls below 917 CFS at the USGS Merrill stream gage.

The co-applicants agree that the PHWD will operate and manage the Recommended Project as a single system to augment the Pascagoula River's flows when necessary and to provide public recreational opportunities. The Project will also include one or possibly two public recreational water park(s) adjoining the Upper and/or Lower Lake(s). The water parks will be patterned after

the PHWD's current water parks and include cabins, R.V. and primitive camping sites, water slides, boat launches, shelters and lodge halls, nature trails, etc. A transparent public process and economic impact and feasibility study will be used to determine the size, number and mix of amenities which the water park will include.

The Upper Lake on Little Cedar would be entirely in George County at 130 feet above mean sea level (MSL) maximum pool elevation. The Upper Lake would cover approximately 1,715 acres with 31,410 AF of water storage. Initially, the Lower Lake, positioned below the confluence of Big and Little Cedar Creeks was anticipated to have a maximum pool elevation of 65 feet MSL. At that elevation, the Lower Lake would have covered approximately 1,750 acres, with 1,227 acres (70%) of it in south George County and 523 acres (30%) in north Jackson County and had about 21,228 AF of water storage capacity. In late 2014, modeling results showed that the projected water storage capacity achieved by the original two lake scenario slightly exceeded the River's projected long-term needs. Additional modeling determined that reducing the Lower Lake's maximum pool elevation to 60 feet MSL would sacrifice approximately 1,000 AF of water storage capacity but reduced the lake footprint by approximately 523 acres and considerably reduced the Recommended Project's environmental impacts. Accordingly, the Lower Lake is proposed at 60 feet above MSL maximum pool elevation which would cover approximately 1,153 acres, with about 667 acres (58%) if it in south George County and about 484 acres (42%) in north Jackson County. As proposed, the Lower Lake would provide roughly 20,228 AF of water storage capacity. The 70 feet of elevation gain between the Lower and Upper Lakes reflects the area's dramatic topography.

The Upper Lake's proposed dam is anticipated to be approximately 0.80 miles (4,232.5 feet) long and is located in George County, Mississippi. The Lower Lake's proposed dam is anticipated to be approximately 0.53 miles (2,821.5 feet) long and is located in Jackson County, Mississippi. Both dams are planned to be earth-fill embankments with an impermeable core. The primary spillways will be uncontrolled concrete structures approximately 20 feet in width, constructed with surface elevations at the top of the conservation pools for both lakes. Emergency spillways will be designed and constructed for both dams to allow passage of the probable maximum (500-year) flood without overtopping the embankment. Releases will be controlled using a structure capable of selective, multilevel withdrawal and an outlet discharging into a stilling basin at the base of the primary spillway. Minimum downstream flows will be maintained on both Big and Little Cedar Creeks during construction and their subsequent operation. The Recommended Project is presented in Section 3.

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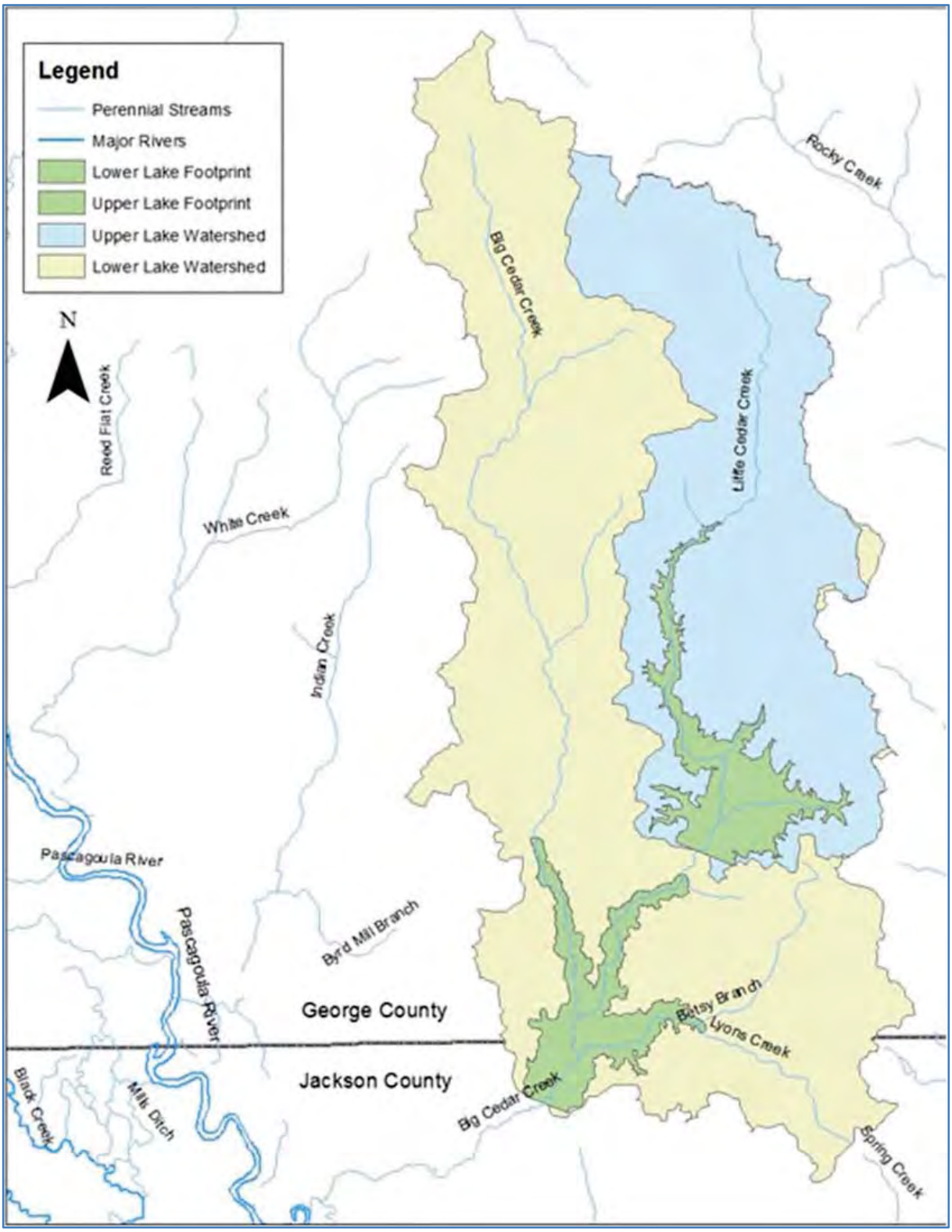

Figure 1.5 - Proposed Upper and Lower Lakes with Watersheds

The Recommended Project's operational procedures for water releases and lake/shoreline management remain to be negotiated with MDEQ and the COE. A Shoreline Management Plan will be developed and adopted based on those the PHWD uses to manage its other public recreational lakes. The Project was sited and sized for drought resiliency. Water releases from the Upper to the Lower Lake, and ultimately the Pascagoula River, would be coordinated to maintain Pascagoula River flows while minimizing lake surface evaporation and to maintain recreational uses on both lakes to the extent possible. However, based on stakeholder discussions and resource agency comments, there are several alternative operational schemes that could provide important secondary environmental and ecological benefits to:

1. Maintain a natural, historic hydrograph;
2. Create periodic artificial high water events to provide downstream and coastal environmental and ecological benefits without increasing flood risks; and
3. Create a seasonal hydrograph to enhance the aquatic habitat of the threatened and endangered fish species and important commercial and recreational marine fisheries. This alternative is discussed in detail in Section 4.2.2.

The Project's exact operational parameters are still under discussion with stakeholders and federal and Mississippi State resource agencies.

1.3. Project History

This project started in late 2009 when the Mississippi Legislature authorized the PHWD to proceed with permitting and construction of a lake and related structures and facilities in George County, Mississippi (House Bill 27, 2009 2nd Extraordinary Session § 10). The project was in response to projected climate change predictions coupled with growing demands for diminishing water supplies, which was causing communities in the Southeast U.S. and southeastern Mississippi to take steps to ensure reliable, long-term water supplies. With the Southeast experiencing prolonged and severe drought conditions that threatened water supplies, constrained economic development, and led to an escalation of the interstate *Water Wars* among the states of Alabama, Florida, and Georgia, which resounded with neighboring states. Mississippi was spared the drought's worst impacts but the Pascagoula River still suffered a drought of record in 2000.

In July 2010, the PHWD and the George County Board of Supervisors selected PFI to provide professional services for the project. Subsequently, PFI met with neighboring County Boards of Supervisors, the JCPA, the JCUA, the MDEQ, the DMR, and the COE, the Pascagoula River Basin Alliance and other parties knowledgeable about or interested in the Pascagoula River. Recognizing that the Pascagoula River fell below the minimum flow established by the Mississippi Commission on Environmental Quality at the USGS Merrill, Mississippi stream gage in 1999, 2000, 2007, 2010 and again in 2011, there was a general consensus that it was appropriate and timely to research and quantify the Pascagoula River's long-term water needs for environmental, ecological and economic benefits.

The parties unanimously agreed a regional approach was necessary to analyze the issue and identify potential solutions. The effort was initially titled the *Southeast Mississippi Regional Water Supply Project* and endorsed by the George, Greene, Harrison, Jackson, and Stone County Board of Supervisors, the JCPA, and the JCUA. Initially, the two major challenges were 1) to establish an objective methodology to quantify the Pascagoula River's long-term supplemental water needs for drought resiliency; and 2) to use the best available science to quantify the projected water quantity impacts of climate variability or change on the river's future flows. The Environmental Protection Agency (EPA) Region 4's Guidelines on Water Efficiency Measures for Water Supply Projects in the Southeast (June 21, 2010) helped clarify both

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issues. After consulting with EPA Region 4, the MDEQ, the DMR, and the COE Mobile, it was decided to respond to the EPA Region 4 Guidelines and evaluate Region 4's response before proceeding with a Clean Water Act § 404 Joint Application and Notification.

A *Southeast Mississippi Regional Water Supply Project Application* was submitted to EPA Region 4 on November 21, 2012. Region 4 responded on January 29, 2013 (Appendix A). Region 4 offered substantive recommendations which are incorporated into this application and Environmental Assessment. Based on Region 4's recommendations and other agency consultations, it became obvious that this was a drought resiliency project instead of a normal water supply project, as the project was always a proactive response to maintain the Pascagoula River's minimum stream flows for environmental, ecological and economic benefits over the next fifty years given projections of more severe, prolonged and frequent droughts.

On June 2, 2014, a preliminary Draft Clean Water Act § 404 Joint Application and Notification was submitted to the COE Mobile District and DMR. An inter-agency, pre-application meeting was held on June 26, 2014 with representatives from the George County Board of Supervisors and coordinating federal and Mississippi state agencies. Agency representatives made additional recommendations during the meeting relating to the Statement of Purpose and Need's importance, quantifying the firm water yield necessary to meet the described need; the quality/quantity of wetlands and streams which the project would impact, mitigation; threatened and endangered species; water quality certification; and coastal impacts. Agency coordination and consultation activities are detailed in Section 11 and Appendix F.

The George and Jackson County Supervisors have been very proactive in meeting with residents in and adjacent to the Recommended Project site. After the Recommended Project footprint was finalized the George County Board of Supervisors held a Public Event at the George County High School in Lucedale, Mississippi on April 16, 2015. The event was well publicized in local media to encourage turnout and was designed to provide local residents with information about the Recommended Project. Five information stations with large maps and collages of field work were set up and staffed for the event. Over 250 attendees were able to talk one-on-one with their elected officials, PHWD staff and PFI employees about the project. A total of 300 Color 11x17 handouts of the lake footprints with Frequently Asked Questions and Answers handouts were distributed at the event or the following morning at the George County Government Office Building. The PHWD and the Jackson County Board of Supervisors were provided more handouts shortly after the event for distribution.

At the event, most comments related to: 1) public access (especially fishing and recreation); 2) management of the lakes and the shoreline; or 3) very detailed questions about the lake footprints and potential impacts on specific properties or structures. After the meeting, the George County Board of Supervisors set up a display in the County Office Building with a large map, handouts and comment cards. As of July 2015, the display is still regularly visited and comment cards are still being received. As of May 30, 2015 forty written comments had been received. Approximately 50% of the comments were generally positive, 5% negative, 25% had follow-up questions and 20% had suggestions for the Recommended Project.

1.4. Project's Purpose and Need

The Statement of Purpose and Need essentially defines the scope of the Clean Water Act § 404 application and the Environmental Assessment. Since the Purpose and Needs section addresses future circumstances, it includes some unavoidable uncertainty. This section

discusses speculative versus non-speculative purposes and needs and then presents the Recommended Project's Purposes and Need.

1.4.1. Non-Speculative Need-Forecasting Drought Frequency, Severity and Duration

The COE will not review a speculative project that fails to clearly specify its ultimate *purpose*. The COE requires that, "the likelihood that the project purpose will in fact materialize during a reasonably foreseeable period of time must be reasonably demonstrated" (USACE 1990 at paragraph 2). However, the reality is that reasonableness is unavoidably uncertain in the Global Climate Change or Variability context. The difficulty is further magnified when attempting to translate climactic trends into actual projections of drought frequency, severity or duration for a specific river or river basin.

Recently the COE published a climate change and hydrology literature review for the South Atlantic-Gulf Region (USACE 2015). The report found that regionally, there was a *strong* consensus that air temperatures will increase by 2 to 4 degrees Celsius over the next century, with the largest increases in the summer months. There was a *reasonable* consensus on projected increases in "extreme temperature events, including more frequent, longer, and more intense summer heat waves". Precipitation projections are roughly evenly split between increases or decreases in future annual precipitation. Similarly, hydrologic projections are evenly split, showing potential increases or decreases in regional stream flows (USACE 2015 at page 35). In 2013, EPA Region 4 released a Draft Study reporting that the "expected climate change-related impacts to the Region 4's aquatic ecosystems include longer durations of low summer stream flows, average stream flow decreases, higher flooding incidences, and increased periods of extremely high and low flows (greater flashiness), with resultant scouring" (EPA 2013 at page 15). This Environmental Assessment uses the best available science to project the frequency, severity and duration of low flow events on the Pascagoula River based on historical measured precipitation and flow data from the Pascagoula Basin. This analysis is in Section 2.2 with detailed reports on the methodology and data sources in Appendices J and K. The lack of consensus about the timing, duration, or frequency of droughts and low flows does not make drought resiliency speculative (USACE 1990).

1.4.2. Purpose

The Project's purpose is to provide sufficient surface water and restored water table levels to maintain the Pascagoula River's flows above established minimum stream flows (7Q10) through 2060, notwithstanding projected more frequent, severe and longer droughts in the basin.

1.4.3. Need

Since roughly 2000, the Pascagoula River's flows have inexplicably shown an increasing tendency to fall below the established 7Q10, for reasons not clearly understood but appear to reflect an altered base flow regime occurring throughout the basin. Even in the 2000 drought, flow augmentation from Okatibbee Reservoir was unable to keep the Pascagoula River at the Merrill stream gage above its 7Q10, and climate change/variability studies predict that the Pascagoula Basin will have more frequent, severe and prolonged droughts in the future (Pote et al. 2014 and 2015; Appendix F and G). Translating projected drought frequency, severity and duration into stream flows indicates that climate variability will measurably, if not dramatically, impact the Pascagoula River's ability to constantly exceed its 7Q10 of 917 CFS in the future (Figure 1.6).

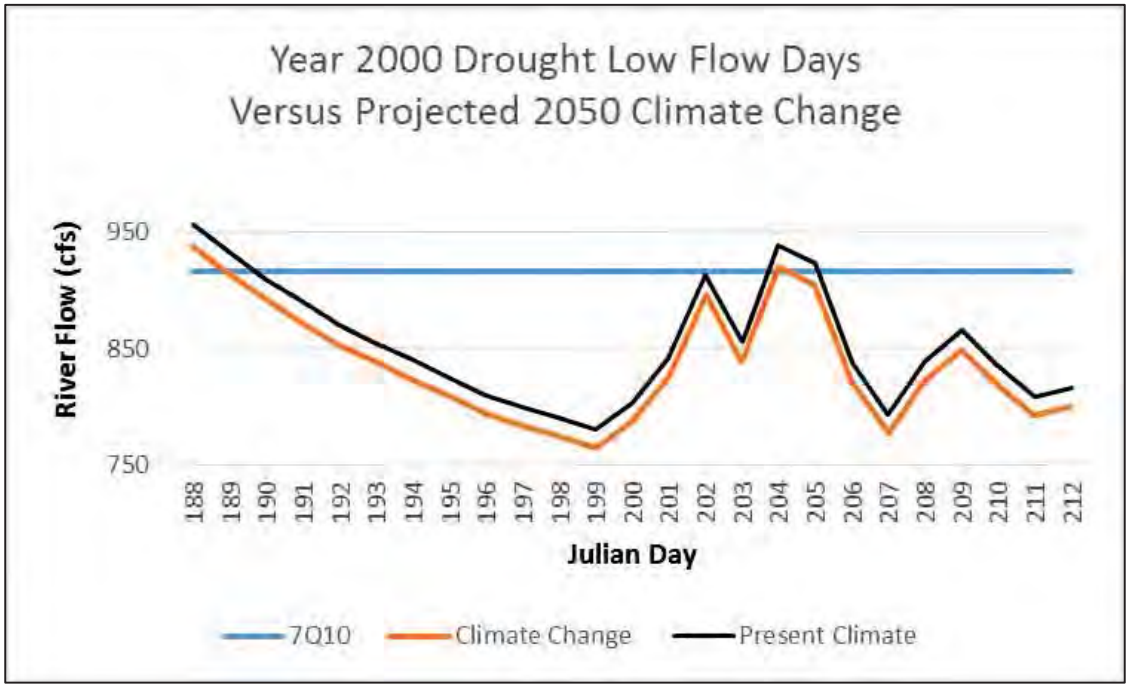

Figure 1.6 - Projected Climate Change Impact on Measured 2000 Low Flows at Merrill Stream Gage

Maintaining established minimum flows on the Pascagoula River during more frequent, severe and prolonged droughts is critical to the river's ability to meet critical environmental, ecological and economic needs. Many of the potential adverse consequences the Recommended Project will avoid are presented in the *No Action* Alternative discussion in Section 9.1. Briefly EPA Region 4's Climate Change Adaption Implementation Plan summarizes most of the Project's environmental purposes (EPA 2013). These purposes include but are not limited to: 1) Maintain surface water assimilative capacity; 2) Prevent seasonal wetlands from drying out and disappearing; 3) Minimize drought driven increased demands on surface and groundwater; and 4) Provide drought resiliency to maintain estuarine salinity regimes against the impacts of projected sea level rise. Similarly, the Project's ecological purposes were identified in a recent Mississippi State University study as including, but are not limited to: 1) Maintain habitat and a migratory corridor for important freshwater and estuarine commercial and recreational fisheries; and 2) Provide critical habitat (i.e. stream flows) for threatened and endangered species' migration, reproduction and nursery areas (Pote et al, 2015 and Appendix J). Finally, the Project's economic purposes include but are not limited to: 1) Maintain water supplies for permitted surface water withdrawals; 2) Maintain biological diversity and richness to support the Pascagoula River's growing eco-tourism industry; and 3) Assure reliable, long-term water supplies for potential new industries and related livable wage jobs in the region.

1.5. Authority for the Project

Two legislative provisions directly pertain to this Recommended Public Project. The first explicitly affirms a public interest in surface and groundwater resources development and management by stating that:

> It is the policy of the Legislature that conjunctive use of groundwater and surface water shall be encouraged for the reasonable and beneficial use of all water resources of the state. The policies, regulations and public laws of the State of Mississippi shall be interpreted and

> administered so that, to the fullest extent possible, the ground and surface water resources within the state shall be integrated in their use, storage, allocation and management.
>
> All water, whether occurring on the surface of the ground or underneath the surface of the ground, is hereby declared to be among the basic resources of this state to therefore belong to the people of this state and is subject to regulation in accordance with the provisions of this chapter. The control and development and use of water for all beneficial purposes shall be in the state, which, in the exercise of its police powers, shall take such measures to effectively and efficiently manage, protect and utilize the water resources of Mississippi (Miss. Code Ann. § 51-3-1).

The second provision provides the PHWD, a Mississippi State Agency the authority:

> to impound overflow water and the surface water of any streams in the [Pascagoula Basin], at the place or places and in the amount as may be approved by the [Mississippi Department of Environmental Quality] Office of Land and Water Resources of the State of Mississippi, by the construction of a dam or dams, reservoir or reservoirs, work or works, plants and any other necessary or useful related facilities . . ., to control, store, and preserve these waters, and to use, distribute, and sell them, to construct or otherwise acquire within the project area all works, plants or other facilities necessary or useful to the project for processing the water and transporting it to cities and other facilities necessary or useful . . . for the purpose of processing the water and transporting it to cities and other facilities for domestic, municipal, commercial, industrial, agricultural and manufacturing purposes . . . (Miss. Code Ann. § 51-15-119(1)(b)).

In 2010 the Legislature authorized the PHWD “to construct a lake and related structures and facilities in George County, Mississippi” (House Bill No. 1351; codified at Miss. Code Ann. § 51-15-119(1)(bb)).

2. PASCAGOULA BASIN, WATERSHED AND RIVER'S CURRENT ENVIRONMENTAL SETTING

Section 1.1 introduced the Pascagoula Basin, River and watershed, their inter-relationship and their critical environmental, ecological and economic roles. Briefly, the Pascagoula River reflects the entire Basin's environmental conditions in the quality and quantity of water discharges into the Mississippi Sound. This section details the environmental setting in the Pascagoula Basin, watershed and river. Section 2.1 presents a broad overview of the Basin's general environmental and ecological setting and Land Use/Land Cover. Section 2.2 presents an in-depth explanation of complex geo-hydrologic inter-relationships in the Pascagoula Basin. Finally, Section 2.3 describes individual resources within and adjacent to the Project area.

2.1. General Environmental Setting

The Mississippi Department of Environmental Quality's (MDEQ) (2001) *Pascagoula River Basin Status Report* describes the Basin as heavily forested with several urban areas such as Meridian, Laurel, Hattiesburg, and Pascagoula. The Basin's central portion is known as the Pine Belt because of its pine forests with scattered hardwoods. Topographically, the Basin is primarily gently rolling hills and broad, flat floodplains and marshlands transitioning to low-lying flatlands and forested wetlands closer to the Gulf Coast. Most of the Pascagoula River's tributary streams are deep to moderately deep, fast flowing, perennial streams. The Pascagoula Basin, River and watershed have important roles in maintaining the environmental and ecological health and diversity of the Mississippi Sound and the Gulf of Mexico. Of the Basin's approximately 6,144,000 total acres roughly 1,000,000,000 acres, or one-sixth, are protected or have some degree of public or private conservation management in place to protect their environmental, ecological and economic functions (Figure 2 (Introduction), The Nature Conservancy 2005). This Section describes the Pascagoula River watershed's EcoRegions and Land Use/Land Cover in George and Jackson Counties, Mississippi where the Project is proposed.

2.1.1. Pascagoula Watershed's Level III and IV EcoRegions

The Project and the impacted area downstream is located in a transition area between two level III EcoRegions: 1) the Southeastern Plains (64) and 2) the Southern Coastal Plain (75). The majority of the Pascagoula River Basin is classified as Southeastern Plains with irregular plains that are mostly forested with a mosaic of cropland, pasture, forest and silviculture. The region has thinner loess deposits than the Mississippi Valley Loess Plains to the west, and elevations and relief are greater than in the Southern Coastal Plain. The region's streams are low to moderate-gradient with mostly sandy substrates. The Southern Coastal Plain extends up the Pascagoula River to roughly the mouth of Big Creek in central George County and is heterogeneous with coastal lagoons, marshes, and swampy lowlands down to the Gulf coast. It is generally lower in elevation with less relief and wetter soils than the Southeastern Plains. The region was once covered by various forest communities including longleaf pine (*Pinus palustris*), slash pine (*P. elliottii*), pond pine (*P. serotina*), beech (*Fagus grandifolia*), sweetgum (*Liquidamber styraciflua*), southern magnolia (*Magnolia grandiflora*), white oak (*Quercus alba*), and laurel oak (*Q. laurifolia*), but is now mostly slash and loblolly pine with oak-gum-cypress forest in some low-lying areas (Chapman et al. 2004).

The Pascagoula River and Big and Little Cedar Creeks include and connect four level IV Ecoregions (Figure 2.1). Moving downstream along the Pascagoula River, these are: 1) the Southeastern Floodplains and Low Terraces (65p), 2) the Piney Woods (65f), 3) the Floodplains

and Low Terraces (75i), and finally 4) the Gulf Barrier Islands and Coastal Marshes (75k). Chapman et al. (2004) briefly characterize these level IV EcoRegions as:

1. Southeast Floodplains and Low Terraces (65p): is a riverine ecoregion of large rivers and backwaters with ponds, swamps, and oxbow lakes. Substrates of the low-relief region are a mix of sands, silts, and clays. River swamp forests of bald cypress (*Taxodium distichum*) and water tupelo (*Nyssa aquatica*) and oak-dominated bottomland hardwood forests provide important wildlife corridors and habitat. The low terraces are mostly forested with some cropland or pasture on the broader, better drained terraces. The larger, wider floodplains of the Leaf and Pascagoula Rivers fall under this classification.
2. Piney Woods (65f): is commonly known as the pine belt, although most of the mixed and longleaf pine forests have been replaced by slash and loblolly pine plantations. The longleaf pine forest provided habitat for now rare or endangered species such as the red-cockaded woodpecker, gopher tortoise, eastern indigo snake, and black pine snake. Wet savannas and bogs contained assorted wildflowers: red lillies, orange milkweeds, yellow pitcher plants, lavender butterworts, and purple sundews. The region's subsurface materials is mostly clays and sands of the Miocene-age Hattiesburg and Pascagoula Formations, with some Catahoula Sandstone in the north. Hill summits and higher elevations are composed of Pleistocene and Pliocene-age deposits such as the Citronelle Formation and are generally sandy, gravelly, and porous, and more erosion resistant than the older underlying Miocene clays and sands. The region's streams may be darker tea-colored and more acidic.
3. Floodplains and Low Terraces (75i): Is a continuation of 65p ecoregion across the Southern Coastal Plain. The region includes the Pascagoula River's broad floodplains. The Pascagoula and its backwater ponds, swamps, and oxbow lakes is composed of stream alluvium and terrace deposits of sand, silt, clay, and gravel, along with some organic muck and swamp deposits. River swamp forests of bald cypress (Taxodium distichum) and water tupelo (Nyssa aquatica) and oak-dominated bottomland hardwood forests provide important wildlife habitat.
4. Gulf Barrier Islands and Coastal Marshes (75k): contains salt and brackish marshes, dunes, beaches, and barrier islands that enclose the Mississippi Sound. Inland, some tidal freshwater marshes occur on the Pascagoula River's alluvial delta deposits. Smooth cordgrass (Spartina alterniflora), marshhay cordgrass (S. patens), and saltgrass (Distichlis spicata) tend to be dominant in the saline intertidal zone. Sea oats (Uniola paniculata) are common on dunes and beaches. The region provides habitat for many waterfowl, shorebird, and fish species, as well as muskrat, raccoon, otter, mink, and alligator.

Figure 2.1 – Pascagoula River's Level IV EcoRegions

2.1.2. George and Jackson Counties Mississippi Land Use/Land Cover

The Project in southeast George County, Mississippi and northeast Jackson County, Mississippi is essentially a microcosm of the Pascagoula Basin. Based on review of available historical data and information and extensive site reconnaissance, the vast majority of the area is undeveloped woodlands with some agricultural and silvicultural activities. Land Use/Land Cover data show the general location and extent of various land use classifications to establish the Project area's general environmental setting. Post-Katrina 2006 Land Use/Land Cover maps for George and Jackson County are shown in Figures 2.2 and 2.3 respectively (Mississippi State University 2009, 2009a). The Jackson County map shows the development concentrated at the mouth of the Pascagoula River (Mississippi State University 2009a).

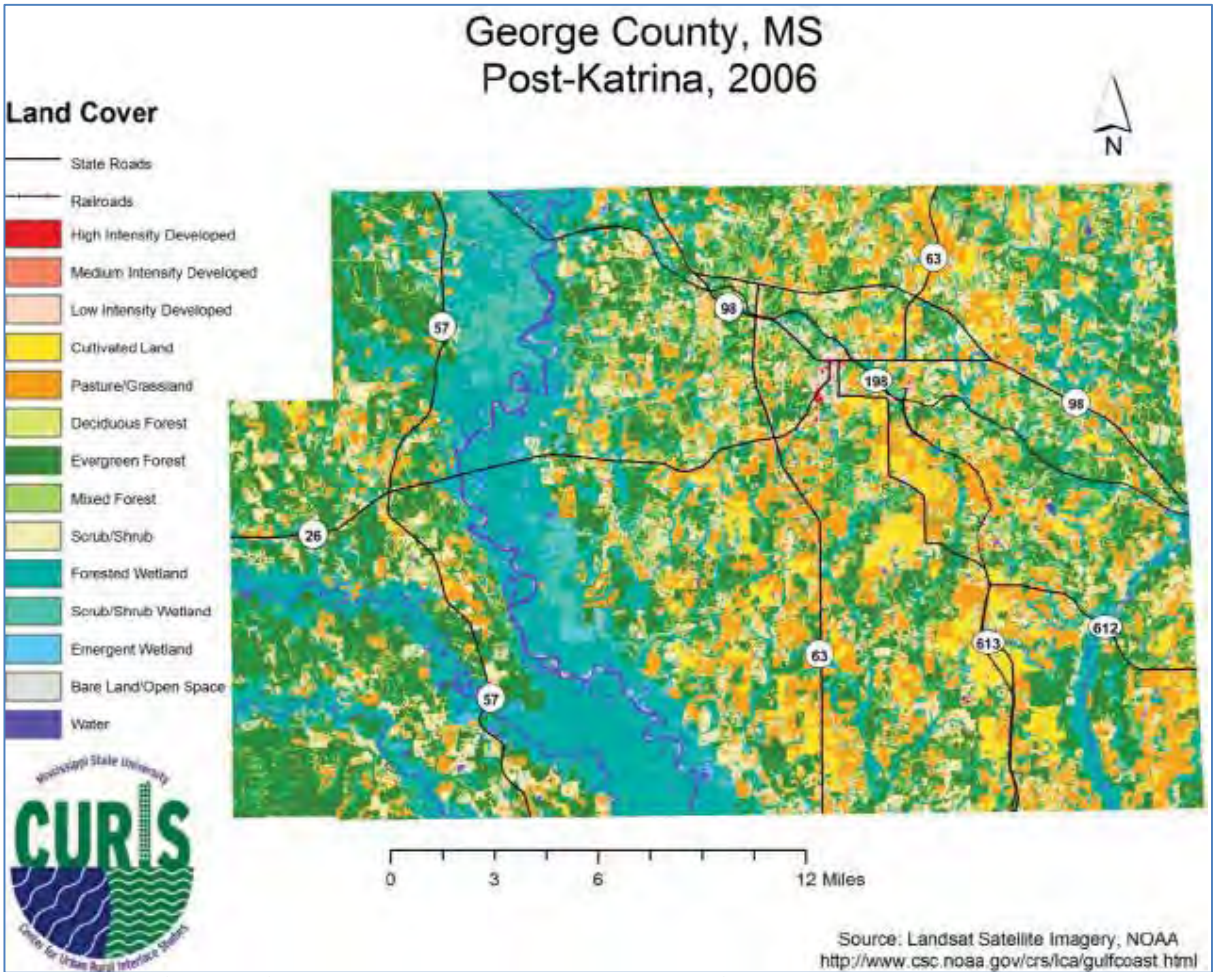

Figure 2.2 - George County, Mississippi Land Use/Land Cover 2006

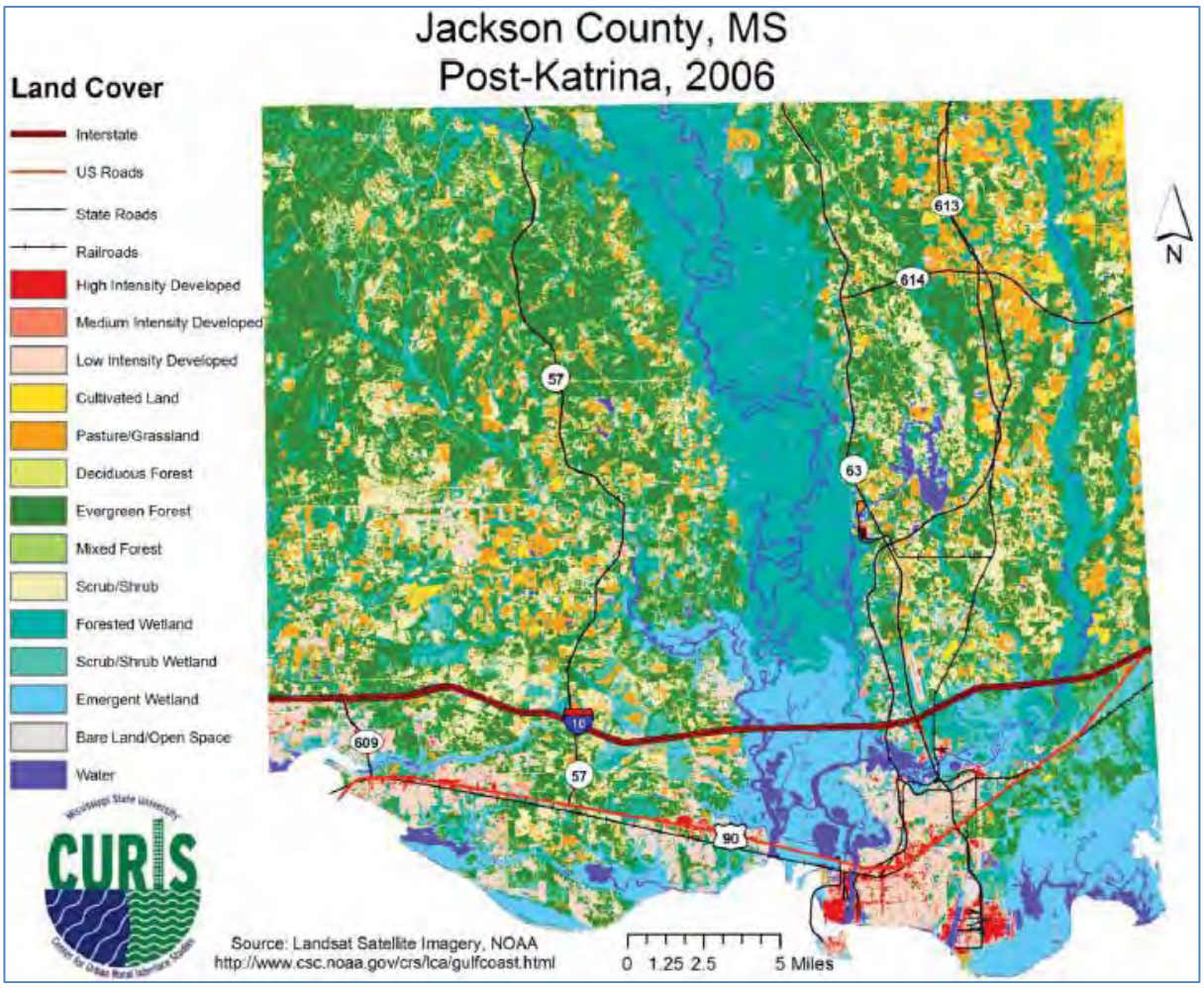

Figure 2.3 - Jackson County, Mississippi Land Use/Land Cover 2006

The location and extent of these classifications were remarkably consistent in both counties from 1996-2006. Except for a 7.23% reduction evergreen forests in George, which might be the result of normal silviculture activities, no other classification underwent even a 5% change in either county from 1996-2006, as highlighted in Tables 2.1 and 2.2 (MSU 2009 at page 7; MSU 2009a at page 7).

Classification	1996	2001	2005	2006	1996-2006 Change
High Intensity Development	0.03%	0.04%	0.05%	0.04%	0.01%
Medium Intensity Development	0.09%	0.12%	0.14%	0.14%	0.05%
Low Intensity Development	1.29%	1.54%	1.57%	1.57%	0.28%
Cultivated Land	3.54%	3.59%	3.69%	3.69%	0.14%
Pasture/Grassland	11.72%	12.58%	14.92%	15.47%	3.74%
Deciduous Forest	0.16%	0.15%	0.14%	0.13%	0.03%
Evergreen Forest	30.83%	27.74%	24.18%	23.60%	-7.23%
Mixed Forest	5.68%	5.25%	4.86%	4.83%	-0.85%
Scrub/Shrub	13.30	15.52%	17.53%	17.59%	4.30%
Forested Wetland	27.53%	27.03%	26.11%	26.09%	-1.45%
Scrub/Shrub Wetland	2.40%	2.85%	3.06%	3.02%	0.62%
Emergent Wetland	0.90%	1.01%	1.13%	1.18%	0.29%
Bare Land	0.59%	0.63%	0.67%	0.67%	0.08%
Water	1.94%	1.96%	1.97%	1.98%	0.04%

Table 2.1 George County, Mississippi Land Cover Change Analysis (1996-2006)

Classification	1996	2001	2005	2006	1996-2006 Change
High Intensity Development	0.49%	0.55%	0.58%	0.58%	0.09%
Medium Intensity Development	0.88%	0.92%	0.98%	0.98%	0.10%
Low Intensity Development	4.69%	4.96%	4.97%	4.97%	0.28%
Cultivated Land	0.81%	0.86%	0.88%	0.89%	0.08%
Pasture/Grassland	6.40%	6.35%	7.03%	7.26%	0.86%
Deciduous Forest	0.03%	0.02%	0.02%	0.02%	0.01%
Evergreen Forest	30.06%	29.07%	27.53%	27.43%	-2.63%
Mixed Forest	0.98%	0.94%	0.90%	0.89%	-0.09%
Scrub/Shrub	13.14	13.82%	14.80%	14.68%	1.54%
Forested Wetland	24.85	24.41%	23.95%	23.95%	-0.90%
Scrub/Shrub Wetland	3.22%	3.31%	3.49%	3.41%	0.19%
Emergent Wetland	8.41%	8.51%	8.53%	8.56%	0.15%
Bare Land	2.34%	2.54%	2.59%	2.61%	0.27%
Water	3.69%	3.72%	3.73%	3.77%	0.08%

Table 2.2 - Jackson County, Mississippi Land Cover Change Analysis (1996-2006)

2.2. The Pascagoula River: Regional Environmental, Ecological and Economic Foundation

Since the historic 2000 drought, the Pascagoula River's flows have fallen below the established 7Q10 (minimum flow) of 917 cubic feet per second (CFS) at the Merrill stream gage in 2007, 2010 and 2011. The reasons for this are not clearly understood; however, it seems to reflect an altered basin-wide base flow regime. During the 2000 drought, flow augmentation from Okatibbee Reservoir was unable to keep the Pascagoula River above its 7Q10 at the Merrill stream gage and climate change/variability studies predict that the Pascagoula Basin will have more frequent, severe and prolonged droughts in the future (Pote et al. 2014 and 2015; Appendix F and G). Nonetheless, the Environmental Protection Agency Region 4, contends that "ecologically, the Pascagoula River system is adapted to periods of severe drought. Droughts have occurred throughout the River's history and the ecology of the River is likely

adapted to recover from such events. Thus, maintaining low flows may not be necessary to maintain the ecology of the [R]iver" (EPA Region 4, 2013).

The EPA's (2015) report, *Connectivity of Streams & Wetlands to Downstream Waters* offers scientific-based guidance to understanding the possible causes, impacts and solutions to recurrent low-flows. The first consideration:

> Wetlands and river networks expand and contract in response to seasonal and decadal cycles and longer term changes in environmental conditions. In wet conditions, streams and rivers expand longitudinally into headwaters and laterally into floodplains or riparian areas, wetlands inundate and connect via surface water and ground water to other wetlands and the stream network, the water table rises, and local aquifers are recharged. In dry conditions, the river network is limited to perennial streams, wetlands dry down, and the water table level lowers (pages 1-8 & 9, references omitted).

The second consideration:

> River system hydrology is controlled by hierarchical factors that result in a broad continuum of belowground and aboveground hydrologic flowpaths, connecting river basins and river networks. At the broadest scale, regional climate interacts with river-basin terrain and geology to shape inherent hydrologic infrastructure that bounds the nature of basin hydrologic flowpaths. Different climate-basin combinations form identifiable hydrologic landscape units with distinct hydrologic characteristics. [T]hree first-order controls of watershed streamflow [are] generated under specific hydroclimatic conditions: (1) the ability of different landscape elements to generate runoff by surface or subsurface lateral flow of water; (2) the degree of hydrologic linkage among landscapes by which surface and subsurface runoff can reach river networks; and (3) the capacity of the river network itself to convey runoff downstream to the river-basin outlet. River and stream waters are influenced not only by basin-scale or larger ground-water systems, but also local-scale, vertical and lateral hydrologic exchanges between water in channels and sediments beneath and contiguous with river network channels. The magnitude and importance of river-system hydrologic flowpaths at all spatial scales can radically change over time at hourly to yearly temporal scales (pages 2-8 & 9, references omitted).

This Environmental Assessment uses this hierarchical, systems approach for an extensive geo-hydrologic analysis of the Pascagoula River watershed and basin. The United States Geological Survey (USGS) has collected precipitation and stream discharge data at various sites throughout the Pascagoula basin since the 1960's. When precipitation occurs, the amount of water in a stream temporarily increases and is reflected in the hydrograph. After the rain event, the stream returns to its previous level prior to the rain event. The water that comprises the stream flow not contributed directly from precipitation is baseflow, which reflects the groundwater table and groundwater storage. Hydrographs are used to represent this data and can be interpreted to show the three types of flow discharges that make up a stream: 1) surface runoff (overland flow), 2) subsurface flow (interflow), and 3) groundwater flow (baseflow) (Figure 2.4). Previous Pascagoula basin studies found that groundwater sustained baseflow for many of the basin's streams (USGS 1967). Groundwater is discussed under water resources in Section 2.3.1.3.

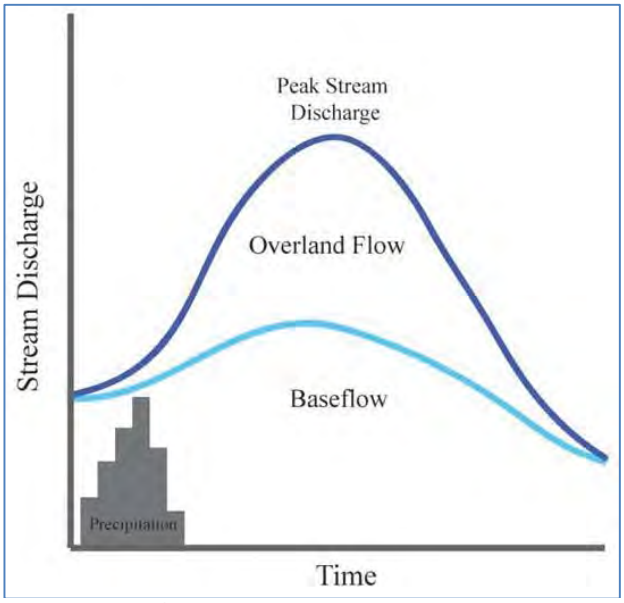

Figure 2.4 - Simple Hydrograph

Accordingly, the Sections below present the Pascagoula River's longitudinal and latitudinal geo-hydrology relevant to flows. Section 2.2.1 summarizes the regulatory perspective on minimum stream flows. Then the basin's surface flows are shown in Section 2.2.2's Water Budget. The River's natural baseflow is discussed in Section 2.2.3. Next Section 2.2.4 documents how these surface and subsurface water supplies have been inadequate to prevent periodic low flows during droughts in the Pascagoula. Finally, Section 2.2.5 uses the best available data and science to project, quantified climate variability impacts on the Pascagoula River's flows.

2.2.1. Regulatory Minimum Flows

Mississippi's legislature has declared that all surface and groundwater are the State's basic resources belonging to the people. The control, development and use of water for all beneficial purposes is vested in the state, which in the exercise of its police powers, shall take measures to effectively and efficiently manage, protect and utilize Mississippi's water resources (Mississippi Code Ann. § 51-3-1, Mulvaney, and Park 2008). Further, the legislature accommodated diverse uses of the State's rivers by defining minimum stream flow as:

> "the minimum flow for a given stream at a given point thereon as determined and established by the [Mississippi] commission [on Environmental Quality] when reasonably required for the purposes of this chapter. **'Minimum flow' is the average streamflow rate over seven (7) consecutive days that may be expected to be reached as an annual minimum no more frequently than one (1) year in ten (10) years (7Q10)**, or any other streamflow rate that the commission may determine and establish using generally accepted scientific methodologies, considering biological, hydrological and hydraulic factors. In selecting a generally accepted scientific methodology, the commission shall consult with and shall consider recommendations from the [MDWF&P]. **In determining and establishing the minimum streamflow rates, the commission shall give consideration to consumptive and nonconsumptive water uses, including, but not limited to, agricultural, industrial, municipal and domestic uses, assimilative waste capacity, recreation, navigation, fish and wildlife resources and**

other ecologic values, estuarine resources, aquifer recharge and aesthetics." ((Miss. Code Ann. § 51-3-3(i)) emphasis added).

The 7Q10 methodology may not fully protect aquatic habitats and nonconsumptive instream functions, but it does provide an objective, numerical minimum stream flow measure (Richerter et al. 2011). The Mississippi Commission on Environmental Quality used the 7Q10 methodology to set minimum stream flows on many of the Pascagoula Basin's streams and rivers (Figure 2.6 and Table 2.3). On the Pascagoula River, the 7Q10 is 917 CFS at the USGS Merrill stream gage immediately below the confluence of the Leaf and Chickasawhay Rivers and 103 CFS downstream at Cumbest Bluff (USGS 1991, MDEQ 1998).

After the Commission sets a minimum instream flow, the Mississippi Permit Board (hereinafter the board) makes decisions on water withdrawal permit issuance, reissuance, denial, modification and revocation (Miss. Code Ann. § 51-3-15(1)). Specifically, the board can,

> **permit the use of water of any stream only in excess of the established minimum flow**… However, exceptions may be made for municipal users… The board may [also] authorize a permittee to use the established minimum flow for industrial purposes when the water shall be returned to the stream at a point downstream from the place of withdrawal, where the board finds that the use will not result in any substantial detriment to property owners affected thereby or to the public interest - Miss. Code Ann. § 51-3-7(2) (emphasis added).

However, the board may "**revoke** any permit as the board deems appropriate for failure to adhere to permit conditions" - Miss. Code Ann. § 51-3-15(2)(d) …(emphasis added).

Low flows are detrimental to both consumptive (out-of-stream) and non-consumptive (instream) water uses. Yet, these statutory provisions together with the Pascagoula River's low flows in 2000, 2007, 2010 and 2011 threatens the operations of existing downstream consumptive industrial water users during future droughts. Additionally, the lack of secure, reliable long-term water supplies may limit the ability of existing industrial water users to expand and constrain efforts to recruit new industries to locate in the region.

2.2.2. Water Budget

Having established the regulatory framework for minimum flows, it is appropriate to identify and quantity the surface water flows that contribute to the Pascagoula River's flows. Figure 2.5 shows the Pascagoula basin's major tributaries. Those tributaries and their flows into the Pascagoula River are shown in a water budget that graphically depicts the inflows the Pascagoula River receives from tributaries. (Figure 2.6) Minimum flows (7Q10) in CFS for tributaries are tied whenever possible to the five USGS stream gages upstream of the project area (Figure 2.6 and Table 2.3). For the water budget, the stream gage near Leakesville marks the Chickasawhay River's northern limit. The Okatibbee Creek stream gage at Arundel, a Chickasawhay River tributary, is included because in 2000 water was released from Okatibbee Reservoir to augment the Pascagoula River's flows. The stream gage near McLain marks the Leaf River's northern limit. Numerous ungaged intermittent and perennial streams flow into the Leaf and Chickasawhay River before they converge to form the Pascagoula River just upstream of the Merrill stream gage. The Merrill stream gage is the nearest upstream gage from the Jackson County Port Authority's (JCPA) Cumbest Bluff intake structure and because of its long historic data record is heavily relied on to estimate Pascagoula River flows at Cumbest Bluff. The Pascagoula River also has numerous tributaries of its own, two of the larger being Big Cedar and Black Creeks. A portion of Black Creek which flows through the Desoto National Forest before flowing into the Pascagoula River is Mississippi's only designated Scenic Stream.

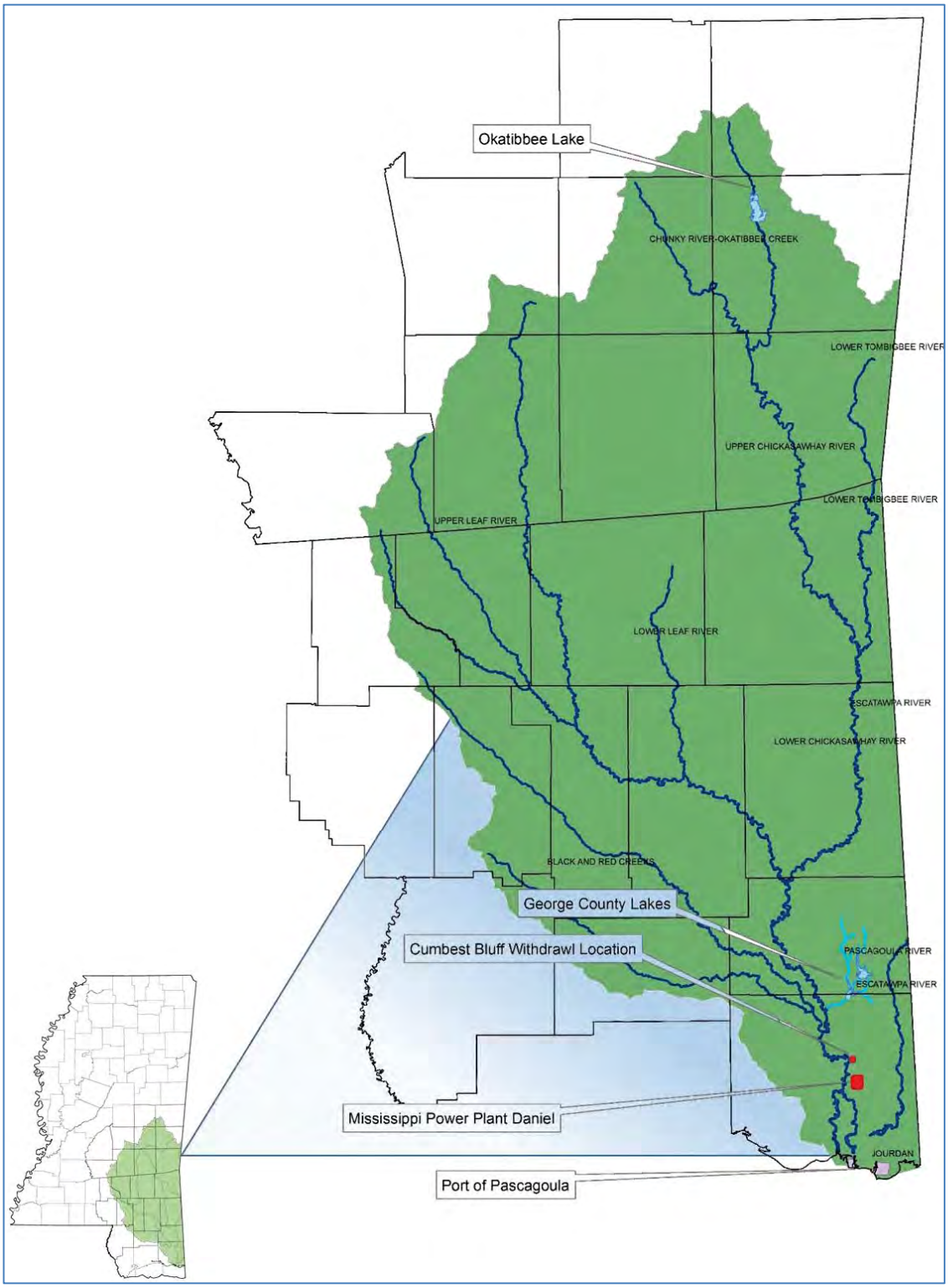

Figure 2.5 - Pascagoula Basin and Major Tributaries

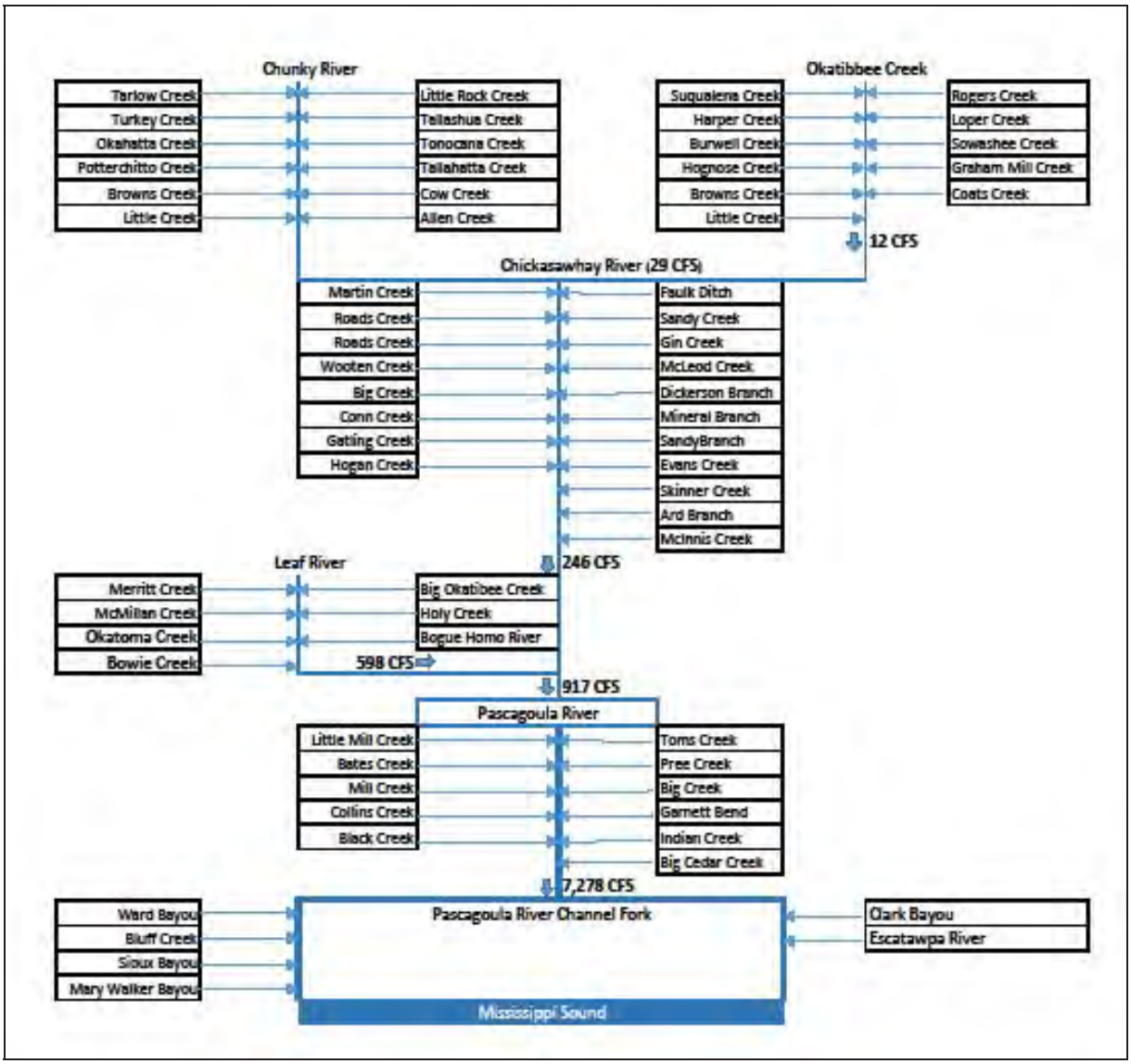

Figure 2.6 - Pascagoula River Surface Water Budget Schematic

USGS Gage	Waterway	Location	7Q10 (cfs)
2475000	Leaf River	McLain, MS	598
2476600	Okatibbee Creek	Arundel, MS	12
2477000	Chickasawhay River	Enterprise, MS	29
2478500	Chickasawhay River	Leakesville, MS	246
2479000	Pascagoula River	Merrill, MS	917

Table 2.3 - Pascagoula Basins USGS Stream Gages and 7Q10s

The 298 surface water withdrawal permits that the Mississippi Department of Environmental Quality (MDEQ) has issued in the Pascagoula River Basin are shown in Figure 2.7. This includes the Basin's four largest withdrawal permits by volume, which are summarized in Table 2.4. The Leaf River's two large permitted withdrawals are upstream of the McLain stream gage.

So the McLain gage accurately tracks the Leaf River's surface water contribution to the Pascagoula River. The Jackson County Port Authority (JCPA) has the remaining two large withdrawal permits. Both withdrawals occur downstream of Merrill stream gage and the project area. The JCPA's Pascagoula River withdrawal is at Cumbest Bluff at Pascagoula River mile 25.4. Although permitted to withdraw up to 99.9 MGD, JCPA normally withdraws less than 40 MGD. The Jackson County Utility Authority (JCUA) recently completed a 1 MGD surface water treatment plant which will also use water from the Cumbest Bluff pipeline to provide potable water for the Eastern Jackson County Regional Water System. JCPA also has a withdrawal permit for the Escatawpa River near its confluence with the Pascagoula River, downstream of Cumbest Bluff.

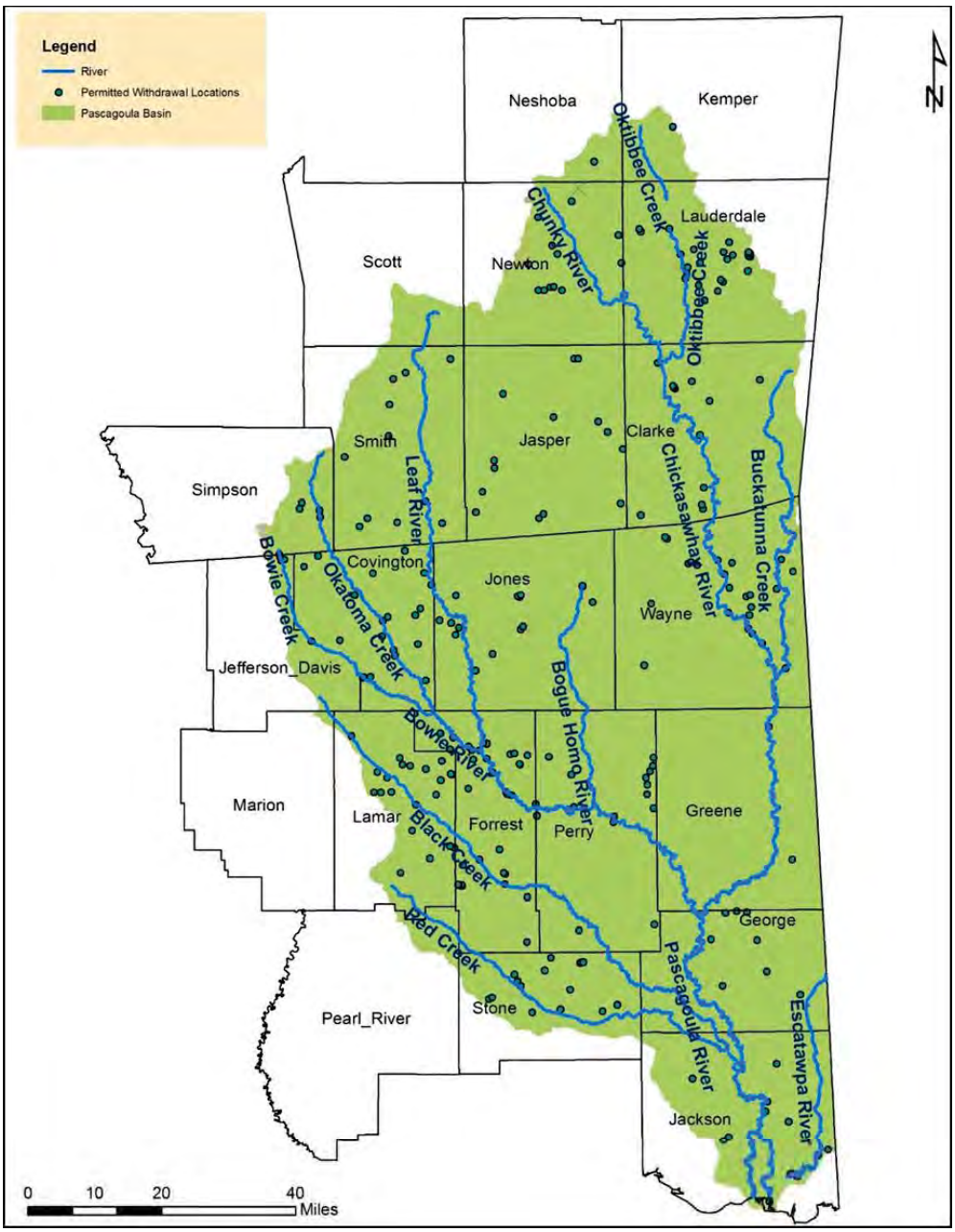

Figure 2.7 - Pascagoula Basin Permitted Surface Water Withdrawals

Permit Number	Water Source	Volume	Permit Holder
MS-SW-02034	Leaf River	115.2 MGD	MS Power Co.
MS-SW-00121	Pascagoula River	99.9 MGD	JCPA
MS-SW-01898	Leaf River	26.0 MGD	Leaf River Cellulose LLC
MS-SW-00330	Escatawpa River	22.8 MGD	JCPA

Table 2.4 – Pascagoula Basin Major Surface Water Withdrawal Permits (MDEQ 2012a)

The Basin's remaining 294 permits account for slightly over 40 MGD or approximately 6.8% of the Pascagoula River's 7Q10 flow at the Merrill stream gage. (MDEQ 2012d). Of note, a small but notable reduction in freshwater inflow into the Basin's headwaters recently developed as a result of the City of Meridian, Mississippi's decision to divert treated wastewater to Mississippi Power Co.'s Kemper County Power Generating Facility which is a closed loop, zero discharge system. Specifically the Meridian South and East Meridian Publicly Owned Treatment Works (POTW) will no longer discharge up to 13 MGD and 1 MGD respectively of treated wastewater into Sowashee Creek to be carried on to the Pascagoula River (Pickering Firm Inc. 2013; MDEQ 2012). The Kemper County Power Generating Facility will require approximately 6 MGD, which will reduce flows in Sowashee Creek by roughly 9.3 CFS. Even this relatively minor reduction is important since the downstream Arundel stream gage only has a 12 CFS 7Q10.

The Project area and its relationship to the Merrill stream gage, major downstream withdrawal points and the Gulf Coast is shown in Figure 2.8.

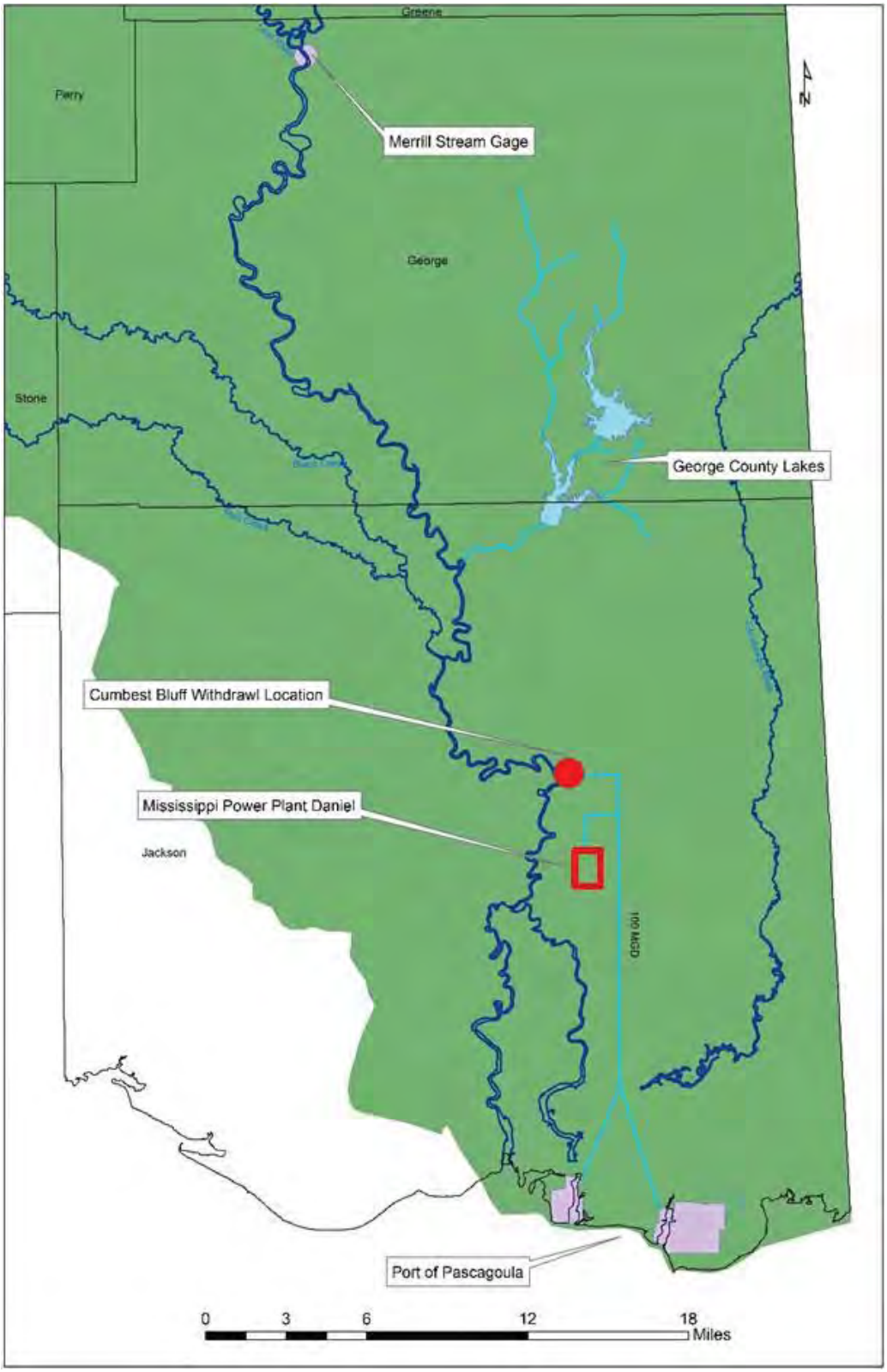

Figure 2.8 - Pascagoula River Surface Water Infrastructure

2.2.3. Baseflows

The Water Budget does not account for groundwater's contribution to flows. Schmitz et al. (2015) and EPA (2015) discuss the interaction of streams with groundwater and the water table. Subsurface water occurs in two main zones: the unsaturated zone and the saturated zone. In the unsaturated zone, spaces between soil, gravel, and other particles contain both air and water. In the saturated zone, water completely fills the spaces. Groundwater is any water that occurs and flows in the saturated zone. Rapid flow, or interflow of water, can occur through the unsaturated zone's large pore spaces (EPA 2015). Most streams either gain or lose water to or from localized water tables. A gaining stream receives water when groundwater levels in the water table (aquifer) are at a higher elevation than surface water contained in a stream (Figure 2.9-A). If these conditions change and stream level elevations are higher than those associated with the surrounding water table, then the stream loses flow to groundwater (Figure 2.9-B). Finally, there are also disconnected losing streams that are separated from the water table by an unsaturated zone (Figure 2.9-C). Regions with humid climates like the Pascagoula Basin tend to have primarily gaining streams; however, a stream or stream reach can change seasonally from gaining to losing. Because of the complexity of the hydrogeology in the Pascagoula basin, its streams may not be homogenous and may gain or lose water from different stream reaches (Schmitz et al. 2015, USEPA 2015).

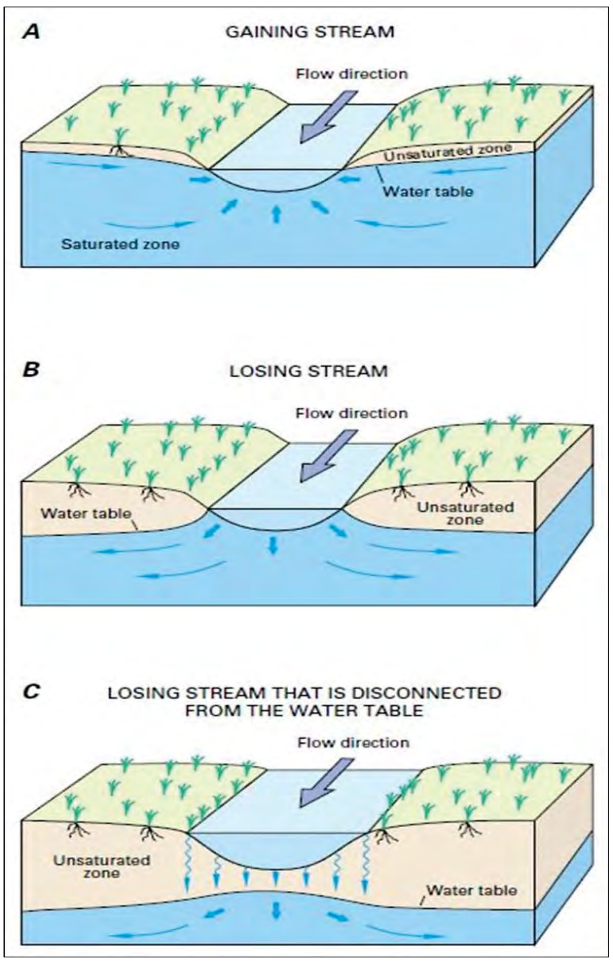

Figure 2.9 A, B and C - Types of Water Table/Surface Water Interactions

A detailed hydrologic analysis of surface and subsurface water interactions and their connectivity within the Pascagoula River system and the project area was conducted to address these questions using two different hydrologic analytical methods. First basin-scale hydrograph separation analysis with USGS stream gage data provided a longitudinal (upstream/downstream) perspective. Next a hydraulic conductivity assessment using grain size analysis from borehole cores in the project area was done for a latitudinal (stream reach and water table) perspective (Schmitz et al. 2015). The entire Geo-Hydrologic Analysis with appendixes is in Appendix I.

2.2.3.1 Basin-Scale Hydrograph Separation Analysis

Two different hydrograph separation programs were used for the basin-scale, longitudinal analysis: 1) the USGS program PART and 2) the Web-Based Hydrograph Analysis Tool (WHAT).

Data for both programs was derived from four USGS stream gages which were selected for the availability of data, completeness of data, and location longitudinally on the Pascagoula and Chickasawhay River stream reach (Table 2.5). However, gage 02479310 on the Pascagoula River at Graham Ferry, Mississippi was not installed until October 1, 1993 and provided continuous daily discharge data until the end of 2004 and again from 2007 to 2008 before being decommissioned on September 30, 2009. The Graham Ferry gage was included because it was the closest gage to the Gulf of Mexico with a considerable amount of daily stream discharge data (Schmitz et al. 2015).

Gage Number	Gage Name	Gage Location	Drainage Area	
			(mi^2)	(km^2)
02476600	Okatibbee Creek	Arundel, MS	342.0	885.0
02477000	Chickasawhay River	Enterprise, MS	918.0	2377.0
02479000	Pascagoula River	Merrill, MS	6590.0	17068.0
02479310	Pascagoula River	Graham Ferry, MS	8204.0	21248.0

Table 2.5 - Site Information for Hydrograph Baseflow Analysis

The PART program showed streamflow and baseflow volumes increasing from Okatibbee Lake downstream to the City of Pascagoula. This is supported because the basin's drainage area increases downstream, taking more and more of the basin into account. The PART results gave one of the lower baseflow estimations; however, it showed more drastic change in response to rainfall suggesting that the aquifer responds rapidly to water table changes (Table 2.6). A lower baseflow estimate provides a margin of safety for better water resources management.

USGS Station		02476600	02477000	02479000	02479310	
Drainage Area	(mi^2)	342.00	918.00	6590.00	8204.00	
	(km^2)	885.00	2377.00	17068.00	21248.00	
Time Period		1973 - 2013	1973 - 2013	1973 - 2013	1994 - 2004	2007 - 2008
Mean Stream Flow	(cfs)	516.16	1366.73	10469.82	12027.55	7055.64
	(cms)	14.62	38.70	296.47	340.58	199.79
	(in/yr)	20.50	20.22	21.58	19.91	11.68
	(m/yr)	0.52	0.51	0.55	0.51	5.07
Mean Baseflow	(cfs)	333.44	726.32	5845.12	7359.45	4239.90
	(cms)	9.44	20.57	165.60	208.40	120.06
	(in/yr)	13.24	10.75	12.05	12.19	7.02
	(m/yr)	0.34	0.27	0.31	0.31	0.18
Base Flow Index		0.65	0.53	0.56	0.61	0.60

Table 2.6 - PART Baseflow Recession Analysis Summary

In conclusion, four baseflow analyses were conducted with the two programs to generate a Base Flow Index (BFI) value for each of the four selected stream gages. The BFI is a ratio of baseflow to total stream flow. The BFI indicates that the stream reach may have a baseflow component of between roughly 50 and 70 percent, decreasing slightly downstream and then increasing again before entering the Gulf of Mexico. All four analyses showed a decrease at gage 02477000. The portion of the reach where groundwater baseflow decreases to near or below a 50 percent contribution would likely become a losing stream reach during extended drought conditions (Table 2.7). So any surface water entering the basin above that gage 02477000 would likely have a notable water loss before reaching the Pascagoula River. The analysis also showed seasonal baseflow variation with higher baseflows typically from December to July. Still, the results strongly suggest that during low flow periods at or approaching minimum flows, the Pascagoula River could lose water to bank storage (Schmitz et al. 2015).

USGS Station	02476600	02477000	02479000	02479310	
Time Period	1973 - 2013	1973 - 2013	1973 - 2013	1994 - 2004	2007 - 2008
PART	0.65	0.53	0.56	0.61	0.60
WHAT - One Parameter 0.925	0.69	0.61	0.67	0.70	
WHAT - One Parameter 0.98	0.52	0.47	0.64	0.66	
WHAT - Recursive Filter 0.98	0.65	0.60	0.51	0.66	

Table 2.7 – Base Flow Index Analysis

2.3.3.2 Project Area- Hydraulic Conductivity Assessment

The hydraulic conductivity assessment used a Geoprobe to gather site specific data on the Project area's water table and ground water including the near surface geology along Big and Little Cedar Creeks. Pickering Firm, Inc. (PFI) contracted with Walker-Hill Environmental of Foxworth, Mississippi, for the drilling. PFI also contacted Mississippi One Call and all impacted property owners prior to drilling.

Thirteen soil borings were taken in the project area from June 23 through June 26, 2014 (Figure 2.10). Borings GC-1 through GC-6 were installed around the upper lake footprint. The northernmost soil boring, GC-1, was west of Little Cedar Creek along Homestead Road to 26 feet below ground surface (BGS). GC-2 was also installed near the upper lake footprint's northernmost reaches, east of Little Cedar Creek along Marcus Pierce Road, to 56 feet BGS. GC-3 was drilled on the western abutment of the proposed upper dam along Clarence Bonnett Road, to 32 feet BGS. GC-4 was drilled inside the upper lake footprint, adjacent to Little Cedar Creek and just north of the proposed dam location to 32 feet BGS. GC-5 was drilled on the eastern abutment of the proposed upper lake dam along an unnamed dirt road off Stonecypher Road to 20 feet BGS. GC-6 was drilled east of the upper lake footprint's main body along Stonecypher Road to 24 feet BGS.

Borings GC-7 through GC-13 were drilled around the lower lake footprint. Piezometer wells were installed in five borings (GC-7 through 11), forming a west to east transect across both Big and Little Cedar Creek in the lower lake's upper reaches (Findings discussed in Section, 4.1). GC-7 was drilled west of Big Cedar Creek off Jodie Baxter Road 56 feet BGS. Soil Borings GC-12 and GC-13 were in Jackson County. GC-12 was on the western abutment of the proposed lower dam location off Sampson Road to 52 feet BGS. GC-13 was drilled on the proposed lower dam's eastern abutment along Emerson Road to 46 feet BGS.

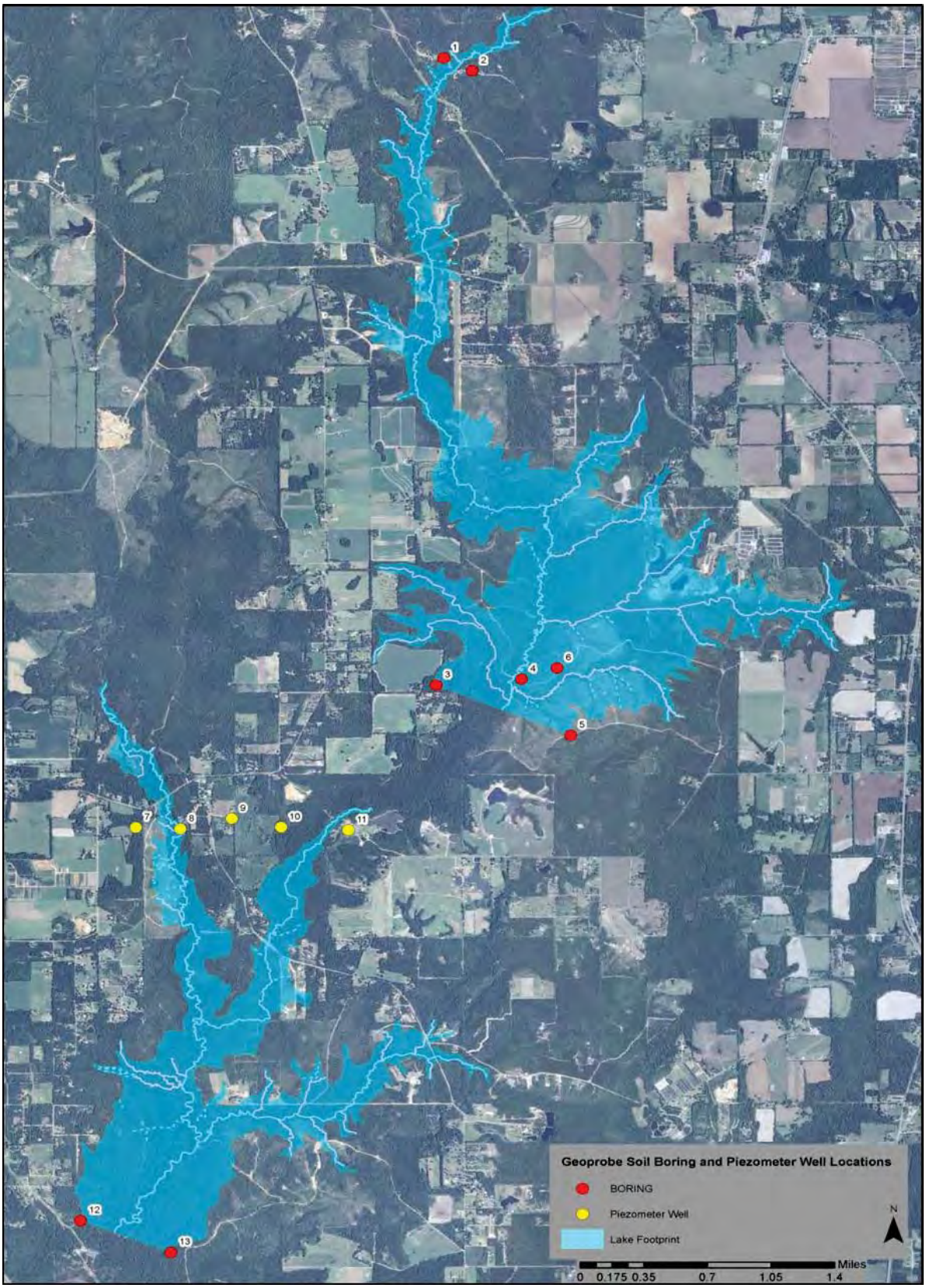

Figure 2.10– Locations of Geoprobe Borings and Piezometer Wells in Project Area

A grain size analysis was performed on cores from each of these thirteen boreholes to determine the hydraulic conductivity, porosity and permeability of the project area's soils. Sandy soil has a high hydraulic conductivity, is highly permeable, and transmits and holds more water than a less permeable clay soil with a lower hydraulic conductivity (Figure 2.11). Soil with a high hydraulic conductivity will increase the amount of water held in bank storage within the project area as the groundwater table reaches a new equilibrium in response to raising the surface water level.

Figure 2.11- Cores Showing Dense Clays Overserved in GC-1 (upper) and Laminated Sands in GC-9 (lower)

The grain size analysis revealed that sediment in the project area is composed primarily of sand, as well as some silt and clay. The sands were medium sized and well sorted with a conductivity coefficient value based on Fetter (2001) has a range of 80-120. The hydraulic conductivity of the sediments ranges from about 40 meters per day to as high as several hundreds or thousands of meters per day. Detailed information about the grain size analysis for each borehole including the cumulative grain size curves for each sample are included in Appendix I. The high hydraulic conductivity of sediments in the project area are very conducive to moving surface water to bank storage within the Pascagoula River watershed and downstream of decreased baseflow at gage 02477000 on the Chickasawhay River at Enterprise, Mississippi (Schmitz et al. 2015). The project area's water table and hydraulic conductivity are discussed further in relation to the Project's Environmental Impacts in Section 4.1.1.

2.2.4. Droughts and Pascagoula River Low Flows

Notwithstanding the inflows of surface and baseflow throughout the Pascagoula Basin, the Pascagoula River has suffered periodic droughts with flows below 917 CFS in 2000, 2007, 2010, and most recently in 2011. There were several unsuccessful efforts to construct water storage reservoirs in the Pascagoula basin during the 1960s and 1970s (Appendix A). However, to date there is only one water storage reservoir in the entire Pascagoula basin. In 1962 Congress authorized the U.S. Army Corps of Engineers (COE) to construct the Okatibbee Reservoir, in northwest Lauderdale County Mississippi, for flood protection on Chunky Creek and the Chickasawhay and Pascagoula Rivers (Public Law 87-874, Title II 87th Congress, 2nd Session, October 23, 1962). Okatibbee has a storage capacity of 67,650 acre-feet of water at the design flood elevation of 355 to 343 feet. The COE contracted with the PHWD in 1965 to provide up to 13,100 acre-feet of water for industrial and municipal water supply not to exceed 25 MGD per day when the reservoir was between the 343 and 328 foot elevation (USACE Contract # DA-01-076-CIVENG-65-362).

In response to the 2000 drought, the PHWD, Jackson County Port Authority (JCPA), Mississippi Department of Environmental Quality (MDEQ), and the COE recognized that maintaining the Pascagoula River's flows above 917 cfs at the Merrill gage would have significant environmental, ecological and economic benefits. Accordingly, in early October 2000 (approximately Julian Day 277) with the Merrill gage reading 707 CFS, at MDEQ's request, the COE and PHWD started supplemental water releases from Okatibbee to augment downstream flows. Flow augmentation continued periodically through November 7, 2000 (Julian Day 312) (Figure 2.12). Consistent with Section 2.2.3.1's Hydrographic Separation Analysis, Pote et al (2015) estimates that it took roughly eight days for supplemental water released from Okatibbee to reach the Merrill gage. It is also estimated that approximately 50 percent of the supplemental water released from Okatibbee is lost to evaporation or infiltration and not available to augment the Pascagoula River's surface water flow at the Merrill gage (PHWD 2001). Okatibbee Reservoir flow augmentation, potentially in conjunction with water releases from small to very small reservoirs in the basin is analyzed further in Section 9.3.

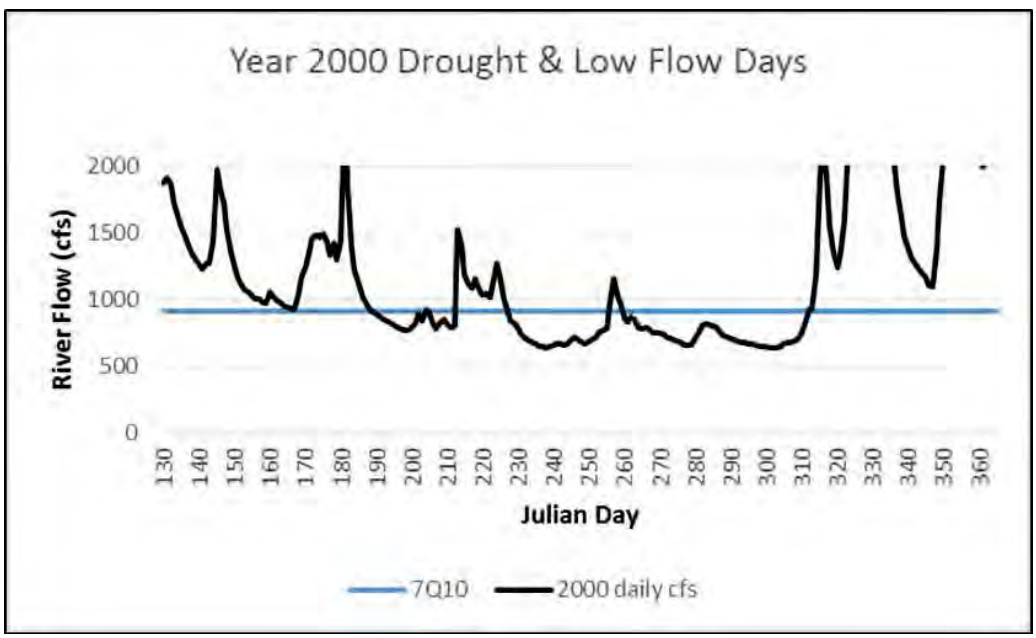

Figure 2.12 - 2000 Drought of Record Hydrograph

During the 2000 drought, minimum daily discharges computed for 19 of 21 gauges were less than the published 7Q10 discharges, and 16 of the Pascagoula Basin's 21 gauges had computed minimum daily discharges that were the lowest recorded. Notably, the five gauges in the basin that did not set new low flow records benefited from flow augmentation from Okatibbee Reservoir (Turnipseed and Baldwin 2001). In short, the benefits of flow augmentation from Okatibbee Reservoir were largely confined to higher up in the basin well above the Pascagoula River. Furthermore, supplemental water from Okatibbee was unable to raise and maintain the Pascagoula River's flows above 917 CFS at the Merrill gage during the drought.

Notwithstanding Okatibbee Reservoir's limitations as a supplemental water supply source, no alternative water supplies were or are available throughout the entire Pascagoula basin. So, in 2003, the PHWD and the JCPA formalized a Water Purchase Contract (PHWD and JCPA, 2003). When the Pascagoula River approached 917 cfs at the Merrill gage, the Contract allowed the JCPA to purchase up to 4,000,000,000 gallons of water from the PHWD to be released from the Okatibbee Reservoir to augment the Pascagoula River's flows during future droughts. This agreement was contingent upon Okatibbee having sufficient capacity to accommodate such releases. The original contract has expired and the PHWD and JCPA have been negotiating the issue.

Since 2000, the Pascagoula River fell below 917 CFS in mid-November 2007 (Figure 2.13). In 2010 the Pascagoula hovered close to and periodically fell below 917 CFS from mid-October till early December (Figure 2.14). Again, in 2011, the Pascagoula approached 917 CFS in mid-June and fell below 917 CFS for a brief time in early September (Figure 2.15).

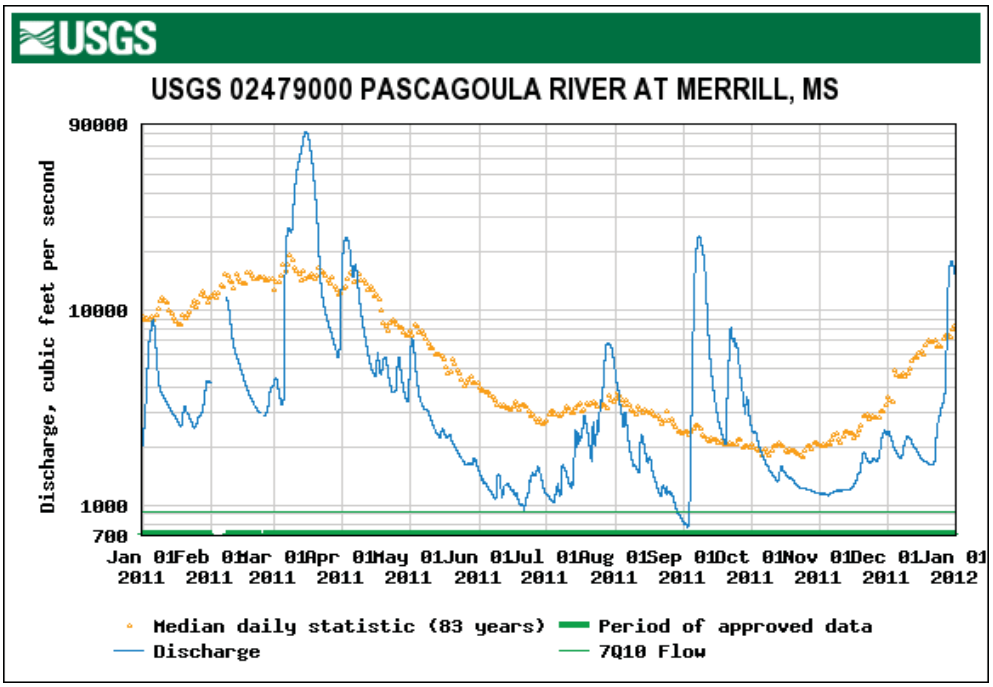

Figure 2.13 - 2007 Merrill Gage Hydrograph

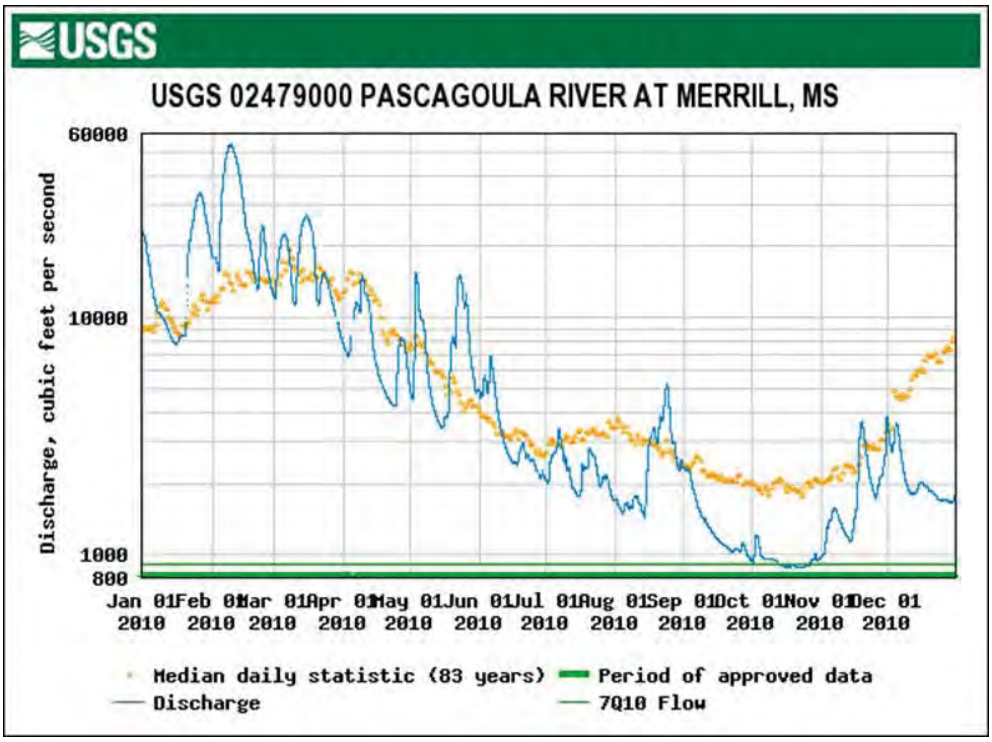

Figure 2.14 - 2010 Merrill Gage Hydrograph

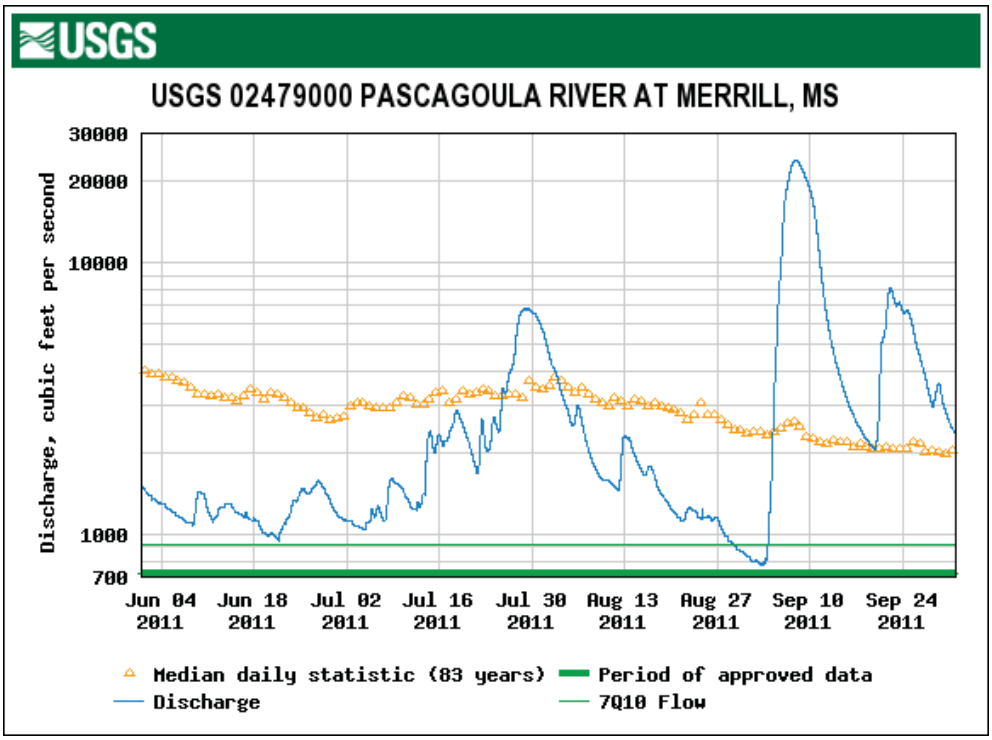

Figure 2.15 - June 4, - Sept. 24, 2011 Merrill Gage Hydrograph

Recalling the water budget in Section 2.2.2, there are no major surface water withdrawals upstream that could be reduced to increase flows. Alternatively, downstream industrial and municipal surface water withdrawal permits may be suspended or temporarily revoked because of these low flows, even though droughts and resultant low flows are basin-wide events. Additionally, downstream water conservation and efficiency measures would not provide any additional water for upstream, instream, environmental and ecological uses. Finally, the Pascagoula basin does not currently have any meaningful water storage capacity.

2.2.5. Projected Climate Variability Changes

The scientific community and peer reviewed literature has failed to reach a consensus on the severity of climate variability in general or quantify its impacts on Pascagoula River flows. However, this project's 2012 Water Conservation and Efficiency Report to EPA Region 4 (Appendix A) and the 2013 Pascagoula River Minimum Flow Supply-Lake Option Analysis by Mississippi State University (Appendix F) provide an overview and analysis of the relevant climate change/variability peer reviewed literature and governmental reports.

Subsequently, both the EPA and the COE have evaluated the relevant peer-reviewed climate change and hydrology literature for their respective regions that include the project area, EPA Region 4 and COE Region 3 (South Atlantic and Gulf Region) respectively (EPA 2013, COE 2015). Both reports found a strong consensus in published reports, temperatures would increase "sharply" over the next century over Mississippi's Gulf Coast and the project area. The COE also found that water supplies in this area may also be strained by increased summer temperatures and heat waves with increased evapotranspiration that lower surface water and groundwater supplies (COE 2015). EPA's draft report (2013) found it highly likely that climate change would lead to longer periods of low summer stream flows, decreases in average stream flows, higher flooding incidences and more frequent periods of extremely high and low flows (flashiness).

Additional analysis was required to quantify the impact of these projected changes on the Pascagoula River's flows to determine how much additional or stored water would be necessary, how often and for how long to offset these projected climate changes. The Pickering Firm, Inc. contracted with Mississippi State University (Dr. Jonathan Pote) and the Mississippi State Climatologist (Dr. Charles Wax) to conduct this analysis (Pote et al, 2014 and 2015; Appendices F and G). The site-specific analysis required accessing several major data sets on soils and hydrogeology, rainfall, evaporation, and river stage. Ideally the selected data would cover the same location for a fifty year historical period. Data was obtained from the following sources:

- Rainfall: The National Weather Service Cooperative climate record at Merrill, Mississippi, was the nearest climate record site. All data was checked for accuracy and completeness of record.
- Evaporation: The two nearest sites were Fairhope, Alabama and Starkville Mississippi. The sites' data were compared and were very close in value, with Fairhope having a slightly lower cumulative value because of its coastal location. Since evaporation changes rapidly from the coast to more inland environments and the Pascagoula basin increases dramatically in size as it moves inland, the Starkville data was used, making the simulation slightly more conservative (higher evaporation rates than what likely exist in reality).
- Soil and geo-hydrology: Dr. Darrel Schmitz, developed much of this information and performed all of the analyses necessary (Appendices H and I).

- River stage and flowrates: Two USGS stream gages were available with very complete records: 1) Merrill, and 2) Graham Ferry. The Merrill gage was selected as it was located at the beginning of the Pascagoula River and flows measured there are a benchmark for the Pascagoula River.

The alternative methods were evaluated to simulate projected climate change:

- Use the existing historic record, but delete the 25 years of highest rainfall, and repeat the 25 years of lowest rainfall. This was abandoned because it did not adequately reflect climate change. The worst year would be no worse.
- Use climate data from another Gulf Coast location, such as Texas, where rainfall would be lower and evaporation higher. This option was discarded because the model used is based on actual, measured historic data and does not mathematically link river flows and rainfall. Weather from an alternative location would have no relationship to the Pascagoula River's flow records.
- Tetra Tech (2010) performed an extensive study of anticipated climate change by the year 2050, including detailed expectation of the changes in evaporation and rainfall for locations across the United States.

Pote et al (2014, 2015) used the Tetra Tech study and applied the projected increase in evaporation and decrease in rainfall shown for South Mississippi directly to their historic data set. A daily water budget was developed for the Pascagoula River by reducing each day's measured precipitation by the corresponding measured daily evaporation and adjusting pan values to open water surface values using procedures described in Wax and Pote (1990). This simulated the water surface impact of weather and climate (Pote and Wax, 2014). A Pascagoula River climate change model through 2060 was developed by increasing measured daily evaporation values by 9.73% and reducing measured daily precipitation values by 1.57%. Finally, assuming that precipitation would directly affect the Pascagoula River's flows measured daily values from 1961-2009 were reduced by 1.57% and projected through 2060 (Pote et al. 2015). A graphic representation of the projected impact of climate change on the Pascagoula River's flows at the Merrill gage during the 2000 drought is shown in Figure 1.6.

2.3. Resource Descriptions

Having discussed the complex river, watershed and basin geo-hydrologic inter-relationships, it is appropriate to shift the geographic focus to the project area's individual resources. This section includes some supplemental information on the project area's water resources and geology but also provides an overview of many additional environmental, ecological, socio-economic and coastal resources.

2.3.1. Water Resources

Section 2.2, presented information on the interaction of various water resources, at various scales, and their influence on the Pascagoula River's flows. This section focuses on describing those resources within the project area, starting with surface water, then followed with surface water quality. Finally, the groundwater discussion presents information on the availability and use of aquifers in the area, but not in relation to the Pascagoula River's baseflow.

2.3.1.1. Surface Water

Portions of 20 counties in southeast Mississippi are drained by tributaries associated with the Pascagoula River, making it Mississippi's second largest river basin (Figure 2.5). The main stem of the Pascagoula is formed by the confluence of the Leaf and Chickasawhay Rivers at river mile (RM) 81, just north of the Merrill Bridge in northwest George County. According to the USGS, the Pascagoula River's mean annual flow at Merrill is ≈10,000 cfs over the period of record (1939 to 2014). The Leaf River is normally the slightly larger contributor of the two primary tributaries, averaging approximately 53 percent of the Pascagoula's total flow at the Merrill gage. During its meandering journey south through the swampy bottomland found in much of George and Jackson Counties, other notable tributaries, including Black Creek, Red Creek, and the Escatawpa River, gradually contribute to the increasing flow associated with the Pascagoula. The character of the River progressively changes in its lower reaches, where it forms several channels and various bayous, before eventually discharging into the Mississippi Sound.

Despite the size of its drainage basin, flow conditions on the Pascagoula River are somewhat unique compared to other streams in Mississippi's southern third. While all streams in the region can experience low-flows, the Pascagoula River and some of its tributaries appear to be more prone to low-flows. These often materialize rather quickly, even during relatively minor stretches of time without notable precipitation in the basin. As a result of this tendency and the fact that there are numerous surface water withdrawal permits in the Pascagoula Basin, MDEQ tracks stream flows in the Basin closely during periods of lower precipitation to determine if or when compliance-related actions are required to protect the ecology of affected streams.

2.3.1.2. Water Quality

Mississippi's surface waters are used for many purposes such as: a) Public Water Supply, b) Shellfish Harvesting, c) Primary or Secondary Recreation, d) Fish and Wildlife and e) Aquatic Life support. MDEQ has developed specific Water Quality Standards (WQS) to correspond with each of these uses. A water body can support multiple uses at a specific location, but the more restrictive WQS always applies. For waterbodies that fail to meet WQS, MDEQ may develop a Total Maximum Daily Load (TMDL). A TMDL is a water body pollution report showing the maximum amount of a pollutant that can enter a water body without it exceeding WQS. The TMDL quantifies the total amount of a pollutant from point sources and nonpoint sources and incorporates a safety factor to maintain the water body's integrity

Within the project area, MDEQ has classified Big Cedar and Little Cedar Creeks for fish and wildlife (MDEQ 2006). Based on a January 16, 2104 assessment, MDEQ found a biological impairment was preventing Little Cedar Creek from meeting its WQS from the headwaters to the mouth at Big Cedar Creek (MDEQ 2014 303b). Thus, MDEQ added Little Cedar Creek to Mississippi's Clean Water Act § 303(d) List for development of a TMDL to remedy this impairment (MDEQ 2014). However, on-site water quality monitoring for priority pollutants at both high flow and baseflow conditions found Big and Little Cedar Creeks in compliance with applicable WQS (Schmitz et al 2013 and 2015). On-site monitoring did find an aluminum concentration of 1.14 milligram/liter (mg/L) which exceeds the U.S. Food and Drug Administration's 0.2 mg/L limit for aluminum levels in bottled water (Schmitz at al. 2013, 2015 and Appendices H and I).

2.3.1.3. Groundwater

The Pascagoula River Basin's groundwater resources are highly variable, ranging from Eocene-aged aquifers in the northern counties to Miocene-aged and younger aquifers in the southern Basin. As is common throughout Mississippi, much of the water supply used throughout the Basin, including virtually all potable water, originates from groundwater. Large-capacity production wells used by public water systems, industries, etc. in the area typically pump from deep confined aquifers that have limited connection to shallower, unconfined aquifers and thus no influence on stream flows within the Basin. The domestic wells, still widely used throughout the Basin, normally pump from shallower aquifers, less than 200 feet deep. Since 2009, numerous irrigation wells have been drilled in George County, primarily for blueberry crops. The project area's groundwater resources were described in the 2012 Water Efficiency and Conservation Submission to EPA Region 4 (Appendix A).

"[Ground] water levels in Jackson County have generally been stable or slightly declining since the mid-1970s. There are ample [ground]water resources (with available drawdown) at present pumping rates in all aquifers for the foreseeable future" (MDEQ 2000 at page 10). The MDEQ record does not document areas of concern in George County with problematic groundwater level declines or notable cones of depression. Still, the complexity of South Mississippi's stratigraphy and accompanying hydrogeology cannot be over emphasized. Locating suitable water-bearing units in some areas of South Mississippi can be "hit or miss" due to the rapid facies changes associated with the subsurface geology. The USGS (1965) explains that one of the principal issues in the area was actually locating an aquifer in the immediate vicinity of the need. This hydrogeologic setting helps explain why after drilling numerous test wells, the Jackson County Utility Authority was unable to locate sufficient groundwater resources for the Eastern Jackson County Regional Water System and ultimately opted for a surface water solution. Likewise, the region's complex hydrogeology was instrumental in the decision years ago to use surface water from the Pascagoula River for Jackson County's industrial water supplies.

2.3.2. Biological Resources

The Pascagoula River is an important transition zone and migratory route for numerous avian, terrestrial and aquatic biological resources. The River, its floodplains, riparian zone and watershed provide habitat for nearly 150 fish and over 325 bird species. The diversity of plants and animals is primarily due to the high quality, diverse habitats found throughout, including coastal marshes and estuaries. The Pascagoula River also supplies a large portion of the fresh water entering the Mississippi Sound and estuary. This water replenishes nutrients and sediments that play a critical role in maintaining the productivity of the coastal waters and protective bays, which are important habitats for seagrass, oysters, finfish and shellfish (The Nature Conservancy 2005). The Basin has eleven federally threatened and six federally endangered species. The Pascagoula's rare and abundant wildlife populations provide great bird watching, hunting and fishing recreational activities as well as a tremendous seafood industry along the coast (Mississippi Department of Environmental Quality 2001). Droughts and low flows disrupt and impair the River's ability to serve these biological functions.

Pickering Firm, Inc. Natural Resource Scientists conducted an extensive onsite review of ecological communities which were classified using Mississippi's Comprehensive Wildlife Conservation Strategy (Mississippi Department of Wildlife, Fisheries and Parks 2005). Pickering personnel determined that the project area consists of four distinct ecological communities: 1) Pine Plantation, 2) Slash Pine Flatwoods, 3) Bottomland Hardwoods, and 4) Small Stream Swamp Forest. In addition, Pickering personnel conducted an onsite survey of

potentially suitable habitats and the presence/absence of any federally-listed threatened or endangered (T&E) species. Terrestrial species of most concern during the survey were the gopher tortoise (*Gopherus polyphe*mus), black pinesnake (*Pituophis melanoleucus spp. lodingi*), yellow-blotched map turtle (*Graptemys flavimaculata*), and Louisiana quillwort (*Isoetes louisianensis*). In addition, the Pascagoula watershed provides critical habitat for four threatened or endangered fish species: Gulf sturgeon (*Acipenser oxyrinchus desotoi*), peal darter (*Percina aurora*), saltmarsh topminnow (*Fundulus jenkinsi*), and Alabama shad (*Alosa alabamae*).

As of the survey dates, eighteen federally protected or candidate species are known to possibly occur within George County and/or Jackson County, Mississippi. Of those eighteen T&E species, only the gopher tortoise was observed within the review area. As such, the proposed project would have direct and indirect adverse effects on the gopher tortoise population. Conservation measures such as avoidance, translocation, and/or habitat management could reduce the adverse impacts and could benefit the gopher tortoise population. No other listed species was observed during our survey of the review area. Detailed biological resource information and maps of gopher tortoise observations are in Appendix C.

2.3.3. Geology, Soils and Slope

Geology, soils and slope are all components of *physiography* which is a contraction of ***physi**cal ge**ography***. In short, physiography is the study of the physical features of the earth's surface including the distribution of land, water, soil and rock material that forms the land surface, along with vegetation and land use. The entire state of Mississippi is located in the North America's Gulf Coastal physiographic province. The project area is located Mississippi's Piney Woods physiographic unit which consists of gently rolling to relatively flat lying terrain, covered predominately by pine forests. Sand, clay and gravel deposits are widely distributed throughout the area; however, resource extractive industries (e.g., mining, oil and gas) do not presently constitute a major portion of George or Jackson Counties' economies. No oil or gas wells or mining facilities are currently operating within the project area. The area's geology and soils are discussed in greater detail below.

2.3.3.1. Geology

The Pascagoula River Basin's surface geology, contains sedimentary deposits ranging in age from Eocene (about 55 million years ago (MYA)) to Quaternary (recent) deposits. Figure 2.16 shows that most of the stratigraphy is composed of sands, silts and clays, with a few limestone units in the Basin's central portion. Surface outcrops become younger southward toward the coast (USGS 1967). The project area's surface geology is primarily the middle Miocene (about ten MYA) Pascagoula Formation and recently deposited alluvial stream sediments. The Pascagoula Formation is only exposed at the surface within the project area, where erosion from Big and Little Cedar Creeks has cut down deep enough into the younger deposits to expose the much older Pascagoula formation. It consists of green and bluish-green clay, sandy clay, and sand; gray siltstone and sand; and some locally fossiliferous beds (Schmitz, et.al, 2013).

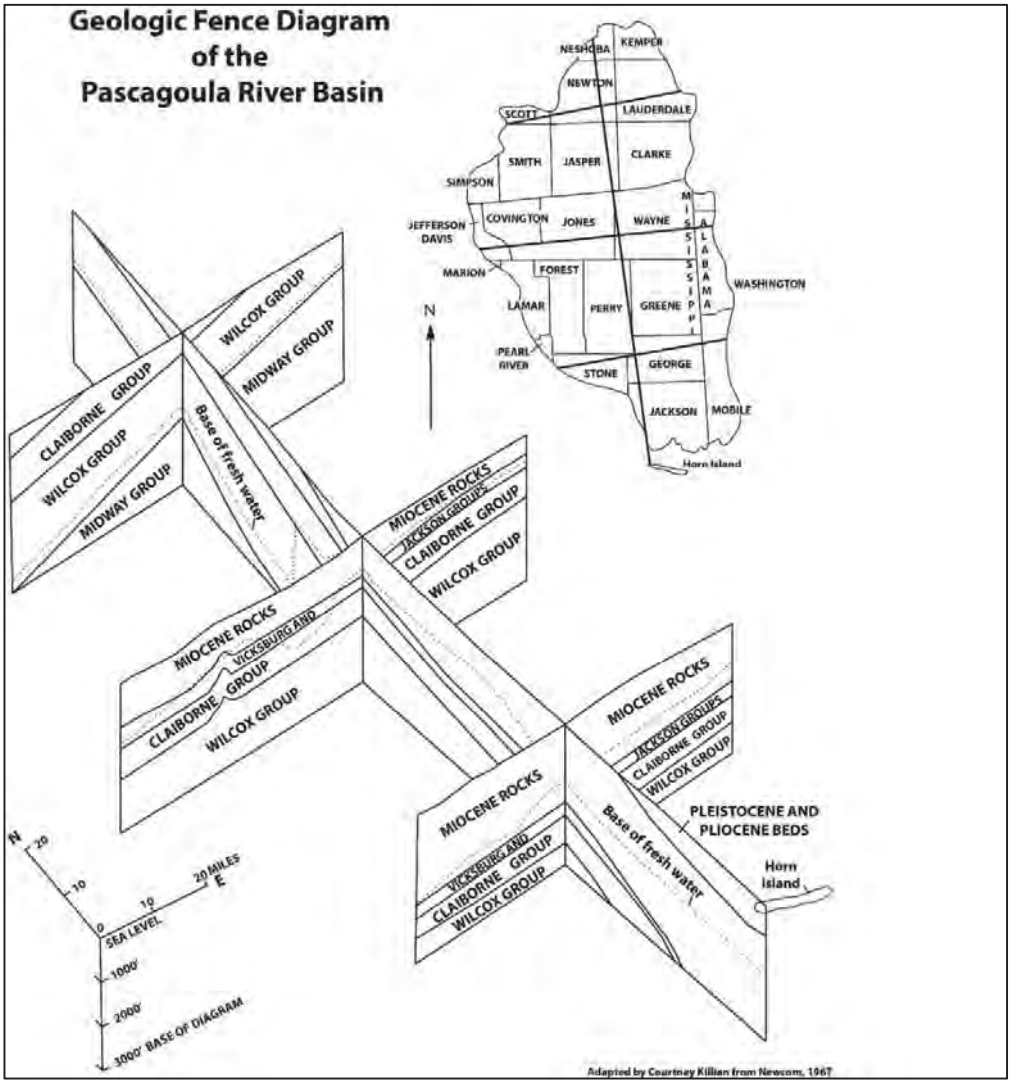

Figure 2.16 - Pascagoula Basin Geologic Fence Diagram

The project area, located approximately 40 miles inland from the present day Gulf of Mexico is underlain and surrounded by multiple structural geologic features. The earliest of these dates go back to the initial rifting of the Gulf of Mexico from the break-up of the supercontinent Pangaea during late Triassic times, approximately 200 MYA. The Gulf of Mexico Basin formed on a divergent margin that was exposed to tectonic rifting and wrench faulting along with phases of crustal extension, sea-floor spreading, and thermal subsidence (Schmitz, et.al. 2013). During Jurrassic times, 200 to 140 MYA, there was extensive east-west trending normal faulting immediately to the south of the project area originating from the Lower Mobile Bay fault system associated with the Gulf Coast Geosyncline (Mancini et al., 1992). To the north, widespread salt movement during the Jurassic age created a complex array of salt-related structures, such as diapirs, anticlines, and graben systems comprising the Mississippi Interior Salt Basin associated with the East Mississippi Syncline (Mancini and Tew, 1990). Minor evidence of these structural features is present in George County's subsurface.

The Wiggins Anticline is another major geological structure that plunges southwestwardly across George County in the project area. The Wiggins Anticline was formed during the Late

Cretaceous (80 MYA) to Late Tertiary (10 MYA) and produced thick sediment accumulation and subsidence north of the project area forming the East Mississippi Syncline, with a thinning sediment supply near George County. During later stages, a gradual shift of sediment deposition to the south caused the development of the Gulf Coast Geosyncline. The westward nosing of the Wiggins Anticline caused the Pascagoula River alluvial plain to be "bowed to the west in George County, closely following the plunge of the Wiggins Anticline" (Williams et al., 1967).

The reddish-colored sandstones, gravels, silts and clays present at the surface throughout most of the project area are Citronelle Formation deposits (USGS 1965) of Pleistocene age (about 2.5 MYA to 12,000 years ago). The Citronelle Formation consists of reddish-brown, deeply weathered fine to very coarse quartz sand and varicolored, typically mottled, lenticular beds of silt, clay and clayey gravel. There, abundant lenses of clay are located throughout the Citronelle in the project area. Limonite pebbles and lenses of limonite cemented sand occur locally in weathered exposures. Gravel, present mostly in the lower part of the Citronelle, is composed of chert and quartz pebbles (Williams et al. 1967). The Citronelle Formation lies in higher elevations of the project area above Big and Little Cedar Creeks, where it has not been eroded away by the streams (USGS 2014). The contact zone with the underlying Pascagoula Formations is an easily recognized regional unconformity marked by a thin, dark-brown to black, iron-cemented sand (Li and Meylan, 1994).

Recent alluvial sediments, including low terrace deposits and alluvium deposited along Big and Little Cedar Creeks and their tributaries are seen throughout the study area. The alluvial and terrace deposits are typically varicolored fine to coarse quartz sand containing silt, clay and gravel in places, with the gravel consisting of quartz and chert pebbles (Schmitz et al. 2013). The alluvial deposits along the project area's streams are usually seen in a classic fining upward sequence (Williams et al. 1967). These localized alluvial deposits are not laterally extensive over George and northern Jackson Counties, as are the older stratigraphic units. These deposits are composed of mostly fine sands, with some gravels and silts (Schmitz, et.al, 2013).

Figure 2.17 illustrates the distribution of exposed geologic formations in George County covering the majority of the project area. While no geologic maps have been published showing exposed geologic formations in north Jackson County, it is feasible to interpolate how the Pascagoula and Citronelle Formations, and Alluvium, extend along Big Cedar Creek in Jackson County.

As described above, the recent alluvium is seen filling the valley floors of stream channels, with most outcrops in the immediate project area consisting of the Miocene age Pascagoula formation that extends along the stream channels where the streams have cut through the overlying Pleistocene age Citronelle formation located on nearby terraces and upland areas. As both formations contain alternating beds of sand, clay and gravel often difficult to distinguish, the upper part of the Pascagoula formation and the lower part of the Citronelle formation likely contain sediments of Pliocene age (about 2.5 to 5 MYA). The exposed strata generally strike west-northwest to south-southeast and dip to the south-southwest toward the Gulf of Mexico. This structure strongly influences local gradient in Big and Little Cedar Creeks and affects the type and distribution of aquatic habitats.

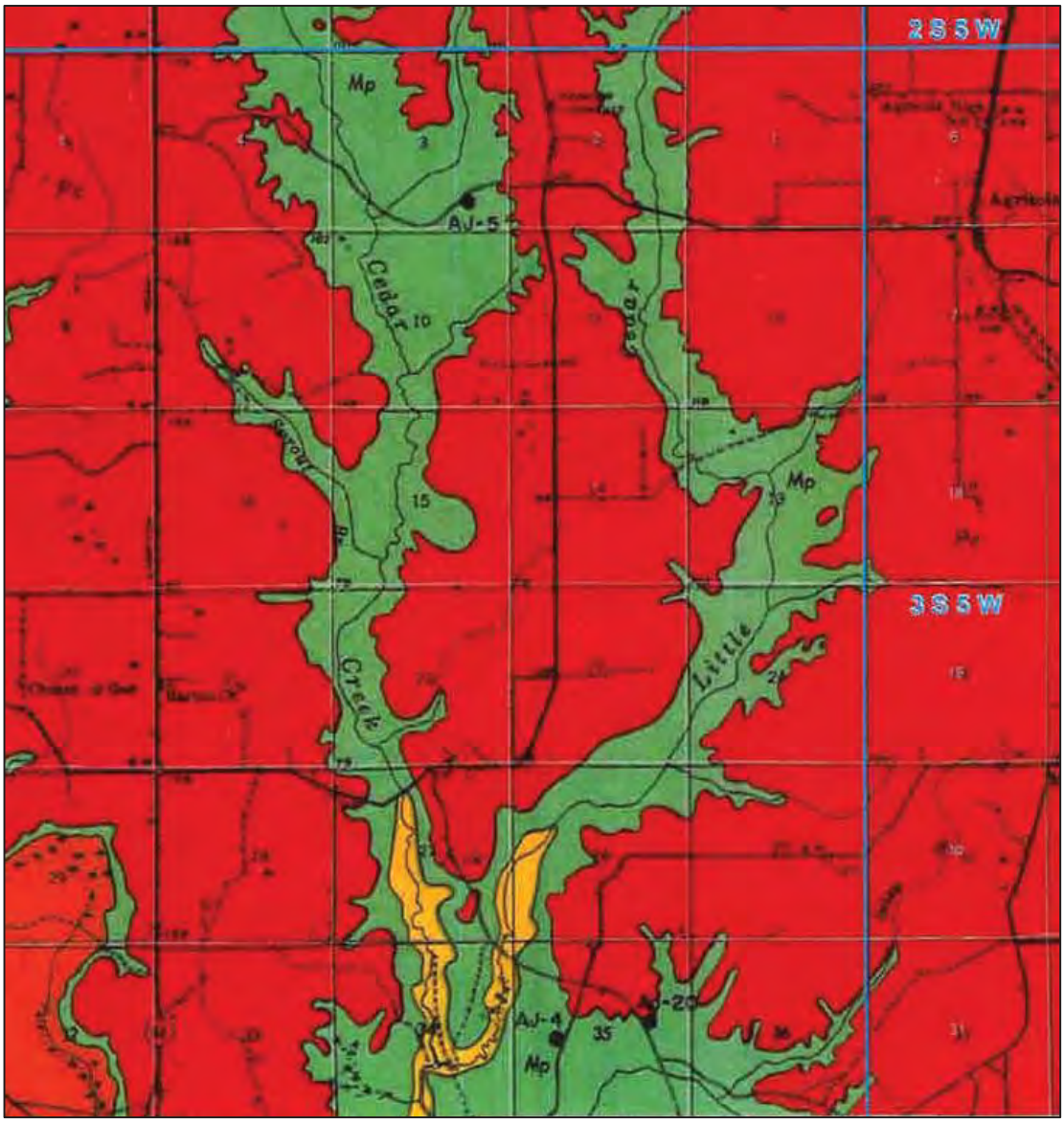

Figure 2.17 - Project Area Geologic Map
(Green=Miocene Pascagoula Fm; Red=Pleistocene Citronelle Fm; Yellow=Recent Alluvium
(Williams et al. 1967)

2.3.3.2. Soils

The U.S. Department of Agriculture has defined and mapped soil associations in the project area. These associations are a distinctly proportional pattern that normally consists of one or more major soils and at least one minor soil. The soils are grouped together to create a picture an area's general soils for large scale planning or for projects larger than approximately 100 acres. The Dorovan-Johnston association is prominent in floodplains throughout the project area's small streams where there is minimal slope and the water table is at or near the surface

most of the year. The association is divided mainly between two strongly acidic and poorly drained soils Dorovan (~60%) and Johnston (~18%). (USDA 1971).

Outside the flood plain, the majority of the project area in George County has two predominate soil associations:

1. McLaurin-Benndale-Lucedale association which is comprised of well-drained, nearly level to strongly sloping soils found on extensive ridges and major stream divides which encompass approximately 32% of George County. This association is chiefly divided among McLaurin soils (~30%), Bennedale soils (~25%), and Lucedale soils (~12%), with the remaining consisting primarily of excessively drained Eustis and Alaga soils. The association's soils are formed in loamy parent materials and characteristically have surface layers consisting of dark grayish-brown to dark reddish-brown sandy loam.
2. McLaurin-Susquehanna-Alaga association which is comprised of somewhat poorly drained to somewhat excessively drained, nearly level to moderately steep soils found on uplands dissected by short drainage ways which covers approximately 30% of George County. This association is chiefly divided among McLaurin soils (~20%), Susquehanna soils (~20%), and Alaga soils (~20%), with the remaining consisting of well-drained Bennedale soils and excessively drained Eustis and Lakeland Soils. The association's soils are formed in sandy, loamy, and clayey parent material and characteristically have surface layers consisting of very dark grayish-brown to dark-gray to dark grayish-brown sandy loam (USDA 1971).

As Big Cedar Creek nears the Pascagoula River in north Jackson County, two new soil associations emerge:

1. Rains-Lynchburg-Plummer-Goldsboro association, which is comprised of level or nearly level, poorly drained loamy soils found on broad uplands broken by scattered drains, swales and depressions. This association is chiefly divided among Rains soils (~40%), Lynchburg soils (~20%), Plummer soils (~15%), and Goldsboro soils (~15%), with the remainder of the soils consisting of somewhat poorly drained Scranton and Pheba soils and poorly drained Grady soils. These soils were formed in loamy parent material under a coniferous forest and were affected by a high water table.
2. Ruston-Orangeburg-Norfolk association which is comprised of rolling sandy and loamy soils found on broad, nearly level to rolling uplands. This association is chiefly divided among Ruston soils (~50%), Orangeburg soils (~25%), and Norfolk soils (~20%), with the remaining soils comprised of moderately well drained Goldsboro and Klej soils and well drained to excessively drained Eustis and Lakeland soils. These soils were formed in moderately coarse textured marine sediments under a coniferous forest (USDA 1964).

2.3.4. Wetlands

Pickering Firm, Inc. Natural Resource Scientists did a wetland delineation within the project area to identify and quantify potential wetland and stream impacts. Geographical Information System (GIS) data was used to aid in locating and mapping the extent of wetland areas using elevation contours, aerial imagery, mapped soils and stream data. The wetland study included a review of the USDA's Natural Resources Conservation Service's Custom Soil Resources Report of George and Jackson Counties, Mississippi, the U.S. Geological Survey, Gulfport North, MS, 1996, topographic map; the Federal Emergency Management Agency (FEMA), U.S. Fish and Wildlife National Wetland Inventory (NWI) Maps; and aerial photography. Field investigations lasted from March 2014 through December 2014.

The jurisdictional delineation of “waters of the U.S.” revealed 1,120.51 acres of potential jurisdictional wetlands, 221,565.03 combined linear feet of ephemeral, intermittent, and perennial stream channels, and 22.58 acres of open water. These potentially jurisdictional features were observed primarily within the Small Stream Swamp Forests (SSSF) and Bottomland Hardwood (BLH) habitats on the lake footprints. A small area of Slash Pine Flatwoods (SPF) was observed within the lower lake footprint only.

The SSSF or Bay Forests are typically found at the bottom of slopes, exhibiting long hydroperiods, underlain with a deep mucky organic or mucky sand layer, and contain a network of interwoven stream channels. The overstory of the SSSF areas is dominated by sweetbay, red maple, and swamp tupelo. In wetter areas of the site, Atlantic White-Cedar and pond cypress were observed as the dominant overstory species. Densely packed thickets of evergreen shrubs and trees were present, such as the swamp titi, large gallberry, bayberry, blueberry, and Florida anise. The herbaceous layer is limited due to the heavy shading of the tree and shrubs layers. Cinnamon fern, netted chain fern, and panic grass are the dominant species found in the herbaceous layer.

The BLH are typically found in the floodplain of large order streams. BLH areas within the project area were observed bordering the Big Cedar Creek and interspersed with the SSSF. These BLH areas were observed with a taller and more mature overstory than the SSSF. The dominant overstory consisted of cypress, red maple, and swamp tupelo. These areas were observed with a less dense understory, primarily consisting of young hardwood saplings and switchcane.

The SPF are typically found in poorly drained sites, along lower slopes and broad flats, and near the headwaters and low terraces of large order streams. A small portion of land classified as SPF was observed near the George/Jackson County line and contained open areas exposed to sunlight dominated by pitcher-plant, foxtail clubmoss, tenangle pipewort, and spike-rushes.

It should be noted that potential wetland/non-wetland mosaics were encountered within portions of the lower lake footprint. These mosaics are located in Big Cedar Creek’s large floodplain. The area was observed with numerous swales and depressions with slight changes in elevation over short distances. The delineation procedure for these mosaic features involves establishing and measuring transects or point-intercept sampling at fixed intervals along transects across the area (U.S. Army Corps of Engineers 2010). These procedures can be extremely time-consuming. Given the magnitude of the study area and the time frame to complete the work, Pickering utilized the abundance of available data such as soils maps, NWI maps, GIS tools, and topographic maps in conjunction with focused on-site investigations to delineate these features. The Wetlands Report is included in Appendix C.

2.3.5. Cultural Resources

Brockington and Associates, Inc. (Brockington) developed and implemented a Phase I archaeological research design and sampling protocol for the project area. The project’s objective was to gauge the potential for cultural resources within the study area and develop an approach to identify and document these resources in accordance with Section 106 of the National Historic Preservation Act (NHPA). Ultimately these resources will be evaluated for their eligibility for inclusion on the National Register of Historic Places (NRHP). In addition, the regulations and guidelines of the COE-Mobile District and the Mississippi Department of Archives and History (MDAH) guided this undertaking.

Brockington's study entailed literature and background review, and agency consultation to develop a research design for the cultural resources investigation of the project site. Research included archaeological and architectural site files at the MDAH library, historic maps, government land office records, local histories and consultations with federal and state agencies. This review identified no previously documented resources within the project area and few in the surrounding area, due to a lack of previous archaeological surveys conducted in the region. However, based the few surveys conducted in the area and agency consultations, prehistoric and historic settlements identified in the vicinity were in settings similar to some areas within the study area. Brockington and Associate's report is included in Appendix D.

2.3.6. Socioeconomic Information

South George and north Jackson Counties are primarily undeveloped with wooded land surrounding Big and Little Cedar Creeks. The project area and immediate vicinity is lightly populated with a few small residential developments and a mix of detached, single family housing and mobile homes. Socioeconomic data is organized below by population and population growth, population age groups, racial composition, and finally by occupations.

Table 2.8 shows that from 2010 to 2014, both George and Jackson Counties' populations grew faster than Mississippi's as a whole. George County's population grew by approximately 3.2% and Jackson County by approximately 1.1% as compared to Mississippi's roughly 0.9% growth over that same time period. The counties' population, like Mississippi's, is split almost evenly between males and females (U.S. Census Bureau 2015 and 2015a).

	2010	2013 Estimate	2014 Estimate	Change 2010-2014
Mississippi	2,968,103	2,992,206	2,994,079	0.9%
George County	22,578	23,154	23,303	3.2%
Jackson County	139,668	140,274	141,137	1.1%

Table 2.8 - Population Estimates and Change

Table 2.9 shows that the population age groups in George and Jackson County generally track with Mississippi's as a whole (U.S. Census Bureau 2015 and 2015a). However the Southern Mississippi Planning and Development District (SMPDD), an organization serving fifteen south Mississippi Counties (including George and Jackson County), found that regionally, the largest increase in the age distribution between 2000 and 2010 was from 50 to 64 years of age, with the 65 and over age group the second largest. Thus SMPDD found that, "with an increasing number of South Mississippi's population nearing or entering retirement, strategies must be implemented to deal with the resulting loss in the District's work force." (SMPDD 2013 at pg 7).

Age	George County	Jackson County	Mississippi
<5	7.2%	6.2%	6.6%
<18	26.3%	24.5%	24.7%
65 and older	13.9%	13.8%	13.9%

Table 2.9 - Population Age Groups 2013

The racial composition in South Mississippi and George and Jackson Counties' diverges considerably from Mississippi's as a whole (U.S. Census Bureau 2015 and 2015a; Table 2.10). Regionally, the SMPDD (2013) found that the Hispanic/Latino population doubled from 2000 to

2010, and the trend is expected to continue. Similarly, George County experienced measurable growth in the Hispanic/Latino populations since 2000. Still, George and Jackson Counties have a significantly lower percentage of minority residents than Mississippi.

Race	George County	Jackson County	Mississippi
White	90%	73.4%	59.8%
Black/African American	8.5%	22.0%	37.4%
Hispanic/Latino	2.3%	5.2%	2.9%
Other	1.5%	4.6%	2.8%

Table 2.10 Population Racial Breakdown 2013

Economically, George and Jackson Counties are comparable with Mississippi in most aspects (Table 2.11). Both counties have a higher median household income than Mississippi and a lower percentage of people below poverty level. Also, George County's 84.2% homeownership percentage is higher than Jackson County (70.8%) and Mississippi (69.4%) (U.S. Census Bureau 2015 and 2015a).

	Home Ownership	Per Capita Income	Median household Income	Persons below Poverty Level
Mississippi	69.4%	$20,618	$39,031	22.7%
George County	84.2%	$20,217	$43,958	18.6%
Jackson County	70.8%	$23,879	$48,943	15.9%

Table 2.11 - 2009-2013 Economic Data

Economic conditions are closely tied to available employment sectors. The Manufacturing and Educational Services, Health Care and Social Assistance sectors are the top two employers in George and Jackson Counties. Table 2.12 shows the other major employment sectors (U.S. Census Bureau, 2015b).

Employment Sector	George County	Jackson County
Manufacturing	22.0%	19.1%
Educational Services, Health Care, Social Assistance	20.1%	19.5%
Construction	11.8%	6.3%
Retail Trade	8.4%	11.7%
Professional, Scientific, and Management, and Administrative and Waste Management Services	7.1%	5.7%
Agriculture, Forestry, Fishing, Hunting, Mining	6.4%	1.5%
Transportation, Warehousing, Utilities	6.8%	3.9%
Arts, Entertainment, Recreation, Accommodation, Food Services	4.2%	15.6%
Other services, except public administration	4.9%	4.3%

Table 2.12 - Employment Sectors in George and Jackson Counties

2.3.7. Hazardous and Toxic Materials

The Pickering Firm, Inc. (PFI) followed the procedures for a Phase I Environmental Site Assessment (ESA) in general conformance with ASTM Standard E 2247-08 for the project area.

The ESA included a review of relevant documents, interviews with key local officials and regulatory officials, and a visual inspection of the project area and vicinity. The ESA included a regulatory database search report of all federal, state and local records of registered sites in the project area and vicinity conducted by Environmental Data Resources, Inc. (EDR). Chief Matt Amick of the Lucedale Fire Department and Ms. Loraine Howell, George County Fire Coordinator were interviewed and neither was aware of any environmental concerns located within or in the vicinity of the project area.

The EDR report showed no regulated facilities or hazardous waste sites located within the project area, but did identify one facility, the Marjorie Baxter Pit located at 1119 Jodie Baxter Road, approximately 0.3 miles to the west of the proposed Lower Lake footprint. This facility, owned by Dunn and Bush Construction, produces (excavates) sand and gravel for roadway and construction contractors. The facility obtained a General Permit (#MSR320681) from MDEQ for surface mining on October 17, 1997. Neither the EDR Report nor MDEQ website reported any violations for this facility. The EDR report is in Appendix E. This facility was seen in operation on several site visits to the project area (Figure 2.18). Another apparently unpermitted surface mining operation was observed near Willie Finch Road just south of Buddy Finch Road, a portion of which might be within the Upper Lake footprint.

Figure 2.18 - Majorie Baxter Pit on Jodie Baxter Rd.

During on-site inspections, PFI personnel found several empty 55-gallon drums which were unmarked and rusted and partially buried along a drainage ditch within the Lower Lake footprint, just east of Slaten Road. These discarded drums appeared to be very old, no current access road was nearby so it is presumed that they were dumped from a historical logging road (Figure 2.19). Assorted construction debris, including asphaltic roofing shingles was also observed in this area. More debris, drums and/or other potentially hazardous materials may be buried in this area.

Figure 2.19 - 55-Gallon Drums and Construction Debris East of Slaten Rd. in Project Area

Discarded residential debris such as cans, bottles, appliances and other miscellaneous objects were observed at several other locations in and around the Lower Lake footprint. The largest of these, which also contained an old rusted automobile, was observed in a small ravine on the west side of Beasley Road, just south of Barton-Agricola Road (Figure 2.20). Other than what is identified above, the ESA revealed no other evidence of recognized hazardous or toxic conditions in or adjacent to the project area.

Figure 2.20 - Abandoned Automobile and Residential Debris along Beasley Rd. near Lower Lake Footprint

2.3.8. Flood Plains

Federal Emergency Management Administration (FEMA) Flood Insurance Rate Maps were reviewed to determine the impact each build alternative would have on the Big and Little Cedar and Creek floodplains. The maps reviewed were FIRM map numbers 28059C0100G, 28039C0350D and 28039C0225E, dated March 16, 2009, October 16, 2008 and September 19, 2012 respectively. These maps indicate a large floodplain and floodway associated with each Creek.

2.3.9. Prime and Unique Agricultural Lands

In November 18, 2014, Pickering Firm, Inc. provided the Natural Resources Conservation Service (NRCS) office in Lucedale, Mississippi with a project summary and preliminary footprint and requested a Farmland Conversion Impact Rating. On June 23, 2015, NRCS provided the completed form. Using the Land Evaluation and Site Assessment system, NRCS calculated 135 points for the Upper and Lower lakes with the entire project receiving 270 points. NRCS's Farmland Conversion Impact Rating is in Appendix K.

2.3.10. Noise

The Project is located in a sparsely populated rural area with very limited manufacturing or currently operating mining facilities. The only noise sources in the vicinity of the project are seasonally operated farming machinery, trucks and automobiles. The main noise source appears to be traffic on State Highway 63 in Jackson County, located approximately half a mile southwest of the proposed Lower Lake dam.

2.3.11. Visual Aesthetics

Visual resources are natural and manmade features that give the environment its aesthetic qualities. The project area does not currently have sweeping, panoramic view sheds because of its relatively flat topography and large patches of dense woods. Still visual aesthetics are important to determine if a Project is compatible with the existing visual setting or if it would dramatically alter the visual appeal in the project area.

2.3.12. Air Quality

MDEQ classifies George and Jackson Counties as attainment areas for all air pollutants of concern. Monitoring has shown levels of airborne pollutants to be less than the National primary and secondary criteria and state of Mississippi air quality standards for ozone, carbon monoxide, sulfur dioxide, nitrogen oxides, lead and particulates. MDEQ does not anticipate excess ozone levels to be present in the area in the foreseeable future.

2.3.13. Environmental Justice

On February 11, 1994, the President issued Executive Order 12898, Federal Actions to Address Environmental Justice in minority and low-income populations. The Order focuses federal attention on the relationship between the environment and human health conditions of minority and low-income individuals and communities and calls on federal or state agencies receiving federal funds to make environmental justice part of their mission. Environmental Justice can occur when projects intentionally or unintentionally have disproportionate high adverse impacts on minority or low-income individuals or populations.

The project area is primarily within Census Tract 9501.01 Block Group 1, with smaller portions within Tract 9503.01 Block Group 1, and Tract 401.01 Block Group 2. Information on the total population, minority population, and poverty status for these block groups are located in Table 2.13 (U.S. Census Bureau, 2008-2012 American Community Survey).

Census Block Group	Total Population	Minority Population	Percent Minority	Families Living Below Poverty Level	Percent of Families Below Poverty Level
9501.01 BG 3	2,053	46	2.2	160	25.8%
9503.01 BG 1	1,772	251	14.2	96	23.1%
401.01 BG 2	2856	153	5.4	14	2.0%

Table 2.13 -Total Population, Minority Population and Population Living Below Poverty Level

No significant impacts to minority and/or low-income individuals or populations were identified with the Project or adjacent areas. Some residential displacements will occur that may involve minority and/or low-income residents; however these displacements do not disproportionately impact those populations. Based on this information, the project would not result in disproportionately high and adverse human health and environmental effects on minority or low-income individuals or populations. In addition, the George and Jackson County Boards of Supervisors have personally visited with most, if not all, resident adjacent landowners to discuss the Project. The George County Board of Supervisors held a well-publicized Public Event on April 17, 2015 to ensure that all impacted individuals and communities received the same information about the Project (including maps) at the same time. The co-applicants are all strongly committed to public involvement and an open and transparent decision-making process.

2.3.14. Coastal Zone Management

Mississippi's Coastal Zone includes the three coastal counties (Jackson, Harrison and Hancock) and all adjacent coastal waters and barrier islands. Water from the entire Pascagoula River basin flows into the Pascagoula River and supplies a large portion of the fresh water entering the Mississippi Sound. In so doing, it replenishes nutrients and sediments that play a critical role in maintaining the productivity of the coastal waters. The sediment it carries maintains an extensive salt marsh habitat that helps control the discharge of nutrients into coastal waters. Marshes are effective filters, removing sediment and pollutants from the water, and are also some of the world's most productive habitats. Because the marshes are important for sustaining the coastal ecosystem, changes in marsh area, plant species, and bio-geological habitats adversely affect the water bodies that they help buffer.

Directly related to this Project's Purpose and Need, the Mississippi Governor's Oyster Restoration and Resiliency Council reported that alterations to the natural hydrography, the lack of freshwater retention, and saltwater intrusion contribute to lower production and survival in Mississippi's historic oyster reefs. The report recommended developing a Regional Oyster Restoration, Enhancement and Expansion for Sustainability (REEFS) Plan with a systems approach on sustainability to include detailed hydrologic modeling to document natural hydrography and provide alternative solutions to freshwater retention to stop, slow or off-set saltwater intrusion. The oyster reefs off the mouth of the Pascagoula River are one of four areas for early implementation of REEFS (Mississippi Department of Marine Resources 2015).

3. RECOMMENDED PROJECT DESCRIBED

The Recommended Project to ensure the Pascagoula River's drought resiliency through 2060 is to construct two public reservoirs on Big and Little Cedar Creeks in south George and north Jackson Counties in Mississippi (Appendix B). This Environmental Assessment, incorporating by reference the Appended reports, documents the extensive research and analysis undertaken to finalize the Project's size and location. The two proposed lakes are: 1) an Upper Lake on Little Cedar Creek; and 2) a Lower Lake on Big Cedar Creek with the damn in Jackson County downstream of its confluence with Little Cedar Creek.

The Upper Lake would be entirely in George County. At the proposed maximum pool level of 130 feet above mean sea level (MSL), the Upper Lake would cover approximately 1,715 acres and store roughly 31,410 acre/feet (AF) of water. The Lower Lake's dam would be in north Jackson County. At the proposed , the Lower Lake is proposed at 60 feet above MSL maximum pool elevation, the Lower Lake would cover approximately 1,153 acres, with about 667 acres (or 58%) in south George County and about 484 acres (or 42%) in north Jackson County. The Lower Lake would provide roughly 20,228 AF of water storage capacity. The 70 feet MSL elevation difference between the Lower and Upper Lakes shows the Project area's dramatic topography for South Mississippi.

Initially, a maximum pool elevation of 65 feet MSL was proposed for the Lower Lake which would have resulted in an approximately 1,750 acre footprint and provided an estimated 21,228 AF of water storage capacity. However, model refinements in late 2014, showed that at 130 and 65 feet above MSL, respectively, the Upper and Lower Lakes provided slightly more water storage capacity than necessary to meet the Project's Purpose and Need for projected drought resiliency. The lower, 60 feet MSL maximum pool elevation meets the Project's Purpose and Need but eliminated approximately 1,000 AF of water storage capacity and reduced the Lower Lake footprint by approximately 523 acres. This modification minimized the Recommended Project's wetland and stream impacts.

Preliminary dam estimates are based on topographical maps with 10-foot contours. Final dam design will require site surveys to determine exact elevations. For instance, there are areas on the Upper Lake's northwest dam abutment that show between 130 and 140 feet Above Mean Sea Level (AMSL). The Lower Lake's proposed dam is entirely in Jackson County and proposed to extend from a ridge located at 70 feet above MSL, just east of Hillside Road (latitude 30° 43' 29", longitude 88° 34' 59") in a southeasterly direction and cross Big Cedar Creek to a ridge just west of Payne Road (latitude 30° 43' 20", longitude 88° 34' 25"). The Upper dam will extend in a southeasterly direction from a ridge located at 135 feet MSL, just east of Clarence Bonnett Road (latitude 30° 46' 15", longitude 88° 32' 47") and cross Little Cedar Creek to a ridge located at 135 feet MSL along an unnamed dirt road (latitude 30° 46' 05", longitude 88° 32' 15"), north of Stonecypher Road.

Final design will require an accurate ground level elevation AMSL as some areas could require a buildup to 140 feet AMSL. Further, the final permitted maximum pool elevations for both lakes will impact final dam design and elevation decisions. With these caveats, both dams are planned to be an earth-filled embankment with an impermeable core (USDA 2005; USACE 2004) (Figure 3.1). The primary spillways are proposed as uncontrolled concrete structures approximately 20 feet in width, constructed with surface elevations at the top of the conservation pools for both lakes. Emergency spillways are proposed to be designed and constructed for both dams to allow passage of the probable maximum (500-year) flood without overtopping the embankment. Releases are proposed to be controlled by a structure capable of selective,

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multilevel withdrawal and an outlet discharging into a stilling basin at the base of the primary spillways. Minimum downstream flows will be maintained on both Big and Little Cedar Creeks during construction.

Depending on final approved dam and spillway designs, both dams are anticipated to be 50 feet wide at their crests. The Lower Dam is projected to be 2,821.5 feet long with a height of 40 feet. The Upper Dam is projects to be 4,232.3 feet long with a height of 60 feet. It is anticipated that the Lower Lake's dam/spillway footprint will be roughly 2,821.5 feet x 250 feet (16.19 acres). Estimates for the Upper Lake's dam/spillway footprint are 4,232.3 feet x 351 feet (34.12 acres). Depending on final approved designs the two dams/spillways will require a total of 1 to 3 million cubic yards of suitable fill.

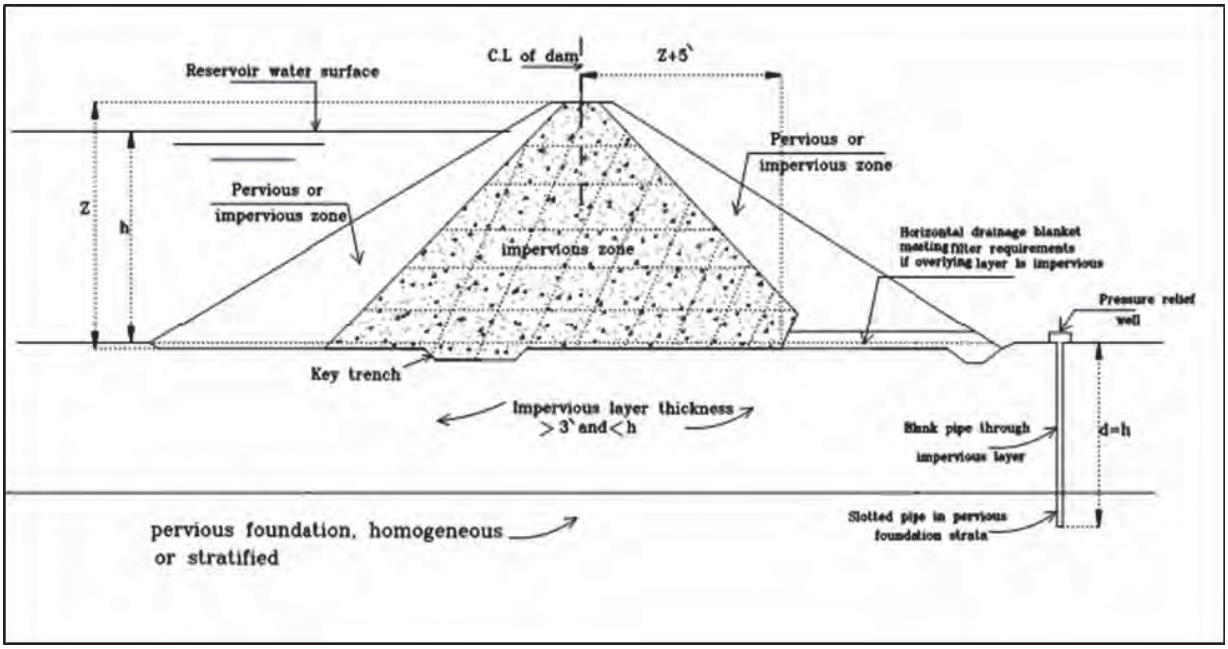

Figure 3.1 - Conceptual Earth Fill Embankment Dam
(http://osp.mans.edu.eg/tahany/DAMS1.htm).

The George and Jackson County Boards of Supervisors agree that the Pat Harrison Waterway District (PHWD) will operate and manage the Recommended Project as a single system to augment the Pascagoula River's flows when necessary and to provide public recreational opportunities. Accordingly, the Project will also include one, or possibly two, public recreational water park(s) adjoining the Upper and/or Lower Lakes. The water parks will be patterned after the PHWD's eight other water parks and include cabins, R.V. Camping sites, water slides, boat launches, shelters, lodge halls, nature trails, etc. (Figure 3.2). A transparent public process and economic impact and feasibility study will be used to determine the size, number, and mix of amenities that the water park(s) will include.

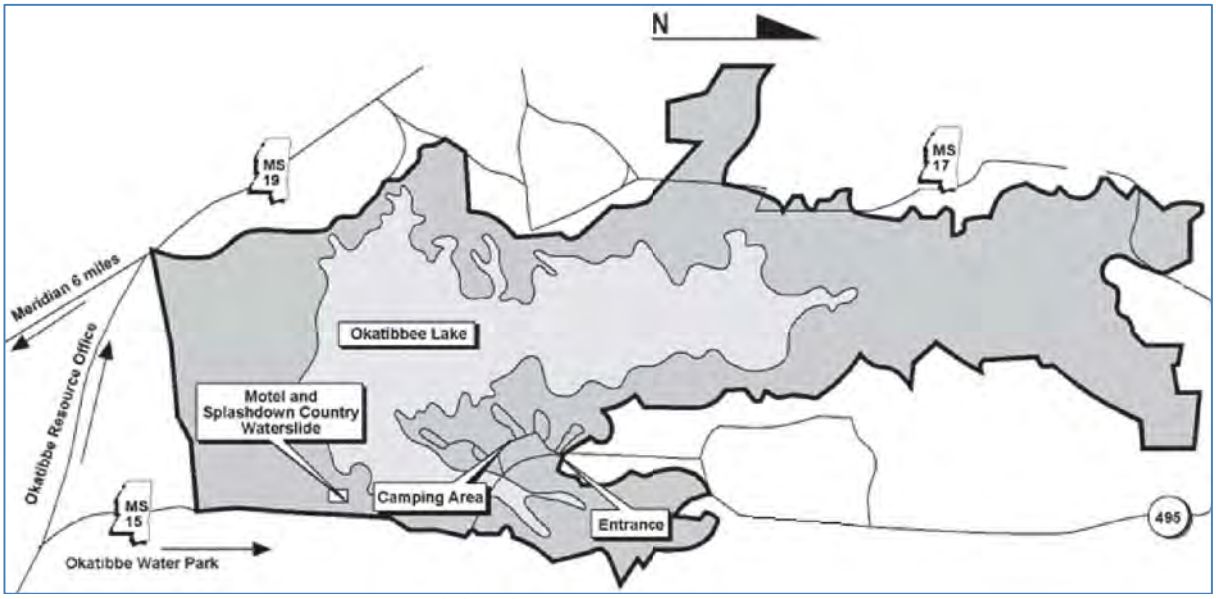

Figure 3.2 - PHWD Water Park at COE Okatibbee Lake

The Recommended Project's final operational procedures remain to be negotiated with MDEQ and the COE but are anticipated to be similar to those in effect at other lakes managed by the PHWD. The Recommended Project's location and size was designed to provide the Pascagoula River with drought resiliency based on river flows measured at the Merrill Stream gage. Furthermore, as shown in Sections 2.2 and 4.1, these two lakes will recharge the water table, which should appreciably increase the Pascagoula River's baseflow to and drought resilience without any supplemental surface water being released from the Project. However, the Recommended Project's two lakes would have sufficient water storage capacity to provide quick and sustained water releases to prevent low flows on the Pascagoula River during prolonged, severe droughts. In addition, water releases from the Upper to the Lower Lakes, and ultimately the Pascagoula River, would be coordinated to minimize the water loss due to evaporation from either lake and to minimize adverse recreational impacts to the maximum extent possible. This would be done while ensuring that sufficient water was released into the Pascagoula River whenever necessary, and for as long as necessary, to avoid drought impacts.

Based on data analysis and from stakeholder discussions in the Pascagoula River watershed, several alternative operational scenarios were proposed that may be compatible with the primary drought resiliency purpose and need. One scenario proposed maintaining a natural, historic hydrograph. A second scenario proposed scheduling periodic artificial high water events to benefit downstream and coastal environments and ecosystems without increasing flood risks. Finally, as discussed in detail in Sections 1.2, 2.3.2 and 4.1, some other seasonal hydrograph might improve the critical habitat to support the recovery of threatened and endangered fish species while also enhancing important commercial and recreational marine fisheries. In short, the Recommended Project's final operational parameters are still under discussion with stakeholders and relevant federal and state resource agencies.

4. RECOMMENDED PROJECT'S ENVIRONMENTAL IMPACTS

In considering the Recommended Project's environmental impacts described below, it is critical to consider the projected environmental and ecological impacts of future droughts and low flows without a proactive Pascagoula River drought resiliency project. Likewise, unpredictable low flows on the Pascagoula River can undermine current economic activities and eliminate potential activities from being able to locate in the Pascagoula basin. The projected ominous ecological and environmental impacts of no action on drought resilience are discussed in Section 9.1. In addition, the Pascagoula River's geo-hydrology, basin-scale low flows, and droughts were also assessed within the National Environmental Policy Act (NEPA) context in conjunction with a U.S. Department of Energy (DOE) Environmental Impact Statement (EIS) for *Site Selection for the Expansion of the Strategic Petroleum Reserve* (USDOE 2006).

In 1988, Congress directed the DOE to explore expanding the national stockpile of crude oil, the Strategic Petroleum Reserve (SPR). A site in the Pascagoula basin on the Leaf River, near Richton, Mississippi, was one of five candidate sites for that expansion and was evaluated in DOE's Environmental Impact Statement (EIS). Based on the EIS, on February 22, 2007 the DOE issued a Record of Decision (ROD) selecting the Richton Site for the SPR expansion (Federal Register, Vol. 72, No. 35, pp 7964-7972). The proposed Richton SPR expansion would require raw water to solution mine the necessary underground crude storage. Initially, DOE proposed a primary raw water intake on the Leaf River at New Augusta, Mississippi with a secondary intake in the Gulf of Mexico. After selecting the Richton site, based on further consultations regarding surface water availability and low flows on the Leaf River, DOE evaluated the Pascagoula River near Merrill as an alternative primary supply of up to 78 CFS per day of freshwater. Consequently, on March 5, 2008, the DOE announced its intention to prepare a Supplemental EIS (SEIS) for the proposed Richton SPR Expansion (Federal Register, Vol. 73, No. 44 pp 11895-11897). The proposed the proposed SEIS study largely corresponded with this proposed project's study area (Figure 4.1). Additionally, the two proposed projects are concerned with many of the same resources within that area:

- Water Resources including the quantity and quality of local and regional marine, freshwater and groundwater systems. Minimum stream flows and low flows on the Pascagoula River was an important element of this evaluation;
- Ecological Resources including terrestrial and aquatic plants and animals, state and Federally listed threatened and endangered species and other protected resources (e.g., wetlands and essential fish habitat);
- Geological Resources; local geology and soils;
- Socioeconomics including the potential influx of workers and the increase in demand for local services; and,
- Environmental Justice including the potential for disproportionately high and adverse effects on populations protected under Executive Order 12898.

The DOE held a town meeting on the SEIS in Pascagoula, Mississippi on April 10, 2008. Many individual stakeholders and interest groups made oral and written comments on the record emphasizing different aspects of the Pascagoula River's regional environmental, ecological and economic importance. Many of those comments recalled the 2000 drought and stressed the importance of avoiding future threats to the river's minimum stream flows to protect its various benefits (DOE 2008). The DOE cancelled the Richton SPR SEIS on September 9, 2011 (Federal Register, Vol. 76, No. 175 p 55890). Notwithstanding the SEIS's cancellation, some individual studies extremely relevant to this proposed project were completed and publically available.

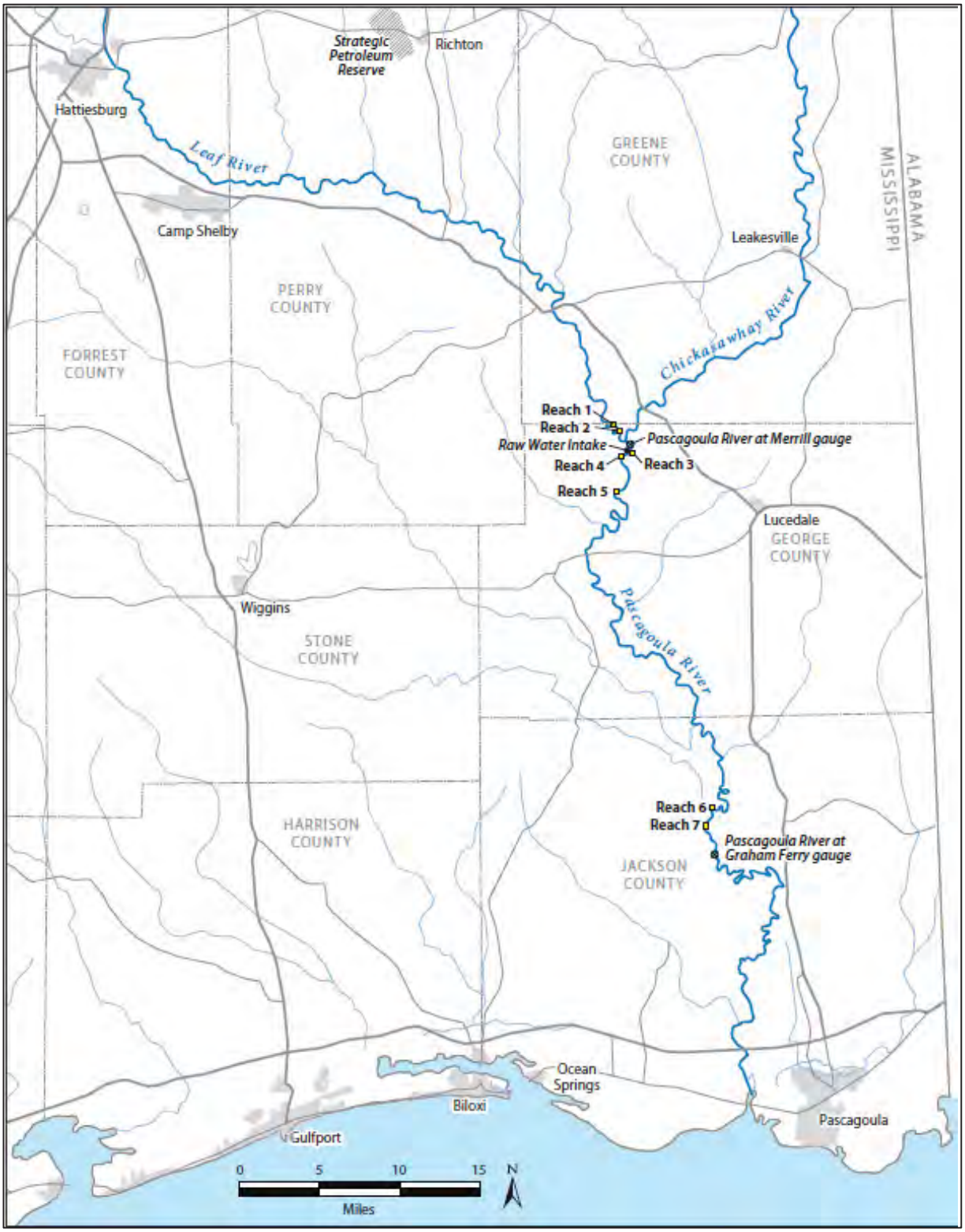

Figure 4.1 - Richton SEIS-Instream Flow Study Area (ICF Jones & Stokes, Inc. 2009 Figure 1-1)

The DOE's efforts on the Richton SEIS highlights the difficulty in quantifying the environmental, ecological and economic impacts of droughts and low flows on the Pascagoula River under both the current setting and in light of proposed changes. Still, regardless of the permitting complexities, reservoirs are unavoidably one viable response to drought resiliency. As required by the Joint Clean Water Act Application and Notification form, this Environmental Assessment presents a preliminary report on the Recommended Project's environmental impacts. The impacts are presented in the same order used to describe the Project Area's current environmental setting in Section 2. The Recommended Project's impact on the Pascagoula River's baseflows and hydrograph is presented first, followed by positive and negative impacts to individual resource impacts, if any. The DOE's EIS and partially completed SEIS evaluating the Richton, Mississippi expansion of the SPR provides substantial, timely data and analysis to quickly and efficiently facilitate a transition to an EIS if deemed necessary and appropriate for this Recommended Project.

4.1. Pascagoula River Drought Resiliency

Sustained, predictable flows on the Pascagoula River will have positive impacts on environmental, ecological and economic resources throughout the Pascagoula watershed and in the Mississippi Sound off the river's mouth. To summarize from the 2012 EPA Region 4 Water Conservation and Efficiency Report (Appendix A), initially three watersheds in George County, Mississippi were evaluated for potential reservoir sites: 1) Big Creek, 2) the Escatawpa River, and 3) Big Cedar and subsequently Big and Little Cedar Creek. Based on an initial assessment of topography, geology and geo-hydrology the Big and Little Cedar Creek watershed was identified at the preferred location for a drought resiliency reservoir. The Big and Little Cedar Creek watershed offered the most flexibility to define and evaluate alternative theoretical lake footprints to meet the Project's Purpose and Need (Schmitz et al. 2013, Appendix H).

This flexibility was used to develop the Recommended Project's two lake footprint to provide a two-pronged drought resiliency approach. First, each lake will provide extensive subsurface water storage to restore and maintain the Pascagoula River's baseflow. Secondly, at full pool, the two lakes will provide roughly 51,638 AF of water storage which would be available for immediate and prolonged release during prolonged, severe droughts. In short, the two lakes in the Big and Little Cedar Creek watershed will restore baseflows in the upper Pascagoula watershed to maintain downstream flows during droughts. The two lakes are necessary to restore baseflow and provide sufficient surface water storage capacity to increase flows during extreme, prolonged droughts when baseflow alone is insufficient to maintain flows. Note, the benefits of restored baseflows were not quantified or factored into the lake storage model. This Environmental Assessment did not analyze the complex interaction between the two lakes' size and storage capacity and the quantity of subsurface water provided to restore baseflows to determine the optimum balance between surface and subsurface water storage for drought resiliency.

4.1.1. Restored Baseflows

The Geoprobe analysis in Section 2.2.3 and the geology discussion in Section 2.3.3.1, reported that the shallow sediments within the Project Area were laid down as fluvial (river and stream) deposits, with alternating units of sand, silt and clay deposited by meandering streams. This resulted in individual sediment lenses stacked one on top of the other throughout geologic time. Sandy soil has a high hydraulic conductivity, is highly permeable, and transmits and holds more

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water than a less permeable clay soil with a lower hydraulic conductivity. Soil with a high hydraulic conductivity will increase the amount of water held in bank storage as the groundwater table reaches a new equilibrium in response to raising the surface water level. So the amount of water held in bank storage influences the amount of time needed to fill the reservoir.

Geoprobe samples were limited by the depth drilled due to geologic obstacles such as dense clays or heaving sands, and budget considerations on the number of borings installed. The grain size analyses of the sands from the borings indicated that the proposed reservoir locations contain abundant unconsolidated sediments. While some cores contain abundant sands, some abundant clays, and others a mix of sands, silts and clays, the horizontal extent of these units may be relatively small and localized. Overall, the hydraulic conductivity findings from the grain size analysis showed that the permeability of the sands within the sand layers are relatively high, as is generally the case with sand deposits. The relatively high permeability of the sands suggests that, as the water level rises, a considerable amount of water will move into the subsurface as bank storage and contribute to the water table or groundwater system until the new surface-water level created by the proposed reservoirs reaches equilibrium (Figure 4.2).

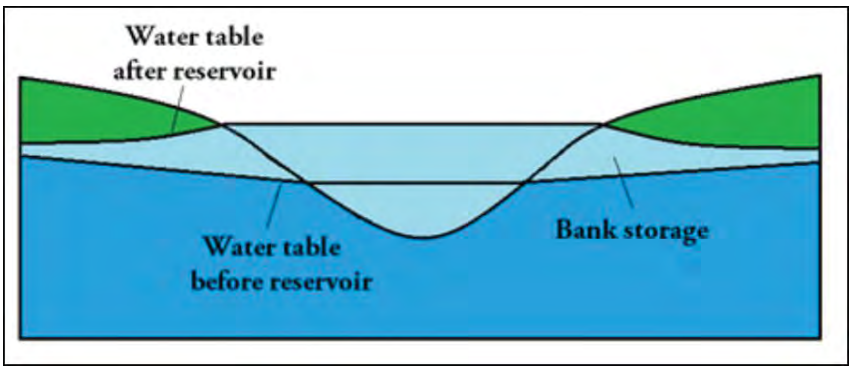

Figure 4.2 Lake Contributions to Bank Storage and Baseflow

The hydraulic conductivities derived from the grain size analyses show that the permeability of the sandy portion of the Project Area's sediment is relatively high. The sediments' hydraulic conductivity ranges from about 40 meters per day to as high as several hundreds or thousands of meters per day. The sediment's measured high hydraulic conductivity will initially allow water to move to bank storage as the Recommended Project's two lakes fill. This movement of water into bank storage will stop once the sediments become saturated. Furthermore, a considerable amount of water would remain in bank storage as water is released from the lakes to supplement the Pascagoula River's low flows (Schmitz et al. 2015, Appendix I). It is important to note that this is not an indefinite, non-beneficial water loss which could prevent the lakes from filling; instead the lakes will restore the Pascagoula River's historic surface-water, groundwater, and baseflow equilibrium. Additional boreholes, analysis and modeling will be needed to confirm how quickly the lateral and vertical extent of these highly hydraulic conductive sediments under the Project Area and project how quickly the lakes will fill.

4.1.2. Immediate Low Flow Response

Pote et al. (2015) have a long-established approach to integrate weather and climate data related to river flows. For the Recommended Project Area there was excellent weather and river stage data for a full fifty-year period from 1961 to 2009. This data was used to establish an integrated historic correlation of precipitation, evaporation and stream flow for the Pascagoula River at Merrill, Mississippi. Figure 4.3 shows the Pascagoula River's actual flows as measured

at the USGS Merrill gage. Merrill also had rainfall data with less than 0.5 percent missing data points (Figure 4.4). Pan evaporation records are less common than flow or rainfall. Two locations near the Recommended Project Area have serially complete evaporation records, Starkville, Mississippi and Fairhope, Alabama. The Gulf of Mexico can exert a disproportionate coastal influence on the records at Fairhope, Alabama. So the Starkville, Mississippi data was selected to better represent the entire Pascagoula basin and eliminate the immediate coastal influence (Figure 4.5) (Pote at al 2015; Appendix F).

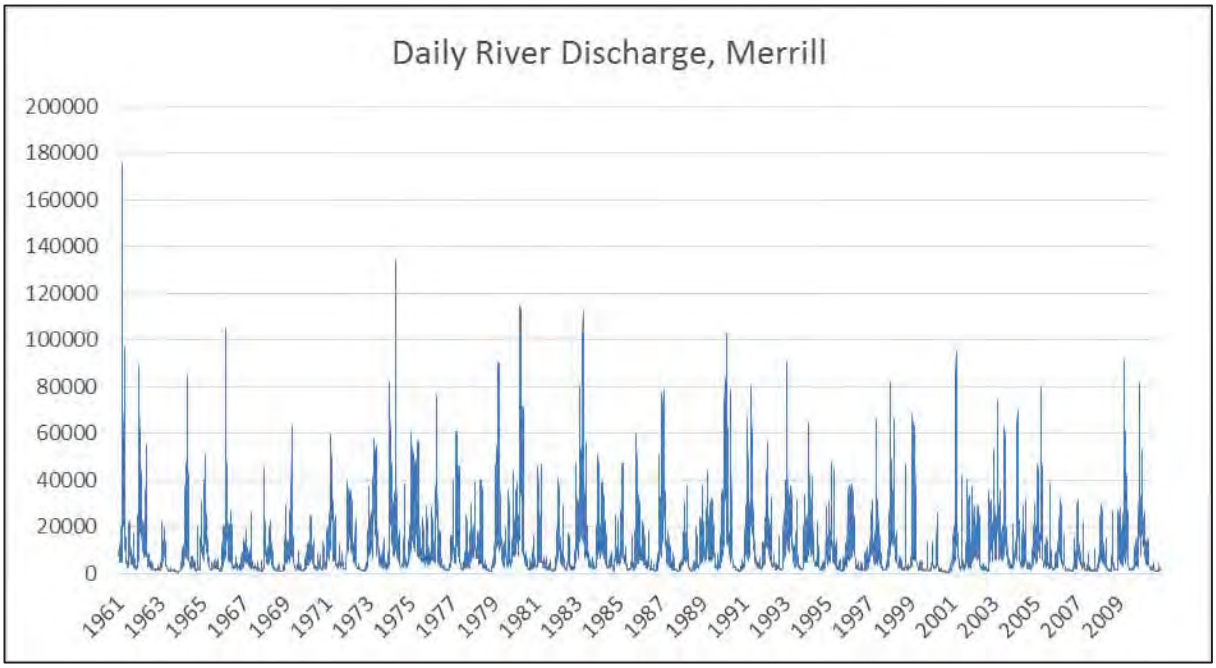

Figure 4.3 - Measured Daily Flows at Merrill Gage (1961-2009)

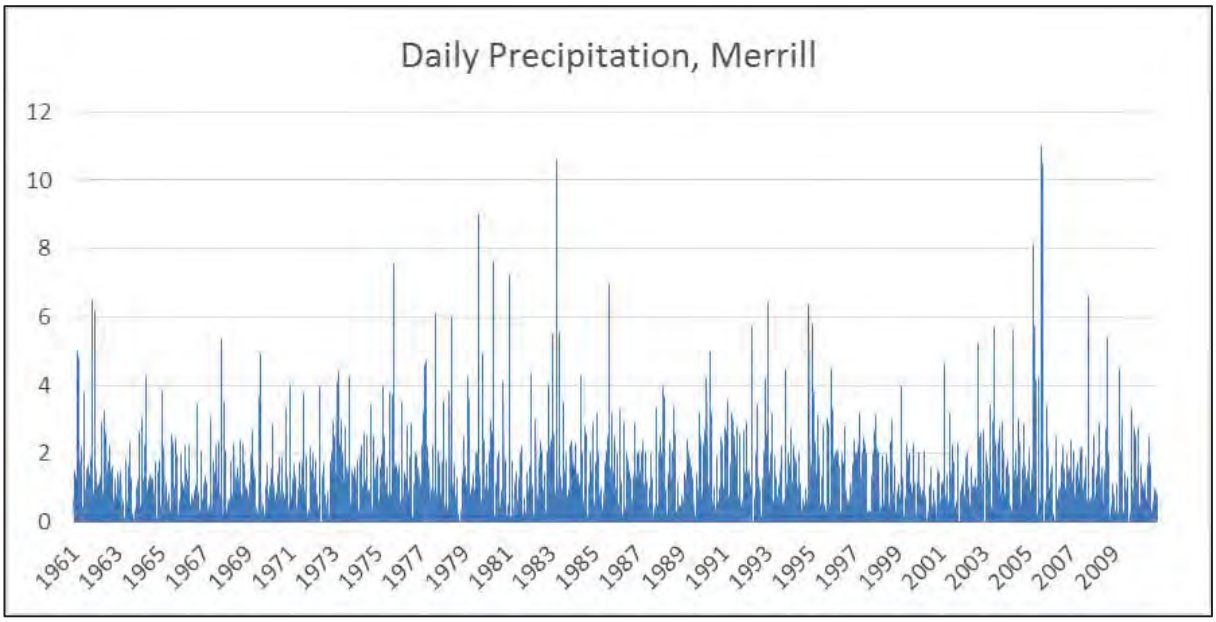

Figure 4.4 - Measured Daily Precipitation at Merrill (1961-2009)

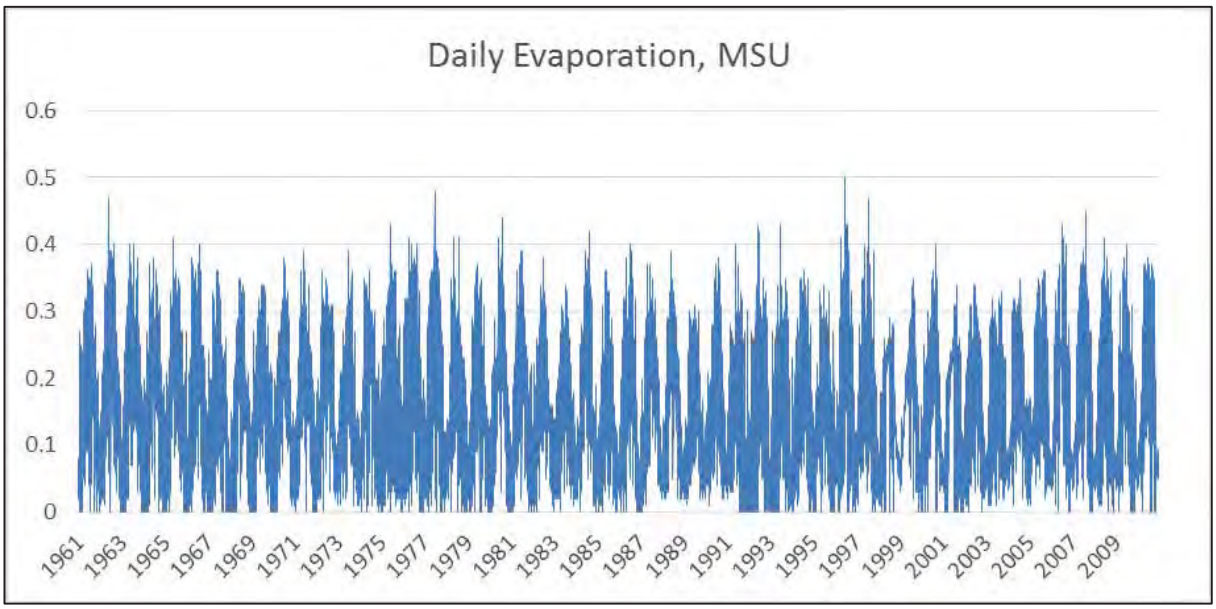

Figure 4.5 - Measured Daily Evaporation, Starkville, MS (1961-2009)

Daily precipitation values were reduced by that day's evaporation and adjusted to change pan values to values for an open water surface. This allowed daily water flows to be simulated, producing the data necessary to simulate the impact of weather and climate on a water surface. The relationship is shown by the formula P-.8E, with E being pan evaporation (Figure 4.6). For climate change, the daily E is increased. Each P is decreased. River flow is decreased the same amount as P.

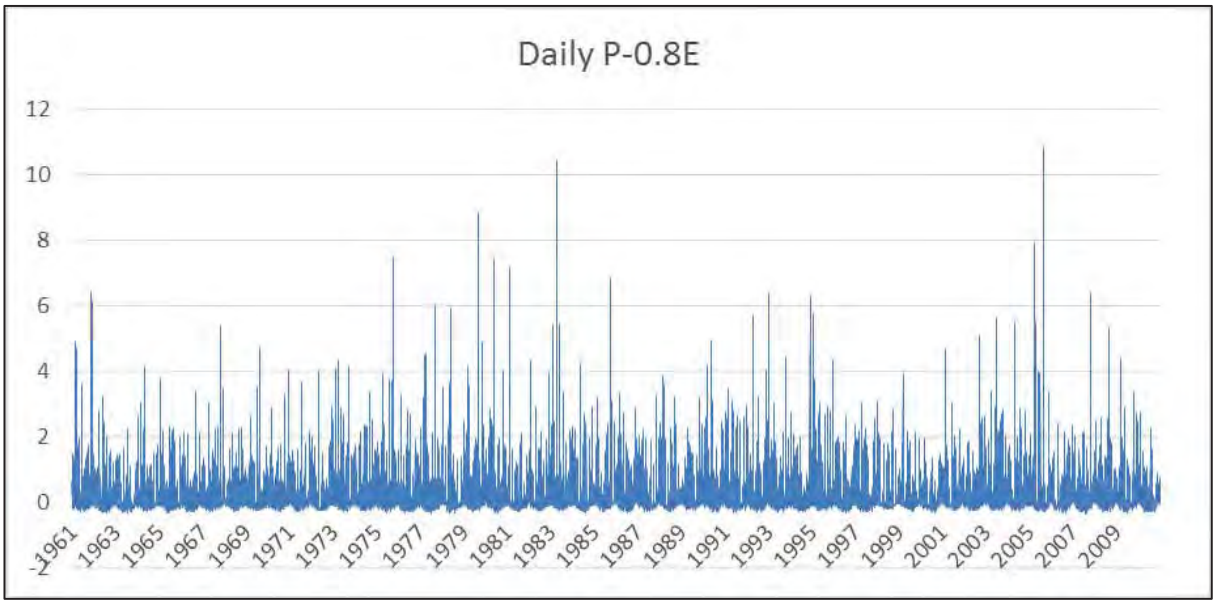

Figure 4.6 - Merrill Flow Budget (1961-2009)

Having established a data-based, fifty year historical record linking precipitation, evaporation and stream flows, it was necessary factor in projected climate change impacts on the data. The Tetra Tech (2010) model was selected in large part because it synthesized numerous other

climate change studies to produce a detailed county-level map of the United States showing the anticipated change in several weather factors, including evaporation and rainfall. For the Recommended Project Area in George and Jackson Counties, Mississippi evaporation was expected to increase by 9.73 percent while rainfall was expected to decrease by 1.57 percent (Pote et al. 2014).

Pote et al. (2014) developed a climate change model by increasing each daily evaporation value of the fifty year period by 9.73 percent. Likewise, a new precipitation data set was constructed by reducing each daily precipitation value over the fifty year period by 1.57 percent. In addition, it was assumed that river flow would be directly affected by rainfall. Therefore, the Pascagoula River's flow rate was also reduced by 1.57 percent. All data values were changed by small static percentages and the data is dense, so the full comparisons are very difficult to detect. Still, even modest changes in the frequency, duration or severity of low flow events will have a disproportionate impact on the Pascagoula River's ability to meet environmental, ecological and economic benefits.

To counteract these climate change impacts, the Recommended Project's two lakes were proposed to provide water storage to quickly and efficiently release water from a tributary to maintain the Pascagoula River's minimum stream flows. The analysis above was critical to determine a site close enough to the Pascagoula River's beginning at Merrill, Mississippi to quickly respond to low flow events and minimize water losses as water moved from the lake to the Pascagoula River. Also, it was necessary to determine the water storage capacity necessary to maintain those minimum flows. The Big and Little Cedar Creek watershed was selected as the preferred location and a two lake approach necessary to provide the projected water storage capacity. At full pool, the Upper Lake would be at 130 feet MSL and cover approximately 1,715 acres while the Lower Lake would be at 60 feet MSL and cover approximately 1,153 acres.

The model assumed that the two lakes would be used simultaneously and have a combined water surface of 2,868 acres and a calculated, combined lake-full volume of 41,632 AF. The Big and Little Cedar Creek drainage basin was delineated at 39,743 acres with a rainfall-runoff coefficient of 0.6, based on land cover and soil types (Appendices G and I). The model was also revised to account for the fact that as a lake loses volume, its area shrinks. Also, as the lake areas decrease, the area of the drainage basin increases. To account for these changes, a series of elevations of the lakes was delineated to calculate the lake basin volume and area change for each ten feet of drop in elevation from the lakes' full pool elevation. Using regression analyses, equations were developed matching this sequence, producing equations in the form of Area = f(Volume). These were used in the model to establish daily changes in the lakes' area and drainage basins.

These calculations were performed first for the Lower Lake and then the Upper Lake. Finally, since the two are modeled as a single lake in terms of drawdown, the specifications of the two lakes were combined and analyzed together, producing a single equation to predict the lake area given the daily volume lost or gained (Table 4.1). Climatological contributions to the lakes' water balance were calculated daily, using changes in the lakes' surface areas (changes in the pool elevations from precipitation or water releases would increase or decrease the lakes' surface area) in relation to changes in the lakes' drainage basins. The equations developed are shown in Table 4.2.

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Elevation	Upper Lake Area (Acres)	Upper Lake Volume (AF)	Lower Lake Area (Acres)	Lower Lake Volume (AF)	Combined Areas (Acres)	Combined Volume (AF)
0	1,715	31,428	1,153	10,024	2,868	41,632
-10	1,681	30,229	1,124	9,659	2,805	39,957
-20	1,647	28,639	1,097	8,583	2,743	37,222
-30	1,613	27,010	1,069	7,507	2,682	34,517
-40	1,579	25,822	1,042	7,085	2,621	32,907
-50	1,547	24,477	1,015	6,663	2,562	31,141

Table 4.1 Calculated Lake Elevations, Surfaces and Storage Capacity

Area =	0.023667	Volume +	968.9136	Upper
Area =	0.03536	Volume +	790.628	Lower
Area =	0.027882	Volume +	1703.40	Combo

Table 4.2 Prediction Equations for Upper, Lower and Combined Lakes

Finally, this analysis methodology was used to generate daily simulations of the lakes' volumes as if they had been operated over the fifty year period of 1961-2010, using the actual precipitation, evaporation and river flow data recorded for that period. These simulations use the following inputs and outflows:

- Inputs: Runoff from rain in the watershed and rain directly into the lakes.
- Losses: Evaporation when greater than precipitation (P-E), infiltration, overflow, and water released to augment river flow.
- Rules of operation: When the Pascagoula River falls below the 917 CFS (1,819 AF/day) at the Merrill gage, a sufficient volume is immediately released from the lakes to raise the Pascagoula above 917 CFS. This flow augmentation continues until the lakes lose their entire volume of stored water.

This simulation is shown graphically for projected climate change scenarios in Figure 4.7, As per Tetra Tech's (2010) predictions, rainfall was decreased by 1.57 percent, evaporation increased by 9.73 percent and river flow decreased by 1.57 percent from historic measured data. The model results showed that there was still not a single day for fifty years, with projected climate change impacts, when the lakes would have been unable to maintain the Pascagoula River above 917 CFS, immediately downstream of the Merrill gage. Drawdowns are shown for the 1963 and 2000 droughts. During the worst case scenario of the 1999/2000 drought, the lakes were needed to provide a total of 32,892 AF of water over a period of 101 days from July 9 through November 7 (Figure 4.7). This worst case drought required the lakes to be drawn down to their lowest point of about 27 percent of their total volume or 11,000 AF of remaining storage capacity (Pote et al 2015; Appendix G).

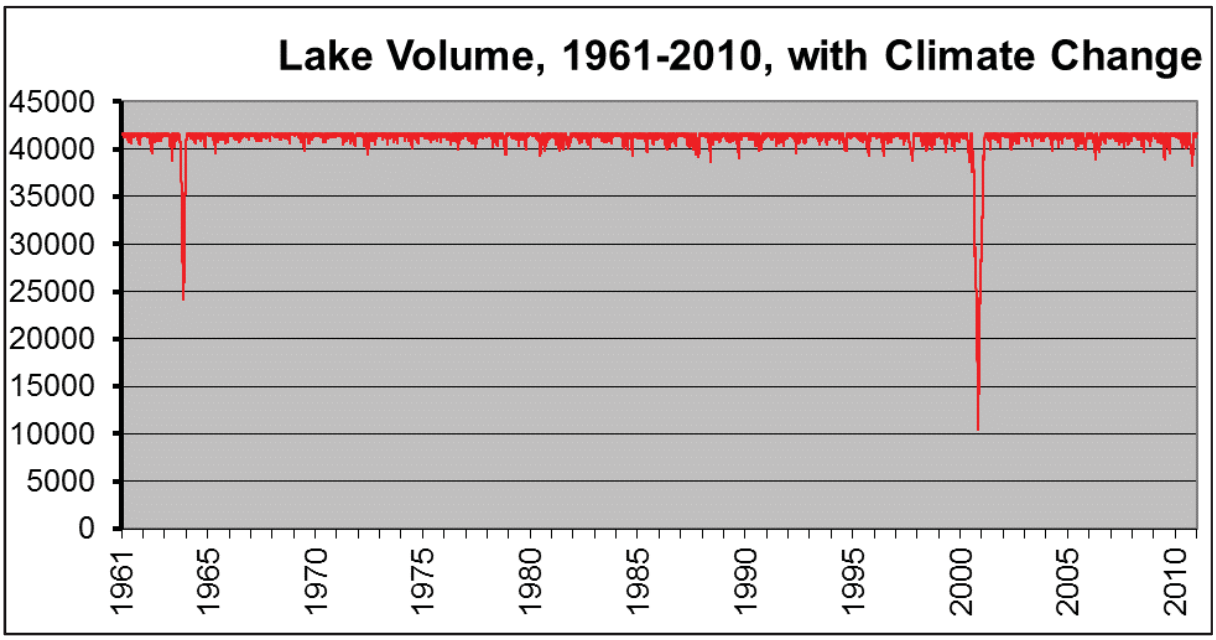

Figure 4.7 - Project Lakes Simulated Daily Volume During Projected 50-Year Climate Change

4.2. Resource Impacts

Having discussed the Recommended Project's complex geo-hydrology from a climate change perspective, it is appropriate to discuss potential impacts on individual resources.

4.2.1. Water Resources

MDEQ records indicate numerous domestic wells in the Recommended Project Area. Approximately 50 percent of these wells appear to be less than 100 feet deep with a number of wells less than 50 feet deep. The extent of actual usage of these domestic wells is unknown, since many of the older ones may have been replaced over time due to failing well conditions or even declines in groundwater levels. There are two public water systems in the vicinity; 1) Combined Utilities in southern George County and 2) the Jackson County Utility Authority (East) in northern Jackson County. Access to these two public water systems may allow homeowners to maintain their domestic wells for the irrigation of lawns and gardens while using community water for potable water supply.

Most of the wells in the area less than 50 feet in depth are believed to be pumping from what is typically described as a perched water table (aquifer). Characteristically, these shallow aquifers are composed of localized lenses of sand capable of yielding only limited supplies of water. Their lateral isolation and perched nature above more reliable saturated zones often makes them especially prone to drought conditions. During construction of the proposed lakes, these shallow aquifers may experience some degree of dewatering or even permanent physical damage depending on the depth excavated for the project and the location of the perched water table. This may result in some homeowners in the immediate area of the project having to replace and deepen their domestic wells into aquifers not impacted by the construction or to hook up to existing community water systems.

During construction and subsequent operation of the proposed lakes, instream flows (7Q10) will be maintained on both Big and Little Cedar Creeks. The USGS (1991) has published a 7Q10 of 40 CFS for Big Cedar Creek at Old Americus Road, near the community of Wade approximately one mile downstream of the proposed lower dam. The Project's pre-construction planning will involve a great deal of interaction with MDEQ's Licensing and Dam Safety Division to meet design requirement specifications for the two proposed dams. Applications will be submitted to MDEQ to obtain the required permits to construct the two dams and impound surface water. Since the dams may be classified as *high hazard*, the final component of the permitting process will entail preparing Emergency Action Plans, using a dam breach analysis to display inundation maps of potentially affected areas downstream.

The Recommended Project will maintain natural flows to dilute permitted downstream discharges, maintain Water Quality Standards to meet MDEQ's designated uses on the Pascagoula River (i.e., fish and wildlife and primary and secondary recreation), and prevent current and future water quality impairments. Finally, maintaining flows downstream will help slow or possibly reverse salt water intrusion off the mouth of the Pascagoula River.

4.2.2. Biological Resources

The Pickering Firm, Inc.'s biological site assessment was consistent with the requirements for an Environmental Assessment. Of the eighteen listed or candidate Threatened and Endangered species possibly found in the Project Area, only the gopher tortoise was observed within the review area. As such, the proposed project would have direct and indirect adverse effects on the gopher tortoise population. Conservation measures including avoidance, translocation, and/or habitat management could reduce the adverse impacts and actually benefit the gopher tortoise population. No other listed species were observed during surveys of the review area. Detailed biological resource information and maps of gopher tortoise observations are in Appendix C.

In conjunction with this assessment, Pickering Firm, Inc. personnel contacted both the USFW and the MDWF&P's Natural Heritage Program by letter on November 18, 2014 requesting comments on potential impacts to threatened and/or endangered species within the proposed Project Area or areas with likely secondary impacts. The UFWS responded, "The proposed project could have significant impacts to wetlands and other waters of the United States." The USFWS recommends a visual survey for the Louisiana black bear (*Ursus americanus luteolus*), red-cockaded woodpecker (*Picoides borealis*), yellow-blotched map turtle (*Graptemys flavimaculata*), dusky gopher frog (*Rana sevosa*), and Louisiana quillwort (*Isoetes louisianensis*). The USFWS also recommends the county [counties] to develop a Migratory Bird Conservation Plan that specifically considers the effects of forest clearing and fragmentation on migratory bird species protected under the Migratory Bird Treaty Act and includes measures to prevent, minimize, or mitigate such impacts. The MDWF&P responded by recommending that comprehensive surveys be conducted to verify whether gulf sturgeon (*Acipenser oxyrinchus desotoi*), pearl darter (*Percina aurora*), Alabama shad (*Alosa alabamae*), yellow-blotched map turtle, ironcolor shiner (*Notropis chalybaeus*), and multiple species of mussels were utilizing the Big and Little Cedar Creeks. These correspondences and responses are in Appendix K.

As part of DOE's SEIS, ICF Jones and Stokes, Inc. applied the Instream Flow Incremental Methodology Process (IFMP) to evaluate changes in the amount of estimated usable habitat available to three species in the Pascagoula River as flow changes relative to a proposed water withdrawal. The three species selected for study were: 1) Gulf sturgeon, (*Acipenser oxyrinchus*), 2) pearl darter (*Pencina aurora*), and 3) the yellow blotched map turtle (*Graptemys*

flavimaculata). ICF Jones and Stokes, Inc. (2009), report that the DOE had proposed limiting water withdrawals from the Pascagoula River as follows:

- No withdrawals when the Merrill gage was below 1,000 CFS;
- Withdrawals up to 39 CFS when the Merrill gage was between 1,000 and 1,100 CFS;
- Withdrawals of up to 78 CFS when the Merrill gage was above 1,100 CFS.

The study was focused on the timing and volume of DOE's proposed water withdrawals rather than drought resiliency or maintaining instream flows. Still, the study concluded that:

- Under **average conditions** DOE's proposed withdraw is far less than the natural hourly or daily variance in flow associated with variability in precipitation, groundwater inputs, other anthropogenic impacts or measurement error.
- **Under most conditions** DOE's proposed withdrawal would not likely be detectible in the field, and may not have an impact on the three species discussed in this report, but
- "These relatively small but detectable changes should be considered when evaluating the impacts of [DOE's] proposed withdrawal at Merrill or other flow alternations in the Pascagoula" (ICF Jones and Stokes, Inc. 2009 page 5-2).

Recognizing that under the Pascagoula River's current flow regime, even "relatively small but detectable" flow alterations (e.g., withdrawals) should be considered. Mississippi State University (MSU) was contracted to evaluate the potential of restored natural flow regimes to improve critical habitat for T&E Species and specifically the Gulf Sturgeon (*Acipenser oxyrhynchus*). Pote et al. (2015) found that the Recommended Project can serve not only to maintain flow regimes to meet instream flow requirements, but can also be used to alter flows seasonally to enhance critical habitat for T&E fish species. However, that data on the specific flow needs of the Gulf Sturgeon, or other T&E fish species, is very limited and poorly tested. The two simulations in this study, the first using the prescribed 7,934 AF/day and the second using approximately 75% of that amount, may or may not be sufficient to satisfy specific species needs. In short, regulatory minimum stream flows and even historic natural hydrographs may not be ideal for the recovery and protection of T&E fish. However, impoundments can be a potentially valuable tool to protect natural landscapes from the impacts of projected climate variability by supplementing natural flows when necessary to protect or enhance the recovery of T&E fish species.

Echoing the ICF Jones and Stokes, Inc. report, MSU found that flows are also an important habitat requirement for three other T&E fish species with critical habitat in the Pascagoula River Basin that may be impacted by an impoundment in the system. The species are: peal darter (*Percina aurora*), saltmarsh topminnow (*Fundulus jenkinsi*), and Alabama shad (*Alosa alabamae*). These species were identified based on a literature review and discussions with scientists at the Mississippi Museum of Natural Science. However, there are important gaps in our knowledge regarding each of these species. First, the negative impacts from low flows and the potential positive impacts from augmented flows are only speculative (though documented for the Gulf sturgeon). And second, while a new impoundment will certainly impede fish passage there is little to no data describing how, or if, these species actually use Big or Little Cedar Creeks. Additional data would be required to better understand how these and other fishes utilize the river and tributaries and their specific habitat requirements, including flow regimes in the Pascagoula River. Recognizing the that the Project's primary Purpose and Need is drought resiliency, it is feasible to factor beneficial impacts to T&E fish species into the Project's operational parameters. The MSU report is in Appendix J.

4.2.3. Geology, Soils and Slope

The Recommended Project will have a minimal impact on the area's geology, soils or slopes during and after construction is completed. The Project Area's geology and soils provide many of the natural materials needed for dam construction and other project infrastructure modifications/relocations. Clearing and borrow areas will be limited to within the lake footprints, including conservation pool areas and the spillway excavations. Any additional supplies of sand, silt, clay and gravel not immediately needed for project construction will be stockpiled in designated areas for later use by the George and Jackson Counties or the Pat Harrison Waterway District. The removal and use of sand, silt, clay and gravel will increase the lakes' water storage capacity. Lastly, the abundant lenses of clay, associated with the Citronelle Formation in the Project Area is a natural impermeable layer beneath the proposed lakes to help retain water. The Geoprobe investigation identified many thick clay layers that can be used during the lake construction as liners in areas where sands are present under the lake footprints to prevent or impede water moving into the surrounding subsurface (section 3.3.3.2, Appendix I).

4.2.4. Wetlands Impacts and Conceptual Mitigation Plan

The Clean Water Act § 404 (33 USC §§ 1251 et seq.; § 1344) authorizes the US Army Corps of Engineers (COE) to regulate construction activities affecting waters of the United States (*wetlands)*. The USACE and EPA define wetlands as "*those areas that are inundated or saturated by surface or groundwater at a frequency and duration sufficient to support, and that under normal circumstances do support, a prevalence of vegetation typically adapted for life in saturated soil conditions*." (U.S. Army Corps of Engineers 1987 at page 9). This definition considers three distinct criteria: a) hydrology, b) soil, and c) vegetation. Wetlands usually exhibit positive indicators of all three criteria. Areas that are unavoidable and cannot be minimized due to project specifics require compensatory mitigation to ensure no net loss of aquatic resources. Mitigation will be required for all wetland impacts under the COE Mobile District jurisdiction. The COE makes the final determination on mitigation requirements.

A wetland delineation was conducted by Pickering Firm, Inc. Natural Resource Scientists from March 2014 through December 2014 within the Recommended Project area to identify potential wetland and stream impacts. The jurisdictional delineation of waters of the U.S. revealed 1,201.697 acres of potential jurisdictional wetlands, 219,506.63 combined linear feet of ephemeral, intermittent, and perennial stream channels, and 24.77 acres of open water. These potentially jurisdictional features were observed primarily within Small Stream Swamp Forests and Bottomland Hardwood habitats. A small area of Slash Pine Flatwoods was observed within the lower lake footprint only. Detailed wetlands maps and data sheets are included in Appendix C.

In determining the mitigation required for the Recommended Project's unavoidable wetland and stream impacts, it should be appropriate to recognize that EPA projects it is *highly likely* that climate change will have serious, adverse impacts on wetlands and streams in the Pascagoula watershed (EPA 2013). These impacts include altering the watershed's structure and function of which can potentially affect regional and state wetlands delineation and protection programs by drying out seasonal wetlands. In short, without this Drought Resilience Project and associated hydrologic restoration in the Pascagoula watershed and River, the spatial extent and loss of functionality of seasonal and coastal wetlands and ephemeral streams will be adversely impacted.

A conceptual four step conceptual mitigation plan is proposed to fully compensate for these unavoidable wetland and stream impacts. First, the Recommended Project should get mitigation credits for protecting downstream wetlands, including coastal wetlands, and streams from the impacts of climate variability. Secondly, as a public project, on-site mitigation will be used to the maximum extent possible. On-site mitigation may include in priority order: a) restoring, b) enhancing, and c) protecting wetlands and streams on or adjacent to the lakefront. This may be accomplished by purchasing lake front property in fee simple or purchasing long-term conservation easements from willing sellers. Similarly, buffer strips following tributary streams upstream may be purchased from willing sellers for restoration, enhancement and/or protection. Thirdly, after all practicable on-site wetlands and stream mitigation is exhausted, off-site public lands will be evaluated for potential mitigation opportunities. For example, in November 2004, the Mississippi Department of Wildlife, Fisheries and Parks (DWF&P) purchased 428.07 acres of land adjacent to Lake Bogue Homa with project funds for wetland and stream mitigation. The applicants have communicated with the DWF&P to retain the use of that land for mitigation regardless of ownership. Similarly, the PHWD's water parks offer significant opportunities for wetland and stream restoration and enhancement. Finally, after exhausting all practicable off-site, public land mitigation, the co-applicants may either; a) seek mitigation credits from an existing public mitigation bank, b) seek to create a new public mitigation wetland/stream mitigation bank or c) purchase the necessary mitigation credits from an approved mitigation bank.

4.2.5. Cultural Resources

Based on efforts and findings discussed in Section 2.3.5, Brockington and Associates on August 26, 2014, Brockington and Associates' consulted with the COE-Mobile District regarding developing a sampling strategy for an archaeological survey of the *Area of Potential Effect* (APE) based on developing a site sensitivity model. As the sensitivity model was being completed, the formal research design document was written and provided for COE comment in December 2014. In January 2015, the COE concurred on the sensitivity model and overall project approach. The package was then provided to MDAH and on February 3, 2015, concurrence was received at a face-to-face meeting with Brockington and MDAH archaeologists and Pickering Firm Inc. personnel at MDAH offices in Jackson, Mississippi. The MDAH concurred with the proposed sampling strategy and archaeological survey for the APE, but suggested refinements beyond the initial sampling strategy and sensitivity model.

According to COE-Mobile District and MDAH recommendations, the efficacy of the sensitivity model was to be tested in an agreed upon percentage of each of the designated sensitivity zones. Based on the results of the sample testing, a revised research design will be developed to guide a comprehensive survey of the Recommended Project sites. To this end, a continuing cultural resources study for the Recommended Project will entail: 1) sensitivity model testing, 2) revising the sensitivity model and research design based on results of the sample study, 3) comprehensive cultural resources survey of the study area as guided by the revised design and in consultation with COE-Mobile District and MDAH, and 4) incorporate findings and cultural resources management recommendations in a full technical report. Brockington and Associate's report is included in Appendix D.

4.2.6. Socioeconomic Impacts

The Recommended Project should provide broad socioeconomic benefits throughout the region. First, drought resilience will benefit the region's flora and fauna and the assorted emerging small eco-tourism businesses that depend on this resource to attract customers. Similarly,

maintaining or restoring important marine and estuarine fisheries provides important small business opportunities. For instance, George County's designated Pascagoula River Blueway is a collaborative effort with the Land Trust for the Mississippi Coastal Plain, the National Park Service and the Mississippi Development Authority to conserve and restore the Pascagoula River while expanding recreational opportunities and supporting economic opportunities and job creation in local communities. The Recommended Project will enhance this Blueway effort by providing adequate flows during normal low flow periods in late summer and fall to allow more time for local healthy outdoor, family based recreational opportunities. Finally, the two proposed lakes will provide new and alternative public recreation in the Pascagoula watershed for individuals and families seeking an alternative to river/stream-based and coastal recreation.

4.2.7. Hazardous and Toxic Materials

Further investigation of the Project Area is recommended including collecting samples of any liquids remaining in the drums, along with soil samples beneath and around these drums for laboratory analysis. Suspect asbestos containing building materials, such as the roofing shingles observed, should also be sampled and properly disposed if found to contain asbestos.

4.2.8. Floodplain

The Project's proposed lake footprints will have unavoidable impacts on the floodplains and regulatory floodway corridors along Big and Little Cedar Creeks. The two proposed lakes will require a Hydrologic and Hydraulic Study and submission of a Letter of Map Revision (LOMR) to the Mississippi Emergency Management Administration and FEMA. The LOMR, together with the modified flood maps associated, will have to be incorporated into the George County Flood Damage Prevention Ordinance. Pickering Firm, Inc. personnel have discussed the Recommended Project and its potential floodplain impacts with Ms. Nancy Smith, George County's Emergency Management Director. Ms. Smith and the relevant staff at the Mississippi Emergency Management Agency have acknowledged that they will be actively involved in evaluating and addressing the Recommended Project's floodplain impacts.

4.2.9. Prime and Unique Agricultural Lands

The Natural Resources Conservation Service's (NRCS) provided a Farmland Conversion Impact Rating using the Land Evaluation and Site Assessment system which calculated that the Upper and Lower Lakes each score 135 points for Agricultural Land Impacts (Appendix K).

4.2.10. Noise

The Recommended Project will have a minimal impact noise in the local area and possibly result in less noise after construction is completed.

4.2.11. Visual Aesthetics

The Project Area does not currently have sweeping, panoramic view sheds because of its relatively flat topography and large patches of dense woods. Still construction of the Recommended Project would substantially change the view shed of some residents. However, Recommended Project's visual impacts would limited because of the remaining densely wooded areas adjacent to the shoreline. Furthermore, the resulting change in view shed caused by the proposed lakes would likely be considered aesthetically pleasing and may benefit the view sheds.

This Recommended Project would include improving and relocating some existing rural roads that are already part of a view shed. Additional secondary, primarily residential development may increase in the area that would have additional minimal visual impact to local residents.

4.2.12. Air Quality

MDEQ's Air Toxics Branch does not expect the Recommended Project to adversely affect ambient air quality; contingent on receiving any required air emissions permits from MDEQ's Permit Board prior to commencing construction and compliance with all applicable asbestos and lead-based paint control regulations.

4.2.13. Environmental Justice

The Recommended Project does not directly or indirectly impact any environmental justice issues or populations.

4.2.14. Coastal Zone Management

Drought resilience has numerous positive impacts on Mississippi's coastal zone and its assorted marine and estuarine resources. Specifically, the Recommended Project is designed to restore the Pascagoula River's natural hydrography which will retard or slow saltwater intrusion to increase the productivity, survival and possible expansion of historic oyster reefs off the mount of the Pascagoula River. Furthermore, the Recommended Project's operational parameters could support some type of modified hydrograph, within the range of the natural historic hydrograph, enhance or maintain habitat, including breeding grounds and nursery areas of commercially and recreationally important marine and estuarine fisheries. This Environmental Assessment and the attached Appendixes F, G, H, and I essentially are the type of geo-hydrological study recommended by the Governor's Oyster Council as a precursor to addressing freshwater inflow impediments to restored and enhanced oyster production.

4.3. Construction Impacts

The project is expected to slightly disturb neighborhoods in and adjacent to the project from short-term construction disturbances and road closures. Construction impacts would include increased noise in the construction areas, increased traffic congestion and potential damage to local roadways. Construction planning and sequencing will be used to minimize traffic delays at all times. Temporary access roads will be constructed along portions of the proposed project during construction. Locations of these temporary access roads will be identified during the design phase. Generally construction impacts would be relatively short-term and minor. Best Management Practices will be employed during construction to protect all tributaries and drainage ditches on the project from runoff and sediment deposition during construction activities. A Stormwater Pollution Prevention Plan to manage and dispose of runoff associated with construction and creek crossings will be developed for this project. Construction impacts are also discussed to some extent in Section 6 in relation to unavoidable or irretrievable commitments involved if the recommended project is implemented.

5. RECOMMENDED PROJECT'S SECONDARY AND CUMMULATIVE IMPACTS

Unlike direct impacts discussed above in Section 4, secondary or indirect impacts are those which may result from the Recommended Project but occur later in time or are further removed in distance. Similarly, cumulative impacts account for potentially many relatively small, individual impacts which may not be fully regulated. Over time these small impacts may have a meaningful impact. Secondary impacts within the Recommended Project Area will be minimized by the adoption of an enforceable *Shoreline Management Plan*. The co-applicants have all agreed that an open public process will be used to develop a *Shoreline Management Plan* which will have to be approved prior to beginning construction. To the maximum extent possible, this permit application identifies the Recommended Project's direct, long-term cumulative impacts.

Still, secondary or indirect impacts may result from induced development following the Recommended Project's construction. This induced development and associated secondary impacts might occur well outside the Project Area in South George and North Jackson Counties. However, since portions of the Project are located within the wetlands and floodplains, the induced development in these areas would be subject to additional government regulated controls. Although much of the Project Area is undeveloped and sparsely residential, considerable new residential and some commercial development could occur as a result of the Recommended Project. Both George and Jackson County officials were contacted regarding any future development projects that the Recommended Project could impact. Based on information received, no future or current projects are currently planned that the Recommended Project would negatively impact. The following potential secondary and/or cumulative impacts address specific environmental areas of concern addressed throughout this report:

- Land Use: Potential secondary and cumulative effects associated with land use in the Project Area could include future new residential and commercial development surrounding the proposed lakes. This type of secondary development would be considered typical with a project of this nature. Development of the lakes could change the assessed property values of adjacent land. Any new residential or commercial development would change the property classification and increase the tax base for George and Jackson Counties.

- Geology and Soils: No secondary or cumulative effects are anticipated to the area's geology or soils. The majority of impacts related to geology and soil will occur during construction and all anticipated changes should stabilize shortly after. If an erosion pattern occurs that could produce a cumulative impact on local drainage patterns, the issue will be identified and corrected in a timely manner to prevent negative cumulative impacts.

- Air Quality: The Recommended Project may cause slight, temporary increases in area emissions during construction. Potentially, increased motorized recreational activities could cause a *de minimus* increase in air emissions.

- Noise: Potentially increased traffic and recreational activities in the area could result in secondary or cumulative effects to residents. However, these impacts are expected to be minimal and would not produce any substantial secondary or cumulative impacts to area noise levels.

- Water Resources: As discussed at length above in Sections 2.2 and 4.1, the Recommended Project is designed as a long-term solution to provide measurable benefits to water quantity, groundwater recharge, and baseflow in the Pascagoula River.

- Wetlands: Assuming climate variability projections are correct, drought resiliency should provide long-term secondary and cumulative benefits to maintain or increase the extent and functioning of wetlands well outside the Project Area. Potential new residential and commercial developments might have additional cumulative impacts on wetlands. Similarly, roadways and related infrastructure to support new residents and visitors could be a secondary result of the Recommended Project and have a cumulative impact on wetlands. All appropriate measures to identify and avoid, minimize or mitigate impacts to wetlands will be observed during the planning of all future development in the area. If these measures are taken, the Recommended Project should have minor secondary or cumulative impacts on wetlands.

- Floodplains: Local residents and businesses are intimately aware of the exorbitant costs of building and insuring buildings in identified floodplains. Accordingly, it is highly unlikely that the Recommended Project will result in any major new development in floodplains. If construction within the floodplain is unavoidable, existing regulatory measures and eligibility for National Flood Insurance should ensure that no net rise in the floodplain will occur as a result of the action and should be undertaken. As such, the Recommended Project would not likely result in major secondary or cumulative floodplain impacts.

- Biological Resources: Again, assuming climate variability projections are correct, drought resiliency should provide long-term secondary and cumulative benefits to maintain or increase stream flows during severe droughts and preserve wetlands habitat for biological resources, including threatened and endangered species. New residential and commercial developments, as well as future roadways, could potentially affect areas that serve as habitat for threatened and endangered species. Future effects to biological resources as a result of secondary development associated with the Project can be mitigated using avoidance, minimization, and conservation methods. The identification and avoidance of threatened and endangered species and their critical habitat should be considered prior to all future development in the Project Area. If these measures are taken, the Project would not have considerable secondary or cumulative impacts on wetland resources in the Project Area.

- Socioeconomics: The Recommended Project is a proactive effort towards sustainable, drought resilient communities, which is anticipated to provide meaningful secondary and cumulative socioeconomic benefits. Drought resiliency will protect the Pascagoula River's existing economic and cultural values. Recreational opportunities are a secondary consideration, which could increase tourism and possibly accelerate population growth in South George and North Jackson Counties. The Recommended Project may have many unquantified regional secondary and cumulative socioeconomic benefits.

- Environmental Justice: The Recommended Project does not have any identifiable secondary or cumulative impacts on minority or low income populations within the Project Area or the region. It is possible potential future residential or commercial

development would displace or negatively affect minority and low-income populations in the Project Area.

- Hazardous Materials: Potential secondary and cumulative effects related to hazardous materials could involve incidental petroleum spills during Project construction or from transportation and recreational vehicles after completion of the Recommended Project. Small spills of this nature would likely have minimal impacts. Trained hazardous material response teams are typically available to respond to larger incidental spills and full clean up and mitigation is required to ensure no major impacts. The Recommended Project would not result in major secondary or cumulative impacts related to hazardous materials.

- Cultural Resources: Potential secondary and cumulative effects to cultural resources in the area could include the possible disturbance of historical properties or archaeological resources during future residential or commercial development activities. Efforts to identify and avoid historical properties, including archeological resources and historic architecture resources, should be undertaken prior to all future development in the area. If these measures are taken, the Project would not cause noteworthy secondary or cumulative impacts to cultural resources in the Project Area.

- Coastal Resources: There is a growing recognition of the importance of freshwater inflows to maintain a variety of coastal resources (coastal wetlands, oysters, commercial and recreational marine and estuarine fisheries, etc.) The Recommended Project should provide direct, secondary and cumulative benefits to a variety of coastal resources and at least imped destructive coastal erosion and salt water intrusion.

6. UNAVOIDABLE OR IRRETRIEVABLE COMMITMENTS INVOLVED IF THE RECOMMENDED PROJECT IS IMPLIMENTED

Implementing the Recommended Project would unavoidably involve a major financial commitment with a serious impact on a relatively small number of families who reside within or immediately adjacent to the lake footprints. Similarly, the Recommended Project would unavoidably impact a few rural road segments and necessitate the modification, elevation, and extension of some bridges. The Project may also impact some other public infrastructure. Finally, the Lucedale Publicly Owned Treatment Works plant which is located just outside the Upper Lake's footprint, would likely need to be upgraded and possibly expanded to maintain recreational water quality standards in the Project's two lakes.

6.1. Residential Relocations

The Uniform Relocation Assistance Act and Real Property Acquisition Policies Act of 1970, (Uniform Act) sets minimum standards for all federally funded programs and projects that require the acquisition of real property (real estate) or displace persons from their homes, businesses, or farms (42 USC § 4651). The Uniform Act's objectives are to ensure the following:

- Property owners are treated fairly and consistently, to encourage and expedite acquisition by agreements with the owners, minimize litigation and relieve congestion in the courts, and promote public confidence in federally-assisted land acquisition programs;
- Persons displaced as a direct result of federally-assisted projects are treated fairly, consistently, and equitably so that they will not suffer disproportionate injuries as a result of projects designed for the benefit of the public as a whole; and,
- Agencies implement these regulations in an efficient and cost effective manner.

The Lake footprints were not surveyed and are based on existing topographic data and public domain imagery. To date, every effort has been made to avoid or minimize residential relocations, however, the Recommended Project will likely result in several residential relocations due to one of the following scenarios:

- A structure is located in part or whole within a finalized lake footprint;
- A lake footprint necessitates acquiring residential property, which would negatively affect its functional use or occupancy; or
- A lake footprint will result in the loss of access to and from a structure or property because of closure or relocation of local roadways within a finalized lake footprint.

Potential displacements/relocations were identified utilizing a combination of field observations, topography and public domain aerial imagery. It is possible that some residential structures might qualify as potential relocations but are not included in this information due to large setbacks from roadways and construction taking place after field activities and/or aerial photography. No residential displacements/relocations were identified in northern Jackson County in the Lower Lake footprint. Eight residential structures will potentially be displaced/relocated within the Lower Lake's footprint including: four detached, single-family homes and one mobile home located along Watters Road; one detached, single-family home north of the intersection of Beesley Road and Watters Road; one detached, single-family home on the west side of Beesley Road, just south of Barton Agricola Road; and one detached, single-family home at the western terminus of Bismark Road. General locations of potential Lower Lake residential displacements/relocations are shown in Figure 6.1.

Thirteen residential structures will potentially be displaced/relocated within the Upper Lake's proposed footprint. These potential relocations include: two single-family detached homes on the south side of Buddy Finch Road; two detached, single-family homes and three mobile homes on the north side of Buddy Finch Road; three detached, single-family homes on the east side of Jordan Mae Road; two detached, single-family homes on the west side of Air Ranch Road; and one detached, single-family home south of Barton Agricola Road, near the intersection with Air Ranch Road. The Upper Lake's potential residential displacement/ relocation sites are shown in Figure 6.2. The Recommended Project's total potential residential displacements/relocations are summarized in Table 6.1. The Recommended Project would not require any commercial displacements/relocations.

Lake Site	Residential Displacements		Commercial Displacements
	Detached	Mobile	
Upper Lake	10	3	0
Lower Lake	7	1	0
Total	17	4	0

Table 6.1 - Potential Total Displacements/Relocations

6.2. Infrastructure Relocations and Modifications

The Proposed Lakes will also impact existing roads, bridges and utility lines. Utility lines within the lakes' footprints will need to be relocated. Decisions have not been finalized on all road relocations, however, after extensive discussions with the George County Board of Supervisors, it is anticipated that the Recommended Project would require the modification and expansion of three existing bridges in the Lower Lake footprint including: Barton-Agricola Road, between Jodie Baxter and Beesley Roads; Beesley Road, just north of Bismark Road; and Beesley Road, just northwest of Watters road (Figure 6.1). Figure 6.1 also shows two road segments that will likely be removed. The George County Supervisors plan to remove the portion of Emerson Road that the Lower Lake will inundate. Likewise, the George and Jackson County Boards of Supervisors plan to remove the segment of Bismark Road that the Lower Lake will inundate.

On the Upper Lake, one existing bridge on Barton-Agricola Road will need to be expanded and/or elevated. A new small bridge will likely be needed on the extreme north of the Upper Lake on Marcus Pierce Road. Figure 6.2 shows the approximate location of the new bridge, but it does not accurately reflect the location or extent of Marcus Pierce Road because an accurate shapefile is not available from any public domain geo-spatial databases, nor is it apparent on any public domain map viewers.

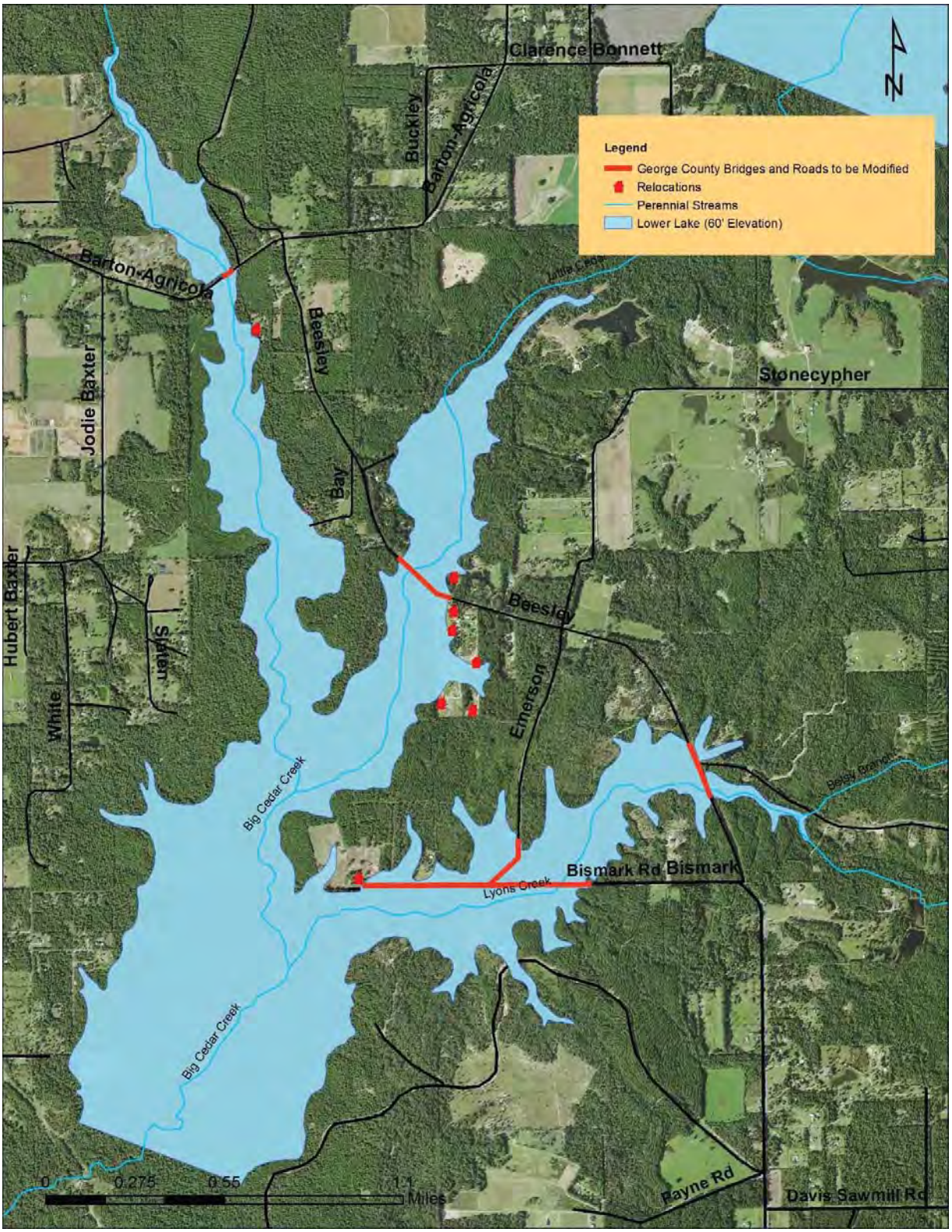

Figure 6.1 - Lower Lake Potential Residential Relocations and Modified Bridges and Roads

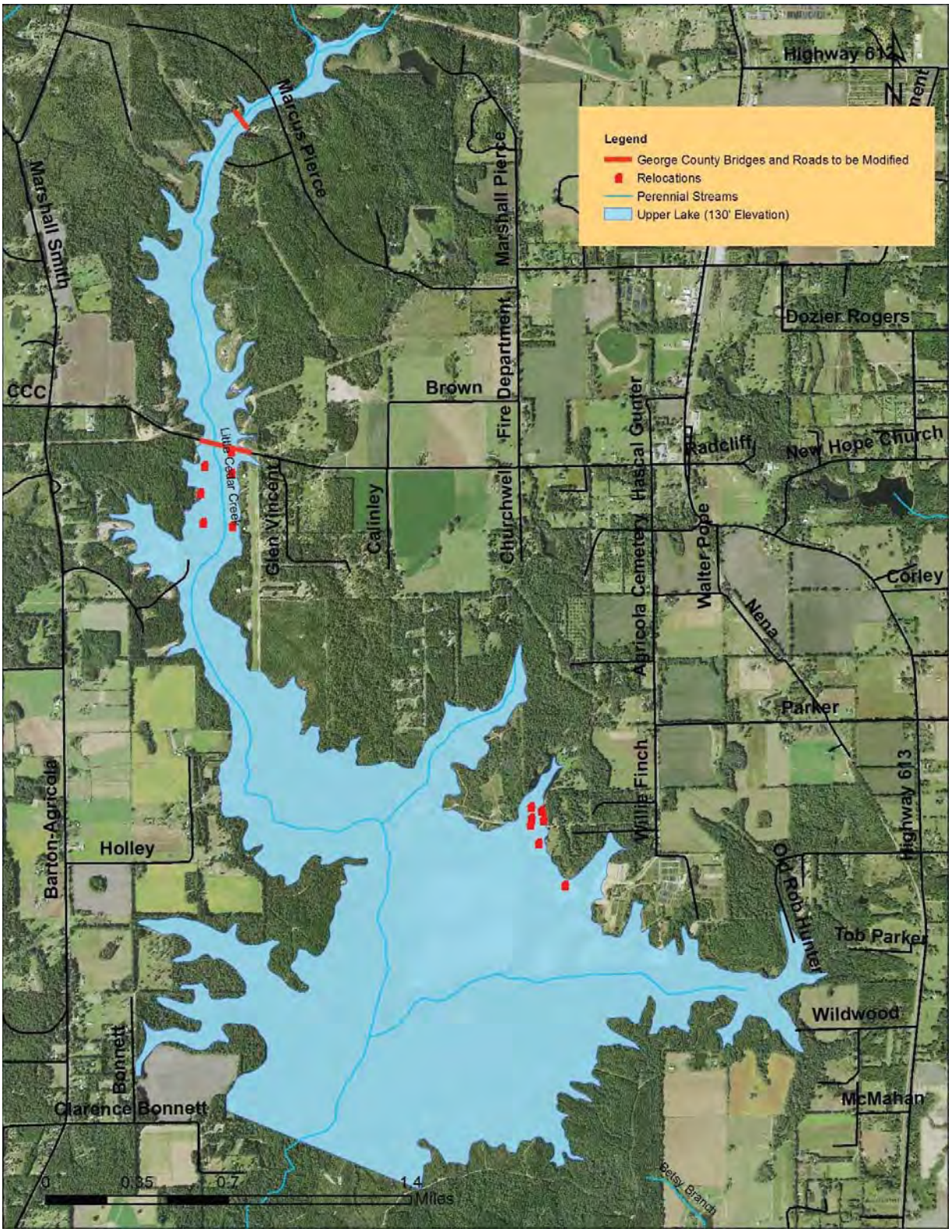

Figure 6.2 - Upper Lake Potential Residential Relocations and Bridge and Road Modifications

7. PROJECT'S UNAVOIDABLE ADVERSE ENVIRONMENTAL EFFECTS

The Recommended Project's two impoundments will unavoidably inundate approximately 2,868 acres in the Big and Little Cedar Creek watershed (Upper Lake-1,715 and Lower Lake-1,153 acres). Section 4 presents the environmental impacts of these proposed actions for the Project Area, the larger Pascagoula watershed and the Mississippi Sound. Some of those impacts are beneficial, while others are not clearly positive or negative (adverse). However, regardless of the final, approved lake footprints and the area inundated, the Recommended Project will have some unavoidable, adverse impacts on the Project Area's environment. Section 8 supplements this discussion by examining the relationship between these local environmental uses (adverse effects) and maintaining, restoring, and enhancing the watershed's long-term environmental, ecological and economic productivity.

The Pickering Firm, Inc.'s Natural Resource Scientists conducted a jurisdictional delineation of waters of the U.S. which the Recommended Project would unavoidably, adversely impact. That delineation revealed 1,201.697 acres of potential jurisdictional wetlands, 219,506.63 combined linear feet of ephemeral, intermittent, and perennial stream channels, and 24.77 acres of open water. These potentially jurisdictional features were observed primarily within Small Stream Swamp Forests and Bottomland Hardwood habitats. A small area of Slash Pine Flatwoods was observed within the lower lake footprint only (Section 4.2.4; and Appendix C).

Of the numerous threatened and endangered species or species of special concern identified by the USFWS and/or the MDWF&P which may be present at sometime within the Project Area, Pickering Firm personnel only observed gopher tortoises within the Project Area during their time physically on-site. The Recommended Project is likely to have unavoidable direct and indirect adverse effects on the area's gopher tortoise population and habitat. Multiple conservation measures (e.g., avoidance, translocation, and/or habitat management) could reduce the adverse impacts and might actually provide long-term benefits to the area's gopher tortoise population (Section 4.2.2 and Appendix C).

The NRCS's Farmland Conversion Impact Rating form (November 18, 2014, Appendix K), reports that the Project Area's Upper Lake would inundate 206.35 acres of prime and/or unique farmland. The NRCS evaluated a larger 1,750 acre Lower Lake footprint instead of the proposed 1,153 acre footprint and for the larger footprint found 335.72 acres of primate and unique farmland. That acreage would undoubtedly be notably reduced with the 1,153 acre footprint. Still these acreages cover 0.003 and 0.004 percent respectively of George and Jackson Counties' total prime and unique farmland acreage.

8. RELATIONSHIP BETWEEN LOCAL, SHORT-TERM ENVIRONMENTAL USES AND MAINTAINING, RESTORING AND ENHANCING REGIONAL, LONG-TERM PRODUCTIVITY

It is impossible to evaluate the Recommended Project without considering the relationship of short or near-term environmental uses and impacts within the Project Area with the regional maintenance, restoration, enhancement or long-term productivity of the Pascagoula River and watershed. Without discounting the importance of local environmental uses and impacts, it is necessary to put the Project Area, short term uses and impacts into context of the maintenance, enhancement or protection of the long-term productivity of the Pascagoula River and watershed. This section provides an opportunity to summarize the detailed information provided above to place the Recommended Project and Project Area within the appropriate spatial and temporal context in relation to the Pascagoula River and watershed.

Spatially, the Project Area would unavoidably impact roughly 2,868 acres on Big and Little Cedar Creeks, which are Pascagoula River tributaries. However, the Project would maintain, restore and protect the environmental, ecological and economic services of the approximately 6,144,000 acre Pascagoula River watershed. Federal and state agencies already protect over 1,000,000 of the Pascagoula River watershed's 6,144,000 acres for environmental and ecological purposes (The Nature Conservancy 2005). The Project Area's roughly 2,868 acres would not be *sacrificed* to maintain, restore, enhance or protect the Pascagoula watershed's 6,144,000 acres but the short-term tributary stream and stream-wetland environmental and ecological functions would be transformed into lake-based wetlands and habitats.

Sequentially, it is also necessary to recall the projected climate change impacts on the Project Area and the Pascagoula River and watershed. The timing and volume of the Pascagoula River's fresh water flows have impacts as far down-stream as the Grand Bay National Estuarine Research Reserve (NERR) at the mouth of the Pascagoula River (Figure 8.1). The Grand Bay NEER's 2013-2018 Management Plan recognizes that climate change will amplify current threats to coastal habitats, causing greater habitat loss and alteration. Specifically, hydrologic alterations, sea level rise and increased salinities associated with climate change threaten coastal habitats (Grand Bay NERR 2013). Likewise, it is *highly likely* that climate change will increase heavy precipitation, decrease summer flows and effect estuaries (Stratus Consulting 2010). These impacts will affect fish and wildlife and their habitats, recreation, threatened and endangered species and energy companies. In addition, EPA Region 4 (2013) reports that areas with increased drought intensity, such as the Pascagoula River, "may see alterations in the structure and function of watersheds potentially affecting regional and state wetlands delineation and protection programs" (page 41).

Consequently, maintaining the Pascagoula River's historic hydrologic flows is essential to long-term, watershed-scale environmental, ecological and economic benefits. Even in the Project Area, proactive and managed short-term environmental losses are necessary to avoid or minimize projected, highly likely, long-term, adverse impacts from climate change throughout the Pascagoula watershed. In short, the relatively near-term climate change is projected to seriously disrupt the environmental, ecological and economic productivity of the Pascagoula River and its watershed. Section 9 discusses alternatives to maintain or at least approximate the Pascagoula River's historic hydrologic flows or to minimize or replace water withdrawals.

Figure 8.1 - Grand Bay NERR Vicinity Map (page 7).

9. ALTERNATIVES TO THE RECOMMENDED PROJECT

In addition to the Recommended Project and the required No Action alternative, preliminary consultations with federal and state resource agencies yielded three other alternatives to consider relative to the Recommended Project's Purpose and Need. These alternatives need to be evaluated in drought resiliency, recognizing the surface and shallow subsurface connections of small or temporary streams, non-tidal wetlands, and open waters. The No Action alternative considers the potential environmental, ecological and economic impacts in the Pascagoula watershed without a drought resiliency plan. The Flow Augmentation from Okatibbee Lake evaluates the potential to expand an existing emergency flow augmentation arrangement for the Pascagoula River. The remaining two alternatives 1) water efficiency and conservation and 2) desalination could reduce water use and specifically surface water withdrawals from the Pascagoula River but neither would provide additional water to sustain the Pascagoula River's ecological and environmental services during droughts.

9.1. No Action

The scientific community and peer reviewed literature has failed to reach a consensus on the severity of climate variability in general or quantify its impacts on Pascagoula River flows. However, both the EPA and the COE have recently evaluated the relevant peer-reviewed climate change and hydrology literature for their respective regions that include the Project Area, EPA Region 4 and COE Region 3 (South Atlantic and Gulf Region) respectively (EPA 2013, Stratus Consulting 2010, COE 2015).

The COE found "a strong consensus in the scientific literature that air temperatures will trend sharply upward over the next century in the South Atlantic-Gulf Region. There is much less consensus on the future trending, or lack thereof, in precipitation and streamflow in the region" (page 20). Still, the COE found that managing competing water needs can be challenging when water demand is high and supply is low. Sea levels along the Gulf Coast are projected to increase and may exacerbate salt water intrusion into freshwater water supply. Water supplies may also be strained from increased summer temperatures and heat waves, which lead to increase evapotranspiration, lowering surface water and groundwater supplies. Maintaining necessary flows for competing sources, such as power generation, navigation and ecosystem management, may present some significant, additional challenges to an already complex water resource system (COE 2015 pages 37-38).

EPA's draft report (2013) was more convinced of the severity of climate-change impacts stating that:

> Biological integrity is strongly correlated with stream flow. Expected climate change-related impacts to the Region 4's aquatic ecosystems include **longer durations of low summer stream flows, average stream flow decreases, higher flooding incidences, and increased periods of extremely high and low flows (greater flashiness), with resultant scouring** … Additionally, drought or flood-related stream-flow changes can change nutrient and sediment loadings and habitat availability. Moreover, lower flow results in less dilution facilitating higher in stream concentrations of potentially harmful chemicals and aquatic toxicity. **Overall, climate change-induced flow changes are expected to cause significant changes to the Region's aquatic communities**. At a reduced flow of 20-90%, the Region could lose 3 to 38% of its fish species. (EPA 2013 at page 15; emphasis added).

In addition, EPA found that decreasing days of precipitation and increasing drought intensity was likely to occur. Increasing drought intensity had a high likelihood of impacting EPA's Program restore and protect watersheds, aquatic ecosystems and wetlands both nationally and in Region 4. Those impact's risks in Region 4 included:

- Increased growth of algae and microbes that threaten aquatic ecosystems;
- Additional waterbodies not meeting water quality standards and being listed as impaired
- Less water flow to dilute permitted discharges, alterations of aquatic environments, and increased impairments;
- Alterations in the structure and function of watersheds, potentially affecting regional and state wetlands delineation and protection programs;
- Drying out of seasonal wetlands could affect wetland delineations and programs;
- Increased demands on surface and groundwater resources resulting in water supply problems; and
- Coastal aquifers may experience salt water intrusion because demands/use outstrips recharge. An increased pressure head from higher sea levels may worsen this problem resulting in the need to relocate water and wastewater facilities.

9.2. Water Efficiency and Conservation

Water efficiency and conservation were discussed at length in the 2012 submission to EPA Region 4 (Appendix A). Two salient points on municipal and industrial water supply in the Pascagoula River merit clarification in this Environmental Assessment. First, regarding municipal and or domestic water supply, no surface water was used for municipal or domestic water supply in the Pascagoula watershed until very recently. Secondly, while surface water from the Pascagoula River is critical for industrial water supply in southeast Mississippi, the EPA Region 4 Guidelines did not provide any guidance or references on industrial water efficiency or conservation measures.

As part of Mississippi's recovery from Hurricane Katrina, the Gulf Region Water and Wastewater Plan resulted in monumental institutional and infrastructure changes in municipal water supply in Jackson County (MDEQ 2006). The relatively new Jackson County Utility Authority (JCUA) has moved quickly to adapt many water efficiency and conservation measures, which are within its authority. For example it has tiered water rates to encourage customer water conservation and efficiency (http://jcua-ms.us/rates-and-policies). However, it is important to recognize that private, largely unregulated water wells are very common in the Project Area in both George and Jackson County.

Regarding industrial water conservation and efficiency measures, it is important to emphasize that private companies are extremely sensitive to the release of information about water efficiency and conservation measures that they incorporate into their operations. Many of these water efficiency and conservation measures are *de facto* if not in fact Trade Secrets. The 2012 submission to EPA Region 4 summarized the Jackson County Port Authority's ongoing efforts to update and upgrade its water supply infrastructure and incorporate innovative, on-site water conservation measures.

To date, there is no public domain reports quantifying the effect these measures have or are having on historic, current or projected municipal or industrial water supply demands.

9.3. Headwater Flow Augmentation from Okatibbee Reservoir and other Basin Reservoirs

This Environmental Assessment has presented the Pascagoula basin's current water storage capacity and existing contractual arrangements to release water Okatibbee Reservoir in the basin's headwaters to supplement Pascagoula River flows in sections 1.1.4, 2.2.4 and 4.1. Those discussions also documented the limitations of supplemental releases from Okatibbee Reservoir during the 2000 water year (October 1, 1999 through September 30, 2000) drought of record to maintain minimum stream flows at stream gages on the Pascagoula River and its tributaries. Approximately 32,892 AF of supplemental water was released from Okatibbee Reservoir periodically from July 13 to November 11, 2000 to augment the Pascagoula River's flows at the Merrill gage as follows:

1. from July 13 to August 4, 2000 (Julian Day 195 to 217), 3,328 AF were released;
2. from August 20-September 16, 2000 (Julian Day 233 to 260), 11,110 AF were released; and
3. from September 21-November 11, 2000 (Julian Day 265 to 316), 18,454 AF were released (Pat Harrison Waterway District 2001).

Despite these supplemental releases from Okatibbee Reservoir, the Pascagoula River's minimum daily discharges at the Merrill gage were 649 CFS or 29% less than the 7Q10 and 8% less than the previously recorded minimum flow of 704 CFS set on October 21, 1936 (Turnipseed and Baldwin 2001). The Pascagoula River and its tributaries that flowed below 7Q10s and set minimum flow records despite supplemental releases from Okatibbee are shown in the lower right of Figure 9.1 and Figure 9.2. Furthermore periodic rain fall during this period made it difficult to quantify the actual contribution of supplemental water releases from Okatibbee Reservoir to the Pascagoula River's flows at the Merrill gage during the critical low flow period (Figure 9.3).

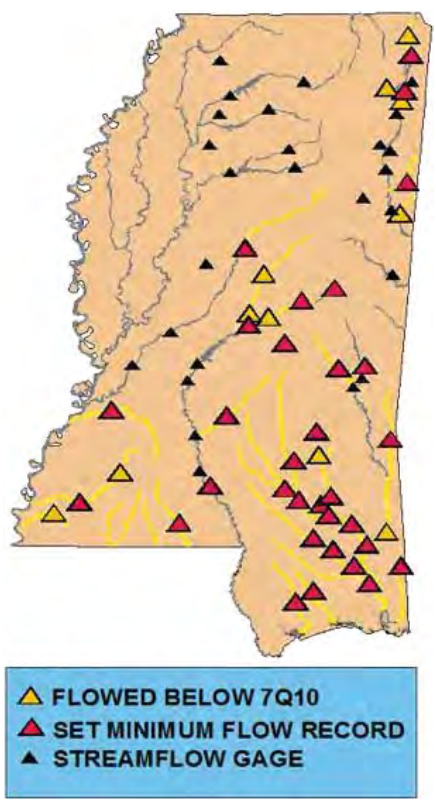

Figure 9.1 - 2000 Drought of Record with Okatibbee Supplemental Releases

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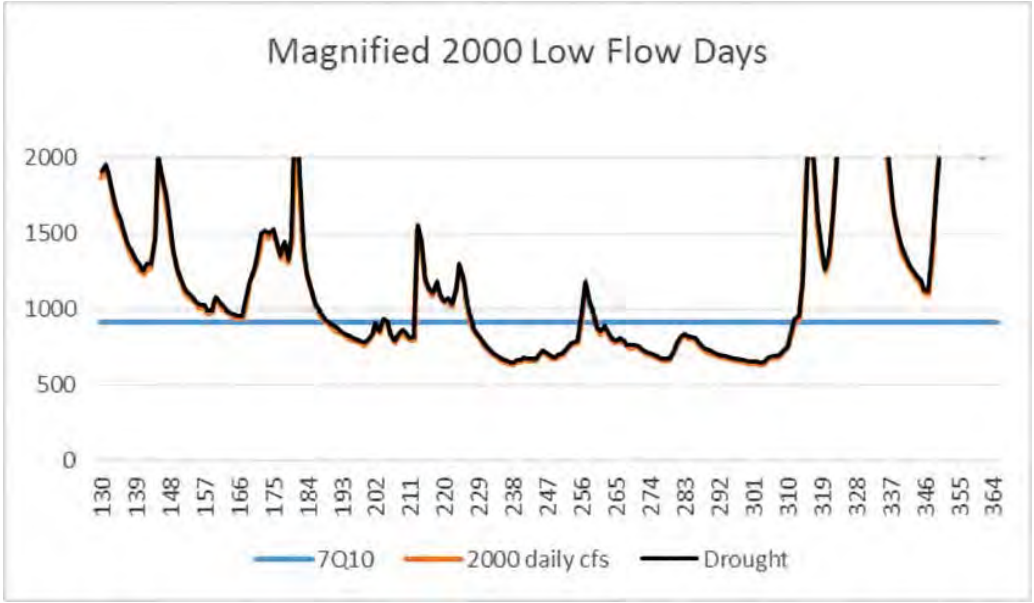

Figure 9.2 - 2000 Pascagoula Low Flows at Merrill gage

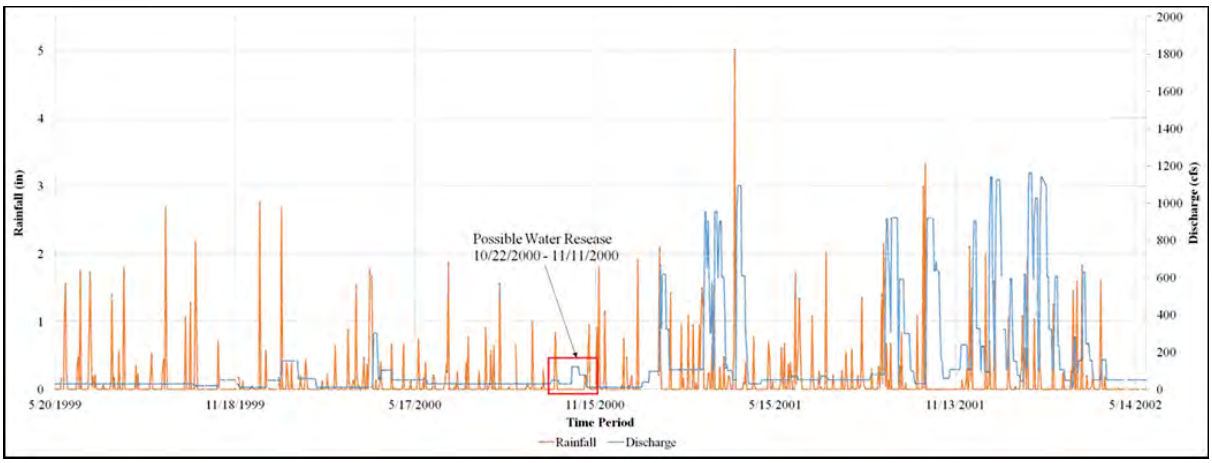

Figure 9.3 - 2000 Precipitation and Low Flows at Merrill gage

Evan after Congress authorized Okatibbee Reservoir, Federal and state agencies and governments in Southeast Mississippi recognized that the lack of surface water supply/storage capacity in the Pascagoula basin, and especially the Pascagoula watershed makes the region's environment, ecology and industrial and economic development extremely vulnerable to severe or prolonged droughts. Accordingly, since Okatibbee Reservoir was authorized, preliminary studies have identified three sites in the Pascagoula Watershed capable of supporting large multi-use/multi-purpose reservoirs to meet the region's long-term water supply needs. It is appropriate to mention these earlier efforts to highlight two points. First, Okatibbee Reservoir was never envisioned as a long-term water supply solution for the Pascagoula River. Secondly, a reservoir in the Pascagoula watershed has long been considered a viable water supply alternative to meet numerous purposes/uses. Briefly the three earlier reservoir projects were:

1. A 15,900 acre Harelston Reservoir on the Escatawpa River in Jackson and George Counties was proposed for flood control, water quality, water supply, recreational and area redevelopment benefits. The Reservoir would have provided 228,500 AF of storage capacity to supplement the Escatawpa River's flows during droughts and an

additional 30,300 AF of water storage for municipal and industrial water supply. When proposed in 1967, the project had a benefit-to-cost ratio of 3.1. The ratio increased to 3.4 if economic redevelopment benefits were included. (COE 1967).

2. In 1970, the Jackson County Board of Supervisors and the Jackson County Port Authority (1970) identified two alternative Reservoir sites in the Big Cedar Creek watershed in northern Jackson and southern George County: a 3,200 acre Reservoir site on Big Cedar Creek and an alternative 5,145 acre site. Either Reservoir was intended to provide reliable municipal and industrial water supply, insure continued regional economic growth, provide major fresh water recreational amenities, augment depleting groundwater supplies and supplement and add reliability to existing water supply systems. The larger site was intended to provide additional water-based recreational amenities and support residential and commercial development adjacent to the reservoir.
3. Finally, in 1974, the PHWD (1974) evaluated a 732 acre reservoir on Big Creek in George County for both recreation and water supply purposes. The Reservoir would have provided 5 MGD of water supply with a maximum five foot draw down.

There projects were all re-evaluated for consideration in Mississippi's Gulf Region Water and Wastewater Plan developed as part of Hurricane Katrina recovery (MDEQ 2006).

In evaluating the feasibility and viability of headwater flow augmentation for drought resiliency on the Pascagoula River, this section identifies the basin's existing water storage capacity from Okatibbee Reservoir and smaller PHWD lakes including inescapable limitations on the maximum volume of supplemental water that could be released from Okatibbee Reservoir without causing unacceptable flooding immediately downstream of the Reservoir. Secondly, the time of travel and natural water loss from evapotranspiration and infiltration are calculated and evaluated over the roughly 251 miles that supplemental water must travel from Okatibbee Reservoir before reaching the Pascagoula River.

9.3.1. Water Storage Capacity and Augmentation Limitations

The Pascagoula basin has extremely limited surface water storage capacity. Okatibbee Reservoir in northwest Lauderdale County, Mississippi is roughly 251 miles upstream of the Pascagoula River. Congress authorized Okatibbee Reservoir in 1962 for flood protection on Chunky Creek and the Chickasawhay and Pascagoula Rivers (Public Law 87-874, Title II 87th Congress, 2nd Session, October 23, 1962). With a storage capacity of 67,650 AF of storage capacity at the design flood elevation of 355 to 343 feet, Okatibbee is by far the basin's largest reservoir. The COE contracted with the PHWD in 1965 to provide up to 13,100 AF of water for industrial and municipal water supply not to exceed 25 MGD per day when the reservoir was between the 343 and 328 foot elevation (USACE Contract # DA-01-076-CIVENG-65-362). Since Congress authorized the Reservoir primarily for flood control with industrial and municipal water supply as secondary purposes, it is likely that Congress would need to authorize, or at least agree, to add drought resiliency as a project purpose.

Recognizing the potential environmental, ecological and economic impacts of future droughts, after the 2000 drought of record, the Jackson County Port Authority (JCPA) and the PHWD negotiated a Water Purchase Contract in 2003 to provide for supplemental water releases from Okatibbee Reservoir. Under the Contract, the PHWD agrees to sell and release up to 4 billion gallons (approximately 12,275 AF) of water from Okatibbee Reservoir during any given fiscal year to the JCPA (Pat Harrison Waterway District and the Jackson County Port Authority. 2003). Releases are coordinated with the MDEQ and the COE. No supplemental water was released from Okatibbee Reservoir during the Pascagoula River's low flow periods in 2007, 2010 or

2011. The contract expired in September 2013 but the PHWD and the JCPA have been engaged in renegotiating the Contract.

Besides Okatibbee Reservoir, there are only eight other reservoirs larger than 100 acres in the Pascagoula basin (MDEQ 2001; Table 9.1). These small reservoirs were designed for recreation, not for water supply. There is essentially no data on their water storage capacity, operational guidelines, or even the mechanisms to regulate water releases. The PHWD manages campgrounds and recreational facilities on six of the eight. However, as discussed in more detail in section 9.2.2, a large amount of any supplemental water released from small reservoirs on the Chickasawhay River and Chunky-Okatibbee Creeks would be lost to infiltration prior to reaching the Pascagoula River. Likewise, although not discussed in detail here, the Leaf River has serious low flow issues during droughts and may be unable to transport supplemental water to the Pascagoula (Dept. of Energy 2006 and 2008). The 600 acre Flint Creek Reservoir on the Black-Red River could potentially provide some direct flow augmentation to the Pascagoula River.

	Reservoir	Watershed	Agency	Surface Acres
1	Bogue Homa	Lower Leaf	DWFP	1,200
2	Flint Creek	Black-Red	PHWD	600
3	Archusa Creek	Upper Chickasawhay	PHWD	450
4	Maynor Creek	Lower Chickasawhay	PHWD	450
5	Turkey Creek	Chunky-Okatibbee	PHWD	250
6	Big Creek	Lower Leaf	PHWD	200
7	Dry Creek	Upper Leaf	PHWD	150
8	Lake Perry	Lower Leaf	DWFP	125

Table 9.1 - Pascagoula Basin's Public Reservoirs Larger Than 100 acres

9.3.2. Downstream Travel Time and Water Loss

Having located and quantified the basin's existing water storage capacity, several additional factors must be considered in evaluating their effectiveness in augmenting Pascagoula River flows during droughts. This analysis evaluates three primary limitations on the effectiveness of headwater water storage for drought resiliency: 1) how much water can be released from those reservoirs, 2) how long does the released water take to reach the Pascagoula River, and 3) how much water is lost in transit to the Pascagoula River. These issues are discussed in turn below.

For Okatibbee Reservoir there are two limitations on how much supplemental water can be released. First, the COE's contract with the PHWD caps supplemental Okatibbee Reservoir releases at 25 MGD. Water released from Okatibbee Reservoir first flows into Okatibbee Creek, which is a small creek with a 7Q10 of 12 CFS. Realistically, Okatibbee Reservoir could never release supplemental water into Okatibbee Creek when the creek was at or near flood stage. So regardless of the 25 MGD cap on supplemental releases, a more realistic limitation is to prohibit supplemental water releases from Okatibbee Reservoir when Okatibbee Creek is in the highest ten percent of natural flows. Similarly potential downstream flooding would limit the timing and volume of supplemental water released from any other reservoir in the basin. This limitation is important because essentially all of the basin's existing reservoirs are on small tributary streams with corresponding small normal flows.

Distance also has a key role in determining how long it takes supplemental water to reach the Pascagoula River. For Okatibbee Reservoir, the Arundel gage on Okatibbee Creek (USGS Gage number 02476600) is the nearest reference gage (Figure 9.4). Pote et al (2015;

Appendix H) identified three occasions during three very low flow years on the Pascagoula River (1999-2001) when it was possible to track a small spike in flows from the Arundel gage to the Pascagoula River's Merrill gage without excessive distortion from precipitation. These three events showed travel times of seven, eight and nine days. For the Okatibbee Precipitation-Evaporation (P-E) Model an eight day travel time was assumed for water from Arundel to reach the Merrill gage.

The Okatibbee model used the same inputs and outflows as the Merrill model discussed in Sections 2.2.5 and 4.1.2. The stream gage record for Okatibbee Creek at Arundel begins in 1968. Therefore, the simulation analyses only included forty years of data. Also the National Weather Service climatological record for Meridian, Mississippi was selected for precipitation in conjunction with the existing evaporation record from Starkville, Mississippi. These new data sets were constructed for use in the new Okatibbee model. The model also referenced the Pascagoula River's flow at Merrill and simulated the release of supplemental water from Okatibbee Reservoir that would be necessary to maintain those flows about 917 CFS (limited by the ten-percentile flood flow at Arundel). Finally, only half of the water released at Okatibbee was added to the Pascagoula River's flows at Merrill, eight days after release to account for water lost to evapotranspiration and infiltration.

The simulations found that technically there were no days during the historic forty year period of record when Okatibbee Reservoir could not have supplied the necessary volume of water necessary to maintain the Pascagoula River's flows at the Merrill gage. However, there are two primary problems.

1. The amount that can be released at any given time is limited by the small normal flow in the receiving water Okatibbee Creek. Any major release from Okatibbee Reservoir could generate a man-made flood event.
2. The eight day time lag between a release and water reaching the Pascagoula River creates a particular problem. Many years the Pascagoula River has long periods when its flow hovers very near 917 CFS at the Merrill gage, occasionally falling under 917 CFS only to quickly rebound after a small rainfall. During these years, the lag between needing the supplemental water and actually receiving it from Okatibbee Reservoir, or likely other reservoirs in the basin's headwaters is so great that it is not likely to be present when it is needed and is likely to show up later when it is not needed.

Given the projected climate change impacts on drought frequency, duration and severity in the Pascagoula Basin, it is likely that the only time the Okatibbee Reservoir or other much smaller headwater reservoirs would be of real use would be during very long, sustained droughts. Even then the headwater reservoirs would only make a relatively small contribution to the Pascagoula Rivers flows (Pote at al 2015; Appendix G).

To better quantify and locate water loss due to infiltration, Dr. Schmitz et al (2015, Appendix I) conducted a hydrograph baseflow-recession analysis of the main Pascagoula River basin stream reach from Okatibbee Reservoir, down Okatibbee Creek, down the Chickasawhay River and following the Pascagoula River to its discharge into the Mississippi Sound. The study found that the baseflow component of streamflow along this lengthy reach is between about 50 and 70 percent. The baseflow component varies seasonally and also decreases as the water flows from the headwaters and increases again when the water reaches Pascagoula (Table 9.2; Figure 9.4). The decrease in baseflow at the Chickasawhay River gage at Enterprise, Mississippi (USGS gage number 02477000) suggests that notable water could be lost to bank storage during times of low flow in the basin, within that portion of the stream reach with the low baseflow contribution. Thus any release of water from reservoirs above this portion of the basin would likely see water loss into the groundwater system prior to reaching the lower reach of the

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basin. In short, baseflow decreases in the stream reach downstream of Okatibbee Reservoir to the Okatibbee Creek gage and then increases again before it reaches the Mississippi Sound (Appendix I). This significant find may suggest that during periods of low flow, when supplemental water is urgently needed in the Pascagoula River, considerable supplemental water released from the basin's headwater reservoirs could be lost to bank storage.

Site Number	Site Name	Site Location	Drainage Area	
			(mi^2)	(km^2)
02476600	Okatibbee Creek	Arundel, MS	342.0	885.0
02477000	Chickasawhay River	Enterprise, MS	918.0	2377.0
02479000	Pascagoula River	Merrill, MS	6590.0	17068.0
02479310	Pascagoula River	Graham Ferry, MS	8204.0	21248.0

Table 9.2 - Selected Pascagoula Basin USGS Stream Gages

To summarize, Pote et al.'s (2015) simulations found that Okatibbee Reservoir was *theoretically* capable of storing and releasing sufficient water to have maintained the Pascagoula River's flows above 917 CFS at the Merrill gage for the forty year period of record from 1968 to 2008 (Appendix G). However, in fact during the 2000 drought of record Okatibbee Reservoir could not deliver sufficient water to the Pascagoula restore or maintain Pascagoula River flows above 917 CFS even with the assistance of periodic precipitation (Turnipseed and Baldwin 2001, Figures 9.1, 9.2, and 9.3). Dr. Schmitz et al.'s (2015) hydrograph baseflow-recession analysis found that the decreased baseflow at the Chickasawhay River gage at Enterprise, Mississippi (USGS gage number 02477000) suggests that critical surface water could be lost to bank storage during low flow periods times in the basin within that portion of the stream reach from the headwaters to the Pascagoula River (Figure 9.4, Appendix I). In other words, during prolonged, severe droughts like the 2000 drought of record, an increasing percentage of any supplemental water released from Okatibbee Reservoir or other reservoirs upstream of the Chickasawhay River gage at Enterprise, Mississippi would be lost to bank storage. Accordingly, supplemental releases from Okatibbee Reservoir would undoubtedly provide environmental and ecological benefits to the upper Pascagoula basin and measurably increase flows on the Pascagoula River; however, collectively Okatibbee Reservoir and the other smaller headwater reservoirs are unable to provide long-term, sustained drought resiliency on the Pascagoula River and the Mississippi Sound in light of projected climate change drought and corresponding low flow impacts.

Figure 9.4 - Locations of Selected Pascagoula Basin USGS Stream Gages

9.4. Desalination Plant

Until recently, the high cost energy requirements and environmental impacts limited the feasibility of desalination to areas with inexpensive energy and extremely scarce freshwater. Continuing advances in membrane technologies and energy efficiencies have made saltwater

desalination competitive with other water supply alternatives in some areas for some high-valued uses (National Academy of Sciences 2008). EPA Region 4 requested that a desalination plant be evaluated to provide a consistent industrial water supply for industries that currently rely on surface water provided by the Jackson County Port Authority (JCPA) withdrawn from the Pascagoula River at Cumbest Bluff, rather than a low flow augmentation approach (Appendix A). This analysis evaluates desalination under this new operational construct. However, it is important to note that the JCPA's existing industrial water supply system and infrastructure was designed to transport, treat and distribute freshwater withdrawn from the Pascagoula River at Cumbest Bluff and would require extensive and expensive modification to accept or deliver water from a desalination plant.

In 2012 and 2013, the Pacific Institute undertook an intensive evaluation of existing, pending or planned desalination plants worldwide and published their findings in several reports on *Key Issues in Seawater Desalination in California* (Cooley and Ajami 2012, Cooley and Heberger 2013, and Cooley, et al 2013). These reports document often significant variations in the desalination costs and environmental impacts resulting from differences in local economies and environmental conditions. Still, generally seawater desalination:

- is significantly more expensive than freshwater water supply and demand management options with costs in California ranging from $1,900 to more than $3,000 per acre-foot of treated water (Cooley and Ajami 2012);
- is not economically viable as a backup or emergency drought response because customers quickly return to much less expensive water supplies as soon as the emergency ends (City of Santa Barbara 2015; Cooley and Ajami 2012).
- is an energy-intensive process that uses more energy per gallon of water provided than freshwater supplies, even with newer energy efficiency measures;
- uses an average of two gallons of sea water to produce a gallon of freshwater, this sea water is habitat for phytoplankton, fishes and invertebrates (Cooley et al. 2013); and,
- produces large amounts of a highly saline brine that must be disposed. The nature and concentrations of other chemicals in the brine vary depending the chemicals used and the frequency of use during the treatment process. (Cooley et al. 2013, National Research Council 2008).

Given the significance of site-specific variations, the general costs and environmental impacts are discussed below. This discussion concludes by outlining a desalination plant's potential direct, secondary and cumulative environmental impacts

9.4.1. Construction and Operation and Maintenance Costs

All water projects have two types of costs: 1) construction costs and 2) continuing operation and maintenance (O&M) expenses. Both of these costs can vary considerably based on anticipated and actual water demand and treatment. Cooley and Ajami (2012) analyzed financial information on numerous desalination plants and found that large plants designed to produce 25 mgd or more generally have higher capital and O&M costs than smaller plants producing less than 25 mgd. So the first step to evaluate a desalination plant as an alternative to the Recommended Project is to determine volume of water it would be expected to provide. MDEQ has permitted the JCPA to withdraw up to 100 MGD from the Pascagoula River at Cumbest Bluff. However, currently JCPA only withdraws roughly 35 mgd during periods of peak demand. To allow for a margin of error and potential near term demand increases, an initial desalination plant capacity of 50 mgd with a potential build out expansion to 100 MGD are evaluated (Table 9.3).

Unit	Capacity (mgd)	Initial (50 mgd)		Ultimate (100 mgd)	
		Qty. Required	Cost	Qty. Required	Cost
Raw Water Intake	100	1	$65,000,000	1	$65,000,000
Pumps	50	1	$25,000,000	2	$50,000,000
Pre-Treatment	50	1	$25,000,000	2	$50,000,000
Main Treatment	50	1	$60,000,000	2	$120,000,000
Piping	50/100	1	$45,000,000	15	$65,000,000
Site Work	50/100	1	$55,000,000	15	$80,000,000
Subtotal – Construction			$275,000,000		$430,000,000
Contingency	20%		$55,000,000		$86,000,000
Engineering			$35,000,000		$55,000,000
Legal			$5,000,000		$5,000,000
Acquisition			$5,000,000		$5,000,000
Total:			$375,000,000		$581,000,000

Table 9.3 - Projected Desalination Plant Construction Costs

O&M costs are even more speculative than construction costs. However, plants operate most efficiently with the lowest costs per unit of water (measured in acre-feet) at or near capacity. For example, Cooley and Ajami (2012) found that a 50 MGD desalination plant operating at full capacity could provide an AF of treated water for $2,678. When producing 20 MGD, that AF of water costs $5,356. When producing 10 MGD, the cost of an AF of water increases to $9,820.

9.4.2. Environmental Impacts

Initial environmental issues associated with constructing a desalination plant include the location of the facility and the design and siting of saltwater intakes and brine disposal discharges. The National Resource Council (2008) identified four broad categories of environmental issues associated with desalination:

1. Impacts from acquiring source water and possible impingement and entrainment of marine organisms;
2. Impacts from managing waste products/concentrate from the desalination process;
3. Issues with the desalinated product waters; and,
4. Greenhouse gas emissions from the energy-intensive desalination process.

Still, the report finds,

> "considerable uncertainty about the environmental impacts of desalination and, consequently, concern over its potential effects. Possible environmental impacts of desalination are impingement and entrainment of organisms where seawater is taken in, ecological impacts from disposing of salt concentrates [brine], and increased greenhouse gas emissions from increased energy use, among other concerns." (National Research Council 2008 at page 2).

Assuming that the facility and associated pipelines would be sited in close proximity to the Mississippi Sound, it is difficult to avoid impact to complex and sensitive coastal wetlands. During operations, the desalination plant would require a large amount of energy. Comparable sized reverse osmosis (RO) desalination plants use an average of 15,000 KWH per mgd of freshwater produced (Cooley and Heberger 2013). Electrical energy for a desalination plant to

provide water for the JCPA's industrial clients would come from Mississippi Power Company's coal-fired Plant Daniel generating unit. Normally, using electricity from a coal-fired power plant would result in greenhouse gas emissions and contribute to global warming. However, in 2008 Plant Daniel joined a United States Department of Energy-sponsored CO_2 sequestration demonstration as part of the Southeast Carbon Sequestration Regional Partnership. The project's goal is to demonstrate safe and secure CO_2 storage in a deep saline reservoir. The Lower Tuscaloosa Formation Massive Sand Unit was selected for CO_2 sequestration after a review of candidate saline reservoirs. In October 2008, over 3,000 tons of CO_2 was injected into the site (Riestenberg 2009).

The desalination process also produces brine, which is a high concentration of salt and minerals that creates buildup of salt deposits near the outflow. The facility discharge would be located on the ocean floor and would alter the temperature and other aspects of the surrounding ocean floor's chemical composition, which are invariability detrimental to marine life. The life cycle and reproductive success of shrimp are highly associated with water salinity. The Mississippi's Gulf coast is a highly productive shrimping area because of the relatively shallow waters and access to abundant brackish water and marsh areas. In 2012 the Mississippi seafood industry contributed approximately $377 million to the state economy (MSU 2015). The desalination alternative has not been formally presented to DMR for comment; however, DMR has expressed significant concerns about a desalinization plant's potential impacts on the coastal ecosystem and commercial and recreational fisheries.

9.4.3. Summary of Potential Direct, Secondary and Cumulative Impacts

As stated in the 2013 water efficiency submission to EPA Region 4, this alternative fails to address the Application's Stated Purpose and Need (Appendix A). Generally, the construction and O&M costs make saltwater desalination a final option that is only pursued when there are absolutely no alternative fresh water supplies available. Notwithstanding the projected more frequent, severe and prolonged droughts in the region, and the periodic threats the Pascagoula River's low flows present to the JCPA's water withdrawals, the River remains a cost effective, environmentally viable, water supply for the JCPA. This alternative is also outside the co-applicants' legal authority to pursue, although the Jackson County Board of Supervisors would likely be involved to some extent with the JCPA as the project applicant. A desalination plant to replace the Pascagoula River as an industrial water supply for the JCPA would ensure up to 35 mgd of water remained in the River from Cumbest Bluff downstream to the Pascagoula River's discharge into the Mississippi Sound. Still, a desalination plant would not return any water to the Pascagoula River during droughts and result in many of the same negative environmental and ecological impacts associated with more frequent, severe and prolonged droughts discussed under the No Action Alternative in Section 9.1. Plant Daniel's proactive participation in a CO_2 sequestration project, coal-fired generation likely faces increasing federal regulatory scrutiny and may result in secondary regional air quality concerns.

The plant would also potentially have significant coastal zone impacts. The location and design of the saltwater intake would have to be carefully evaluated to minimize adverse impacts on a complex mosaic of near-shore, estuarine and marine ecosystems. Likewise, brine disposal and storage would face similar and likely more complex permitting issues with potentially direct and significant impacts on important commercial and recreational fisheries and associated nature based tourism. These impacts could give rise to Environmental Justice issues for minority and low income populations that depend on these near shore fisheries for income and food. For these reasons, a desalination plant still fails to be the least environmentally damaging, practicable alternative to the Stated Purpose and Need.

10. LEAST ENVIRONMENTALLY DAMAGING PRACTICABLE ALTERNATIVE

The first step to determine the least environmentally damaging practicable alternative (LEDPA) is to recall the Recommended Project's Statement of Purpose and Need. These were stated in Sections 1.4.2 and 1.4.3. The Project's purpose is to provide sufficient surface water and restore base flow to maintain the Pascagoula River's flows above established minimum stream flows of 917 CFS at the Merrill stream gage through 2060; notwithstanding climate change projections of more frequent, severe and longer droughts in the basin that will result in more frequent, severe and longer low flow periods (Section 1.4.2). Sections 2.2 and 4.1 in particular document the Pascagoula River and watershed's need for the Recommended Project using historic data sources and field data collection which were then used to project and quantify climate change impacts.

The Recommended Project's Purpose and Need and the LEDPA correspond with the broader international climate change discussion in the fact that small, but detectible changes in the frequency, duration and severity of Pascagoula River low flows can have disproportionate environmental, ecological and economic impacts. As opposed to predicting devastating, widespread 21st Century *megadroughts* (Cook et al. 2015), or recommending draconian, emergency measures such as those being implemented in response to California's ongoing devastating drought, this Recommended Project is a proactive response to what is admittedly a relatively modest, but measurable change in the frequency, duration and severity of Pascagoula River low flows. As a result, during future droughts, the loss of 9.3 CFS of flow into Sowashee Creek in Kemper County, in the Pascagoula basin's headwaters, may adversely impact the Pascagoula River's ability to provide environmental, ecological and economic services downstream (Section 2.2.2). The DOE's proposed *small* water withdrawal structured to minimize Pascagoula River flows parallels this theme (Section 4.2.2). ICF Jones and Stokes, Inc. (2009) found that, under **average conditions** the proposed withdraw was far less than the natural hourly or daily variance in flow associated with variability in precipitation, groundwater inputs, other anthropogenic impacts or measurement error. Likewise, **under most conditions** the proposed withdrawal would not likely be detectible in the field. Perhaps most tellingly, the report found that these types of relatively small but detectable changes should be considered when evaluating Pascagoula River flow alternations (ICF Jones and Stokes, Inc. 2009). Drought resiliency is irrelevant to *average conditions* or *even most conditions* on the Pascagoula River, instead this Statement of Purpose and Need and Recommended Project is concerned with those occasions when every single CFS counts and may be necessary to avert tragic environmental, ecological and economic damage.

In addition to the Recommended Project, this Environmental Assessment identified and evaluated four other alternatives to meet the Purpose and Need: 1) No Action (Section 9.1), 2) Water Efficiency and Conservation (Section 9.2 and Appendix A), 3) Flow Augmentation from Okatibbee and other headwater Reservoirs (Section 9.3), and 4) a Desalination Plant (Section 9.4). In comparing alternatives to arrive at the LEDPA, it is important to identify or separate, to the extent possible, local short-term environmental uses or impacts from maintaining and enhancing regional, long-term productivity. The second step is to separate alternatives' local impact or Project Area. Briefly, the alternatives and their de facto Project Areas and associated impacts are:

1. <u>No Action</u>: Applies to the entire Pascagoula Basin but has no *permitable* impacts.
2. <u>Water Efficiency and Conservation</u>: Applies predominately to Jackson County via the Jackson County Utility Authority and the Jackson County Port Authority as George County does not have a single county-wide water utility.

3. Flow Augmentation: The primary Project Area would be Okatibbee and possibly other headwater reservoirs and their respective receiving waters. The two primary impacts would be: a) impacts or limitations on the reservoirs' primary authorized purpose (e.g. flood control, recreation, etc.); and b) potential flooding in streams receiving initial supplemental releases.
4. Desalination Plant: The plant or plants, if a scalable approach was taken, would have a relatively small Project Area but would involve two decisions with potentially major environmental impacts on Mississippi's coastal zone. These decisions would involve the siting, type and operational parameters of the salt water intake the brine discharge.
5. Recommended Project: The Project Area on the Big and Little Cedar Creek watershed and its impacts are discussed at length in Sections 4 and 7.

Thirdly, it is appropriate to consider the relationship between these Project Areas and local impacts and the Project's regional purpose.

1. No Action: Without a near-term proactive response, projected climate change projections predict more frequent, severe and longer droughts which will result in enormous adverse impacts to the Pascagoula River and watershed.
2. Water Efficiency and Conservation: EPA Region 4's Guidelines on Water Efficiency were developed to slow, minimize or reduce future increases in municipal and industrial water demand and associated water withdrawals not for drought resiliency (Appendix A). Still, reducing future municipal and industrial use of surface and groundwater from the lower Pascagoula River and watershed may slow the water tables decline and slightly increase baseflows in the Lower Pascagoula River near the Mississippi Sound. However, given Mississippi's regulatory framework for surface and groundwater withdrawals and the existing patterns and locations of municipal, individual and especially industrial water withdrawals in the Pascagoula watershed, this alternative would have extremely limited if any regional drought resiliency benefits.
3. Flow Augmentation: Spatially, supplemental water from the basin's few headwater reservoirs would provide some drought resiliency for the Pascagoula River and several of its tributary rivers and streams. No obvious adverse environmental or ecological impacts were identified during this preliminary evaluation. Still, there are several unavoidable constraints on the effectiveness of supplemental water releases from headwater reservoirs for drought resiliency. These constraints include the time of travel and the volume of water lost between the release point and arrival at the Pascagoula River. Furthermore, calculated baseflow decrease at the Chickasawhay gage at Enterprise, Mississippi (USGS gage 02477000) suggests any supplemental water released from reservoirs upstream would see relatively large water losses into the groundwater system before reaching the Pascagoula River (Schmitz et al 2015; Appendix I and Section 9.3.2). A long-term Pascagoula River drought resiliency program could include flow augmentation from headwater reservoirs but would also need the Recommended Project to enhance baseflow and provide an immediate drought response.
4. Desalination Plant: Much like water efficiency and conservation, desalination is much more of a water supply alternative as opposed to a drought resiliency response. Furthermore, much like the DOE's EIS and SEIS related to the proposed expansion of the SPR at Richton, Mississippi, permitting a desalination plant would need to address extremely complex and controversial real and perceived impacts of water withdrawals from and brine discharges into the Mississippi Sound or other estuarine environments (DOE 2006 and 2008).
5. Recommended Project: The Recommended Project is designed and sited to provide flexible, stand-alone, two-prong drought resilience for the Pascagoula River and

watershed. The two reservoirs will restore and enhance the watershed's water table, which will provide watershed-scale benefits to wetlands, streams, and critical habitat for threatened and endangered species. Surface water stored in the reservoirs will be available to immediately respond to Pascagoula River flows below 917 CFS at the Merrill gage and maintain flow augmentation for the duration of any projected drought through 2060. Under the PHWD's management, the two reservoirs would also provide new regional public outdoor recreational opportunities.

In closing, given the Project's Statement of Purpose and Need, the Recommended Project is found to be the LEDPA to provide long-term drought resiliency for the Pascagoula River and watershed as well as the adjacent coastal environments within a comprehensive, integrated watershed-scale or basin-scale analysis.

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11. COORDINATION AND CONSULTATION

To expand on the Project History in section 1.3, this Recommended Project arose from a strong regional concern about the economic, environmental and ecological impacts of a series of recent droughts and projected more frequent, severe and prolonged droughts on the Pascagoula River. Cooperating federal and Mississippi state agencies were consulted early and often to provide guidance for preparing this application. The data collected and analysis for this Joint Application and Notification and Environmental Assessment was undertaken to define the Project's Statement of Purpose and Need and the Recommended Project's size and location, in compliance with applicable federal and State of Mississippi laws and regulations.

11.1. Coordination and Consultation

Conceptually, the Project was initially discussed with MDEQ's Offices of Pollution Control and Land and Water Resources and the Mississippi Department of Marine Resources (DMR). The Project was first presented to staff from the U.S. Army Corps of Engineers (COE) Mobile District Regulatory and Operations Teams in Mobile, Alabama on August 8, 2010. During the meeting, we learned about EPA Region 4's Guidelines on Water Efficiency Measures for Water Supply Projects in the Southeast United States issued June 21, 2010. No participants at the meeting were able to provide clear guidance on how these new Guidelines would be integrated into the Clean Water Act § 404 permitting process.

After reviewing the Guidelines and holding discussions with EPA Region 4's Wetland Regulatory Section staff, we met to discuss the Project and the Guidelines in Atlanta, Georgia on September 26, 2011. During this meeting, Region 4 requested that we consider desalinization as one of the possible alternatives to the Recommended Project. After further discussions with EPA Region 4, the COE Mobile District, MDEQ and DMR, we decided to comply with the Guidelines and evaluate Region 4's response before proceeding with the Clean Water Act § 404 application process.

A substantial *Southeast Mississippi Regional Water Supply Project Application* was prepared to comply with the Guidelines and submitted to EPA Region 4 on November 21, 2012. The Region provided a timely response on January 29, 2013. These referenced documents are included in Appendix A. EPA Region 4's response provided numerous suggestions, which are incorporated into this permit application and Environmental Assessment.

On June 2, 2014, a preliminary Draft Clean Water Act § 404 Joint Application and Notification was submitted to the COE Mobile District and the DMR. The COE Mobile District Project Manager was able to coordinate an inter-agency, pre-application meeting on June 26, 2014. The meeting included representatives from the George County Board of Supervisors, several offices of the MDEQ, the COE Mobile District, the Mississippi Office of the US Fish and Wildlife Service, the DMR, the Mississippi Department of Wildlife, Fisheries and Parks (MWF&P) and the EPA Region 4 (via telephone). These agency representatives provided very helpful information including, but not limited to, the importance of the Statement of Purpose and Need, quantifying the firm water yield necessary to meet the described need, the quality/quantity of wetlands and streams which would be impacted, wetlands and stream mitigation, threatened and endangered species, water quality certification and coastal impacts.

All cooperating federal, state, and local agencies and/or officials have been informed verbally and in writing of the Recommended Project and preparation of the Joint Application. The Native American tribes have indicated that they will only respond on a *government to government*

basis. So, we assume that the COE will manage coordination with the Native American tribes interested in the Recommended Project or Project Area. The Mississippi Department of Archives and History (MDAH) has requested a detailed Cultural Resources assessment of the Project Area, so copies of the completed Cultural Resources report will be provided to those Native American tribes at their request. Copies of request letters sent via certified mail to cooperating resource agencies, along with their response letters, if any, are included in Appendix K. Briefly, agency coordination and consultations include:

Federal

- U.S. Army Corps of Engineers (COE), Mobile District Regulatory Branch was made aware of the proposed Project and provided comments and guidance on a variety of regulatory issues that will be involved throughout the duration of the Project.
- U.S. Fish and Wildlife Service (USFWS) provided a list of federally listed species potentially found in the Project Area and recommended that a qualified biologist conduct a visual survey for the identified species and that George and Jackson Counties develop a Migratory Bird Conservation Plan specifically considering the effects of forest clearing and fragmentation of migratory bird species.
- Natural Resources Conservation Services (NRCS) provided a Farmland Conversion Impact Rating form.

State Of Mississippi

- Mississippi Department of Environmental Quality (MDEQ) Air Toxics Branch does not expect the Recommended Project to adversely affect ambient air quality; contingent on receiving any required air emissions permits from MDEQ's Permit Board prior to commencing construction and compliance with all applicable asbestos and lead-based paint control regulations.
- Mississippi Department of Environmental Quality (MDEQ) Environmental Permits Branch acknowledged participating in interagency discussions and emphasized that the Recommended Project should consider the water quality within waters affected by the Project and the Project's effects be considered.
- Mississippi Department of Environmental Quality (MDEQ) Office of Pollution Control. A response from the Office of Pollution Control has not been received as of this time.
- Mississippi Department of Marine Resources (DMR) has participated in interagency discussion on the Recommended Project but has not responded to the letter notification.
- Mississippi Department of Archives & History (MDAH) Brockington and Associates has facilitated interagency discussions between MDAH, the COE and the Pickering Firm, Inc. related to the Recommended Project and appropriate field methods and sampling scheme for a cultural resources survey of the Project Area (Appendix D).
- Mississippi Department of Wildlife, Fisheries, and Parks (MWF&P) provided a list of species of concern within 2 miles of the Project Area, made several recommendations on aquatic species of concern that are susceptible to sedimentation and stream degradation, possible gopher tortoise impacts, and wetland and stream impacts. Furthermore MWF&P requested that serious consideration be given to the cumulative impacts of stream and wetland disturbance and elimination and appropriate in-kind mitigation provided if those impacts occur. Finally, MWF&P stressed the importance of properly implemented, monitored and maintained stormwater best management practices to prevent suspended silt and contaminates from negatively affecting water quality and habitats in nearby streams and waterbodies.

George County, Mississippi

- George County Floodplain Coordinator was made aware of the proposed Project and provided comments and guidance on process to revise George County flood maps as necessary to reflect the Recommended Project's effects.

11.2. Remaining Federal, State and Local Permits, Approvals and Certifications

Major remaining federal, state and local permits, approvals and certifications, which will be integrated into the Clean Water Act § 404 permit process, include but may not be limited to:

Federal

- FEMA:
    - Floodplain map revision (in conjunction with MEMA)
- USFWS:
    - Threatened and Endangered Species
    - Migratory Bird Conservation Plan (recommended)

State of Mississippi

- MDAH:
    - Cultural Resource Assessment Certification
- MDEQ:
    - Application to Construct a Dam and Impound Surface Water (Office of Land and Water Resources)
    - Application for Permit to Divert or Withdraw For Beneficial Use the Public Waters of the State of Mississippi (Office of Land and Water Resources)
    - Application Large Construction Storm Water General Permit (Office of Pollution Control)
    - Clean Water Act § 401 Water Quality Certification (Office of Pollution Control)
- MDMR:
    - Clean Water Act § 404
    - Coastal Zone Management Consistency Certification
- MEMA:
    - Floodplain map revision (in conjunction with FEMA and George and Jackson County)

REFERENCES

American Rivers. 2009. 2009 America's Most Endangered Rivers: Pascagoula River, MS. #9. Of file with Pickering Firm.

City of Santa Barbara, California. 2015. Desalination-Project Status. Available at http://www.santabarbaraca.gov/gov/depts/pw/resources/system/sources/desalination.asp (Accessed June 9, 2015).

Chapman, S.S. G.E. Griffith, J.M. Omernik, J.A. Comstock, M.C. Beiser, and D. Johnson. 2004. Ecoregions of Mississippi (color poster, descriptive text, summary tables, and photographs): Reston, Virginia, U.S. Geological Survey (map scale 1:1,000,000).

Cook, B.I., T.R. Ault, and J.E. Smerdon. 2015. *Unprecedented 21st century drought risk in the American Southwest and Central Plains*. Science Advancement. February 12, 2015.

Cooley, H, Ajami, N., and Heberger, M., 2013. *Key Issues in Seawater Desalination in California-Marine Impacts*. Pacific Institute. (December 2013).

Cooley, H and M. Herberger. 2013. Key Issues in Seawater Desalination in California-Energy and Greenhouse Gas Emissions. Pacific Institute (May 2013).

Cooley, H. and N. Ajami. 2012. *Key Issues in Seawater Desalination in California-Cost and Financing*. Pacific Institute (2012).

Covarrubias, A. 2015. Santa Barbara working to reactivate mothballed desalination plant. LA Times On-Line Edition, March 3, 2015. Available at http://www.latimes.com/local/california/la-me-santa-barbara-desal-20150303-story.html (Accessed June 9, 2015).

Dean, Thomas J., Barks, James H. and Williams, James H., 1976, *A Guide for the Geologic and Hydrologic Evaluation of Small Lake Sites in Missouri*, Missouri Department of Natural Resources, Water Resources Report, No. 31.

U.S. Environmental Protection Agency. 2015. *Connectivity of Streams and Wetlands to Downstream Water: A Review & Synthesis of the Scientific Evidence*. EPA/600/R14/475F (January 2015). Available at: http://www.eenews.net/assets/2015/01/15/document_gw_03.pdf (Accessed Feb. 18, 2015).

EPA Region 4. 2013. *Draft Adaptation Implementation Plan*. (139 pages). Available at: http://epa.gov/climatechange/Downloads/impacts-adaptation/region-4-plan.pdf (Accessed February 24, 2015).

EPA Region 4. 2010. *Guidelines on Water Efficiency Measures for Water Supply Projects in the Southeast*. June 21, 2010. Available at: https://www.americanrivers.org/assets/pdfs/clean-water-/epa-region-4-guidelines-on.pdf (Accessed February 24, 2015).

Fetter. C. W., 2001. Applied Hydrogeology: Upper Saddle River, New Jersey. Prentice Hall, 598 pp.

Frazier, D.E. and Osanick, A. 1969. *Recent Peat Deposits-Louisiana Coastal Plain*: In Dapples, E.C. and M.E. Hopkins, eds. Environments of Coal Deposition. Geological Society of America, Special Paper 114. Pages 63-86.

George County, Mississippi. 2012. Flood Damage Prevention Ordinance, Adopted October 25, 2006, Amended to include updated maps 10/16/2008, Amended to include new digital maps 9/19/2012.

Grand Bay National Estuarine Research Reserve. 2013. Management Plan 2013-2018. 211 pp.

ICF Jones and Stokes, Incorporated. 2009. *Effects of the Withdrawal of Water on Protected Species in the Pascagoula River: An Application of the Instream Flow Incremental Methodology. Strategic Petroleum Reserve Richton*. Report by ICF Jones and Stokes Incorporated, Olympia, Washington to U.S. Department of Energy, Washington, DC. No. ICF J&S 00356.08. March 2009. 120 pp.

Jackson County Board of Supervisors and Jackson County Port Authority. 1970. Jackson County Water Supply System: A Proposed 100 Million Gallon Per Day Water Supply System with a Multi-Purpose 3,800 Acre Reservoir. (On File with Pickering Firm, Inc.)

Killian, Courtney, 2015, Surface-Water and Groundwater Interactions of a Stream Reach and Proposed Reservoir Within the Pascagoula River Basin: George County, Mississippi, MS Thesis presented to Mississippi State University.

Li, Z. and M.A. Meylan, 1994, *Lithostratigraphy and petrology of Neogene and Pleistocene sedimentary rocks, south-central Mississippi*: Gulf Coast Association of Geological Societies Transactions, v. 44, p. 383-392.

Mancini, E. A., Tew B. H., Mink R. M., 1992, *Hydrocarbon Productivity Characteristics of Upper Jurassic Smackover Carbonates, Eastern Gulf Coastal Plain:* Gulf Coast Association of Geological Societies Transactions, v. 42, p. 237-244.

Mancini, E. A. and Tew B. H., 1990, *Tertiary Sequence Stratigraphy and Biostratigraphy of Southwestern Alabama:* Geological Survey of Alabama, 51 p.

MDEQ. 2014. Governor Bryant Announces Three New Restoration Projects Totaling $28 Million. Office of the Governor. Available at: http://www.deq.state.ms.us/MDEQ.nsf/page/Main_.11172014?OpenDocument (Accessed June 15, 2015).

_____. 2014a. *Community Conversations – Understanding the Public's Priorities for Coastal Restoration in Mississippi*. pp. 18. (October 2014).

_____. 2014b. State of Mississippi Water Quality Assessment 2014. Section 305(b) Report.

_____. 2014c. Mississippi 2014 Section 303(d) List of Impaired Water Bodies (Final July 24, 2014).

_____. 2012. Total Maximum Daily Load for Biological Impairment Due to Organic Enrichment/Low DO for Sowashee Creek. (March 2012). Available at: https://www.deq.state.ms.us/MDEQ.nsf/0/29DD47847956491886257A84006AAE69/$file/PascagoulaRBSowasheeCreekTMDLOELowDOFeb12.pdf?OpenElement (Accessed June 30, 2015).

_____. 2012a. Data request. Brad Segrest, Data Integration Division. (On File with Pickering Firm, Inc.).

_____. 2006. State of Mississippi Water Quality Assessment 2006. Section 305(b) Report.

_____. 2006. Gulf Region Water and Wastewater Plan. Available at http://www.msgulfregionplan.org/ (Accessed on Nov. 2, 2012).

_____. 2001. *Pascagoula River Basin Status Report*. 29 pp. http://www.deq.state.ms.us/mdeq.nsf/pdf/WMB_pastatusreport2001/$File/pastatusreport2001.pdf?OpenElement (Accessed January 6, 2015).

_____. 2000. Office of Land and Water Resources. *Ground-Water Study of Historical Water-Level and Water-Quality Data in Jackson County, Mississippi*. Open-file Report 99-102, May 1999 and revised 2000.

_____. 1998. Presentation to Commission on Environmental Quality for Adoption of a Low-Flow Standard in the Pascagoula River at Cumbest Bluff in Jackson County, Mississippi. August 27, 1998. (5 pages). Copy on file with Pickering Firm, Inc.

Mississippi Department of Marine Resources. 2015. *Governor's Oyster Council Restoration & Resiliency Final Report* (June 2015). Available at: http://www.dmr.state.ms.us/joomla16/images/dmr/Oyster_Council/Governors%20Oyster%20Council%20Report.pdf (Accessed July 31, 2015).

Mississippi Department of Wildlife, Fisheries and Parks. 2005. *Mississippi's Comprehensive Wildlife Conservation Strategy. 2005-2015. Version 1* (October, 2005). Available at: https://www.mdwfp.com/media/63792/cwcs.pdf (Accessed June 15, 2015).

Mississippi State University, Coastal Research and Extension Center. 2015 Economic Impacts of the Seafood Industry. Available at: http://coastal.msstate.edu/impactseafood.html (Accessed June 9, 2015).

_____. 2009. Center for Urban Rural Interface Studies. George County, Mississippi Land Cover Analysis. 12 pages. Available at: http://curis.msstate.edu/publish/Analysis_books/LCB_george_MS.pdf (Accessed June 11, 2015).

_____. 2009a. Center for Urban Rural Interface Studies. Jackson County, Mississippi Land Cover Analysis. 12 pages. Available at: http://curis.msstate.edu/publish/Analysis_books/LCB_Jackson_MS.pdf (Accessed June 11, 2015).

Mulvaney, T.M. and A.J. Park. 2008. *Opportunities for Protecting Instream Flows in Mississippi*. Mississippi-Alabama Sea Grant Legal Program. Available at: http://masglp.olemiss.edu/Opportunities.pdf (Accessed on June 16, 2015).

National Academies of Science. 2008. *Desalination: A national perspective*. Washington, DC: The National Academies Press. ISBN: 0-309-11924-3 (316 pages).

Newcome, R. Jr., 1967, Ground-Water Resources of the Pascagoula River Basin Mississippi and Alabama, Washington: U.S. Geological Survey Water-Supply Paper 1839-k.

Pat Harrison Waterway District. 2001. 2000 Drought Report. Internal PowerPoint Presentation. On file with Pickering Firm.

_____. 1974. Engineering Study of Proposed Big Creek Water Park.

PHWD and Jackson County Port Authority. 2003. Water Supply Contract. (On file with Pickering Firm).

Pickering Firm, Inc. 2013. Mississippi Power Company Kemper Co. IGCC Treated Effluent Pipeline. Mid-South Annual Engineering and Sciences Conference. The University of Mississippi, Mississippi.

_____. 2012. Southeast Mississippi Regional Water Supply Project Application. (54 pages) (Appendix A).

Pote, J.W., C.L. Wax and M.L. Tagert. 2015. Utilizing Impounded Waters in George County to Decrease Incidence of Low Flow in the Pascagoula River, Phase 2. Mississippi State University, Department of Agricultural and Biological Engineering. 25 pp. (Appendix G).

Pote, J.W., C.L. Wax and A.C. Linhoss. 2015a. Utilizing Impounded Waters to Enhance Critical Habitat for Endangered Species of the Pascagoula River. Mississippi State University, Department of Agricultural and Biological Engineering. 21 pp. (Appendix J).

Pote, J.W., C.L. Wax and M.L. Tagert. 2014. Climate Variability Analysis: Pascagoula River Minimum Flow Supply, Lake Option Analysis. Mississippi State University, Department of Agricultural and Biological Engineering. 762 pp. (Appendix F).

Richter, B.D., M.M. Davis, C. Apse, and C. Kondrad. 2011. A Presumptive Standard for Environmental Flow Protection. River Research and Applications. Vol. 28, Issue 8 pp. 1312-1321.

Riestenberg, D.E., G.J. Koperna, Jr., V.A. Kuuskraa, R. Esposito, K. Harrison, R. Berry, J. Sparks, and R. Rhudy. 2009. *CO_2 Sequestration Permitting at the SECARB Mississippi Test Site*. SPE Americas E&P Environmental and Safety Conference, 23–25 March 2009, San Antonio, Texas.

Schmitz, D., Killian C., Foote J., 2015. Geo-Hydrologic Analysis George County Lake Project Phase II with Appendixes. 80 pp. Mississippi State University, Department of Geosciences. (Appendix I).

Schmitz, D, Lenz, A., and Ladner, C. 2013. Geo-Hydrology Theoretical George County Lake. Department of Geosciences Grant Report with Appendixes. 110 pp. Mississippi State University, Department of Geosciences. (Appendix H).

Southern Mississippi Planning and Development District. 2013. Comprehensive Economic Development Strategy 2013-2017. Available at http://www.nado.org/wp-content/uploads/2014/08/MS-Southern-Mississippi-Planning-Development-District-2013-2017.pdf (Accessed June 30, 2015).

Stratus Consulting Inc. 2010. *Overview of Climate Change Adaption in the Southeastern United States with a Focus on Water and Coastal Resources*. Draft Discussion Paper. Prepared for EPA under contract # EP09H001299. (January 26, 2010). Available at: http://collaborate.coast.noaa.gov/climateadaptation/Lists/Resources/Attachments/52/Overview_Climate_Change_Adaptation_in_SE_US_Water_CoastalResources_Focus_January2010.pdf (Accessed February 20, 2015). 65 pages.

Tetra Tech, Inc., 2010. *Evaluating Sustainability of Projected Water Demands under Future Climate Change Scenarios*, Prepared for Natural Resources Defense Council. (July 2010). 30 pages. Available at: http://rd.tetratech.com/climatechange/projects/doc/Tetra_Tech_Climate_Report_2010_lowres.pdf (Accessed February 23, 2015).

The Nature Conservancy. 2005. *Conserving the Pascagoula River Watershed. Conservation Action Plan* (November 2005). Available at: http://www.nature.org/ourinitiatives/regions/northamerica/unitedstates/mississippi/pascagoula-river-conservation-action-plan.pdf (Accessed July 15, 2015).

Thompson, D.E., 2011. *Geologic Map of Mississippi*. (September 2011). Available at: http://www.deq.state.ms.us/mdeq.nsf/pdf/Geology_MSGeology1969Map/$File/MS_Geology1969.pdf?OpenElement (Accessed July 2, 2015).

Turnipseed, P. and W.T. Baldwin. 2001. *Impact of Drought Conditions on Mississippi Streams and Rivers in 2000*. Proceedings of the Mississippi Water Resources Conference.

U.S. Army Corps of Engineers. 2015. *Recent US Climate Change and Hydrology Literature Applicable to US Army Corps of Engineers Missions—South Atlantic-Gulf Region 03*. Civil Works Technical Report, CWTS 2015-03, USACE, Washington, DC.

_____. 2004. Engineering and Design. General Design and Construction Considerations for Earth and Rock-Fill Dams. EM 1110-2-2300 (July 30, 2004).

_____. 1990. *Project Purpose Based on Speculation*. Memorandum Thru Commander, Missouri River Division (October 18, 1990). Copy on file with Pickering Firm, Inc.

_____. 1987. *Corps of Engineers Wetland Delineation Manual.* Wetland Research Program Technical Report Y-87-1, Waterways Experiment Station, Environmental Laboratory, Vicksburg, MS, January 1987.

_____. 1967. Mobile District. Pascagoula River Comprehensive Basin Study, Vol. III. Appendix D-Engineering Studies for Major Reservoirs.

U.S. Census Bureau. 2015. George County, Mississippi QuickFacts. Available at http://quickfacts.census.gov/qfd/states/28000.html (Accessed July 1, 2015).

_____. 2015a. Jackson County, Mississippi QuickFacts. Available at http://quickfacts.census.gov/qfd/states/28/28059.html (Accessed July 1, 2015).

_____. 2015b. Selected Economic Characteristics-Income (2009-2013). Available at http://factfinder.census.gov/faces/tableservices/jsf/pages/productview.xhtml?src=CF (Accessed July 2, 2015).

U.S. Department of Agriculture. 2006. Natural Resources Conservation Service. *Soil Survey of Jackson County, Mississippi*. Available at: http://www.nrcs.usda.gov/Internet/FSE_MANUSCRIPTS/mississippi/MS059/0/Jackson.pdf (accessed June 2, 2015).

_____. 2005. Natural Resources Conservation Service, Conservation Engineering Division. *Earth Dams and Reservoirs*. TR-60 (July 2005).

_____. 1971. Soil Conservation Service. *Soil Survey of George County, Mississippi*. Available at: http://www.nrcs.usda.gov/Internet/FSE_MANUSCRIPTS/mississippi/georgeMS1971/George.pdf (accessed June 2, 2015).

_____. 1964. Soil Conservation Service. *Soil Survey Jackson County Mississippi*. Series 1960, No. 18. Available at: http://www.nrcs.usda.gov/Internet/FSE_MANUSCRIPTS/mississippi/jacksonMS1964/jacksonMS1964.pdf (accessed June 2, 2015).

U.S. Department of Energy. 2008. *Town Meeting, Concerning the U.S. DOE Supplemental Environmental Impact Statement: Site Selection for Expansion of the Strategic Petroleum Reserve*. April 10, 2008. Pascagoula Civic Center, Pascagoula, Mississippi. 133 pages. Copy on file with Pickering Firm, Inc.

_____. 2006. Office of Petroleum Reserves. Site Selection for the Expansion of the Strategic Petroleum Reserve Final Environmental Impact Statement Volume I. Available at: http://energy.gov/sites/prod/files/EIS-0385-FEIS-01-2006.pdf (Accessed August 10, 2015).

U.S. Geological Survey. 2014. *Current Water Data for Mississippi*. 02479000. Pascagoula River at Merrill, MS. http://nwis.waterdata.usgs.gov/ms/nwis/uv/?cb_00065=on&cb_00060=on&cb_00065=on&format=gif_default&site_no=02479000&period=&begin_date=2013-01-01&end_date=2013-12-31 (Accessed February 23, 2015).

_____. 2014a. *Geologic Units in George County, Mississippi*, On-Line Spatial Data.

_____. 1991. *Techniques for Estimating 7-Day, 10-Year Low-Flow Characteristics for Ungaged Sites on Streams in Mississippi*. USGS Water Resources Investigations Report 91-4130 (Table 1, page 49).

_____. 1986 Sources for Water Supplies in Mississippi. A Cooperative Study Sponsored by the USGS and the Mississippi Research and Development Center. Jackson Mississippi.

_____. 1978. *Availability of Additional Ground-Water Supplies in the Pascagoula Area, Mississippi*. A Cooperative Study Sponsored by the USGS and the Mississippi Research and Development Center. By Wasson B.E. Jackson, Mississippi.

_____. 1967. *Ground-Water Resources of the Pascagoula River Basin Mississippi and Alabama*, Water-Supply Paper 1839-K. By Newcome, R. Jr.

_____. 1965. *Water Resources of the Pascagoula Area Mississippi.* Geological Survey Water Supply Paper 1763. 135 pp. By Harvey, E.J., H.G. Golden and H.G. Jeffery.

Wax, C.L. and J.W. Pote. 1990. *A climatological basis for conservation of groundwater in aquaculture in the Southern region*. Technical Bulletin 169. Mississippi Agricultural and Forestry Experiment Station. Mississippi State, Mississippi.

Williams, Jr., C.H. T. Dinkins, Jr., and T. McCutcheon. 1967. George County Geology and Mineral Resources: Economic and Topographical Survey.