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ASSESSMENT OF COASTAL WATER RESOURCES AND WATERSHED CONDITIONS AT FORT PULASKI NATIONAL MONUMENT, GEORGIA

Caroline McFarlin and Merryl Alber

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Assessment of Coastal Water Resources and Watershed Conditions at Fort Pulaski National Monument, Georgia

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Commonly used abbreviations

CRD - Coastal Resources Division (of the Georgia Department of Natural Resources)
DNR - Department of Natural Resources
EIS - Environmental Impact Statement
EMAP - Environmental Monitoring and Assessment Program (of the EPA)
EPA - U.S. Environmental Protection Agency
EPD - Environmental Protection Division (of the Georgia Department of Natural Resources)
FOPU - Fort Pulaski National Monument
HUC - Hydrologic Unit Code area (geographical region defined by USGS)
GA - Georgia
GIS - Geographic information system
NCA - National Coastal Assessment (of the EPA)
NPDES - National Pollutant Discharge Elimination System (of the EPA)
NPS - National Park Service (in the U.S. Department of the Interior)
NOAA - National Oceanic and Atmospheric Administration (in the U.S. Department of Commerce)
UGA - University of Georgia
USGS - U.S. Geological Survey (in the U.S. Department of the Interior)

Executive Summary

Fort Pulaski National Monument is located near the mouth of the Savannah River Estuary in Georgia. The Park is composed of a series of small islands surrounded by salty, tidally-influenced river channels and creeks. The primary habitats in the Park are maritime forest, intertidal salt marsh, and the main channel of the estuary with its associated tidal creeks. This report provides information on the water quality and biological resources of the Park as well as the potential sources of pollution to the region. The study area for this report focused primarily on those parts of the three counties closest to Ft. Pulaski (Chatham, and Effingham County (GA) and Jasper County, (SC)) that fell within the lower Savannah River basin (USGS Hydrologic Unit Code 03060109), as well as the portion of Chatham County that surrounds McQueens Island, which falls primarily in HUC 03060204. However, the upstream portion of the Savannah River was also included as a potential far-field source of pollutants.

Although there are no real sources of pollutants at Fort Pulaski itself, both point and nonpoint sources of pollutants can be found nearby that have the potential to affect its water resources. Wastewater treatment plants and pulp and paper mills are the primary point sources of organic matter and nutrient loading in the lower Savannah River watershed. Numerous industries (including 20 Superfund sites) release contaminants to the groundwater, soil, or air, and there are also contaminants associated with dredge spoil sites. Non-point loading of pollutants occurs via stormwater runoff and atmospheric deposition. In addition, two major nuclear facilities and the Port of Savannah are located upstream of the Fort Pulaski study area.

There have been numerous alterations to the Savannah River that have likely affected conditions at Fort Pulaski, including deepening and widening of the channel for navigation and the operation of tide gates and upstream dams. At present, a proposal by the Georgia Ports Authority to further deepen the channel is being considered. The Savannah Harbor Expansion Project would involve deepening 35 miles of the navigation channel an additional 6 to 8 feet and widening bends at 12 locations. Concerns associated with the proposed deepening include its effects on water conditions (i.e. salinity, dissolved oxygen, water clarity, contaminant concentrations), and how those in turn might affect freshwater wetlands and aquatic resources (i.e. striped bass, shortnose sturgeon). Ongoing population growth and accompanying development in the area is also a concern, as it will likely alter the amount and quality of overland runoff.

The Baseline Water Quality Data Inventory and Analysis for Fort Pulaski National Monument (the "Horizon report",(NPS 2001)) compiled water quality data from the EPA STORET database collected in Fort Pulaski and its immediate vicinity between 1960 and 1998. The query yielded a total of 68 stations (9 located within the park). The report pointed to some potential water quality problems in the region: 19% of the dissolved oxygen measurements were less than the EPA criteria of 4 mg L^{-1} for the protection of freshwater aquatic life and 34% of fecal coliform measurements exceeded the criteria for bathing water. However, in both cases the majority of these exceedances occurred at stations upstream of Fort Pulaski.

Most of the recent water and sediment quality information for the area comes from the Coastal Resources Division (CRD) of the Georgia Department of Natural Resources (DNR), which collects samples from within the Fort Pulaski Study Area as a part of the State's shellfish monitoring program and EPA's National Coastal Assessment Program. Additional data sources for the late 1990s and into 2000 include sampling conducted as part of the EPA Environmental Monitoring and Assessment Program; data collected for the Georgia Ports Authority; and academic studies.

The nutrient data compiled for this report was confined to stations located directly adjacent to the Park, as nutrient concentrations decrease along the longitudinal gradient of the estuary as river water becomes increasingly diluted by salt water from the ocean. Out of all the samples collected for the National Coastal Assessment program, 63% of the dissolved inorganic nitrogen observations were Good (according to the criteria established by EPA to evaluate these observations) and 37% were Fair (none were Poor). In terms of phosphate, 93% of the observations were considered Fair; 5% were Good, and 2% were Poor. These conclusions are based on very limited observations, as only 2-4 stations were sampled each year in the tidal creeks and estuary associated with Fort Pulaski, on a one-time basis only. A two-year effort by USGS (between 2002 and 2003), at which 2 stations adjacent to the Park were sampled regularly, yielded even higher proportions of nutrients considered Fair or Poor. Given these observations, it would be useful to have regular nutrient monitoring directly focused on the Park, particularly in light of reports of increasing nutrient concentrations in nearby areas (Verity 2002a; b)

There have been several studies of dissolved oxygen (DO) concentrations in the lower Savannah River in recent years, as this was identified as a potential problem in the Environmental Impact Statement prepared for the Harbor Expansion Project. In general, surface and bottom oxygen concentrations are similar in upstream areas of the estuary (where it is nearly all fresh), but in downstream areas where the river is vertically stratified there is lower DO in bottom than surface water. Surface water DO samples collected by Georgia CRD at stations near Fort Pulaski between March 2000 and April 2004 ranged from 2.7 to 10.7 mg L^{-1} and averaged 5.8 ± 1.7 mg L^{-1}. Low concentrations (less than or equal to 4 mg L^{-1}) occurred 16% of the time (31 out of 196 observations). The location of the lowest DO concentrations is upstream of Fort Pulaski: recent modeling suggests that the region with the lowest bottom water DO is located between River Mile 15 and 20, which is adjacent to the Port Terminals and major industries in the heavily developed downtown area. (Fort Pulaski is located between River Mile 0 and 7).

Information on metals and other contaminants includes analyses of both sediment and fish tissue. In sediment samples collected to evaluate the proposed Harbor expansion project (Georgia Ports Authority 1998), no pesticides, PCBs, or phenolic compounds were detected in any sample, but elevated concentrations of some metals (chromium, copper, arsenic, cadmium) were reported in the upper part of the estuary (above Fort Pulaski). In areas closer to Fort Pulaski, some metals and PAHs were enriched, but they were either not considered high enough to cause adverse benthic effects or had low bioaccumulation potential. In keeping with this, neither the EPA EMAP nor the NCA analyses from sites near Fort Pulaski yielded high concentrations of any metal or organic contaminant, and sediment toxicity tests were negative. However, there are dredge disposal sites in close proximity to the area, and numerous metals (chromium, copper, arsenic, cadmium, nickel, mercury, zinc, manganese, and molybdemum) have been detected in these sediments (Winger et al. 2000). In addition, Richardson and Sajwan (2001, 2002) reported elevated levels of arsenic in sediment samples collected in and around Fort Pulaski, and Loganathan et al. (2001) reported elevated concentrations of total DDT. These investigators also reported contaminants in seafood near the Park: both shrimp and oyster tissue had elevated concentrations of arsenic and PAH (Richardson and Sajwan 2001; 2002) and fish tissue had elevated levels of PCBs (Loganathan et al. 2001). There are also reports of elevated concentrations of mercury and PCBs in fish samples collected from the lower Savannah River basin. These observations suggest that additional measurements of metals and contaminants are warranted, particularly for those pollutants that have been detected at elevated levels at the Park itself.

Two nuclear facilities, the Savannah River Site and the Vogtle Electric Plant, are located in the Savannah River. Numerous radionuclides (Cobalt-60, Strontium-90, Cesium-137, Plutonium-238, and Plutonium-239) have been found at elevated levels in sediment and Iodine-129 and tritium have been found at elevated levels in surface water near the Savannah River Site. In addition, fish samples from the same locations were elevated in tritium, strontium, and cesium. Tritium is the most common radioisotope found in the Savannah River and is believed to be transported by groundwater (Fledderman et al. 2004). Although this is upstream of Fort Pulaski, radionuclides represent both a human and animal health hazard.

Additional information on water quality impairments comes from the 303(d) list. In 2000, only one stream from the lower Savannah River portion of the study area was listed in 2000 as *fully supporting* its designated uses. A total of 4 stream branches (2 not supporting, 2 partially supporting) and 1 estuarine area (not supporting) have been listed on 303(d) lists for the past 3 reporting years. Together, these streams account for a total of 144 miles and the estuarine area for 6 square miles. Two of the areas were cited for violating fish consumption guidelines, 3 for low dissolved oxygen, 2 for high fecal coliform bacteria, and 1 for low pH. Note that in the Park itself, fecal coliform bacterial concentrations are generally low, and shellfishing is permitted.

Although it is difficult to connect water quality impairments with specific sources of pollution, there are a total of 82 federally-regulated industrial and municipal NPDES permittees within the study area. Fourteen of these are classified as “major” permitees, including 8 municipal wastewater treatment plants that discharge ≥ 1 million gallons per day and 6 industrial facilities, which discharge organic material and oxygen-demanding loads (such as pulp and paper mills), non-contact cooling water (power plants), and various pollutants (such as from chemical and textile manufacturing, metal finishing, etc.). The largest permitted municipal discharge is the President St. wastewater treatment plant in Savannah, whereas the largest permitted industrial dischargers are the Savannah Electric Company, International Paper, and Weyerhaeuser. As part of the water quality monitoring performed for the Port Authority, International Paper was identified as the largest contributor of oxygen-demanding materials to the Savannah River (Applied Technology & Management (ATM) 2004). In terms of contaminants, manganese and nitrate compounds are released in the largest quantities to surface waters, but several industries report releases of PAHs, chromium, nickel, mercury, and zinc, all of which were observed at elevated levels in sediment or fish tissue. Arsenic, which was also detected at elevated levels, is not released to surface water but it is released to the atmosphere.

Fort Pulaski is largely comprised of salt marshes and is not likely a source of non-point pollutants to the area. However, non-point sources from the larger region likely affect the area via stormwater runoff and atmospheric deposition. As part of the 2001 Savannah River Basin Management Plan the Georgia EPD identified non-point pollution, particularly "urban runoff", as having the most significant effects on water quality in the basin since industrial point sources are strictly regulated and sewage treatment has improved (Georgia - EPD 2001).

Although it is challenging to draw direct connections between pollutant sources and specific organisms or habitats, this report describes the organisms that are associated with each habitat in the Park. There are a number of protected species that inhabit Fort Pulaski or its surrounding waters, including shore birds (terns, plovers, oystercatchers, wood storks, swallow-tale kites, peregrine falcons), sea turtles (loggerhead turtles), and marine mammals (manatees, whales). There are also rare plants located in the region, including two species of "special concern" reported at the park (Florida privet, swamp dock). Introduced species include several non-native plants (Chinese privet, China berry, Chinese tallow).

The potential for impairment to the various water resources associated with the park are summarized in **Table i**. Indicators considered include contaminants and other indicators of poor water quality; population effects in terms of harvest and invasive species; and habitat disruption. The largest water quality problem identified was low dissolved oxygen in the Savannah River Estuary due to the large amount of organic material released into the water, coupled with stratification. Although this is less of a problem at Fort Pulaski itself, observations of decreasing dissolved oxygen at sites nearby suggest it is a potential problem (Verity et al., submitted). Metals and contaminants are identified as existing or potential problems based on the large amount of material released into the area and observations of contaminated sediment and animal tissue. Fecal coliform are considered a moderate problem in the areas upstream of Fort Pulaski based on data from both the Horizon report and more recent sampling. Nutrient concentrations are also higher in upstream areas, but this information was not compiled for the present report. However, they are considered an existing problem in and around the Park due to the large number of observations classified as Fair or Poor by the criteria developed by EPA for the National Coastal Assessment. Salinity effects and other types of habitat alteration have occurred in the past due to channel alterations. These effects will be exacerbated if the area is deepened, particularly in the main channel of the estuary. Salinity in groundwater is also listed as an existing problem due to saltwater intrusion into the aquifer. In terms of population effects, the potential exists for introduced species, particularly in light of the large amount of ship traffic associated with the Port. Although there are no existing records of marine introduced species' as persistent problems in the area, this may reflect a scarcity of observations. Fish and shellfish are listed as a potential problem as there are concerns they will be adversely impacted by the combined effects of the impending harbor deepening. There are several categories in **Table i** that were considered low problems and/or for which there were not enough data to make a judgment. Of particular concern was the scarcity of water quality data at the Park itself.

Table i. Potential for impairment of Fort Pulaski water resources.

Indicator	Savannah River Estuary	FOPU Estuary frontage	FOPU Tidal creeks	FOPU Fresh water	Ground water
Water Quality					
Nutrients	ND	EP	EP	PP	OK
Fecal bacteria	EP	OK	OK	ND	ND
Dissolved oxygen	EP	PP	PP	PP	NA
Metals	EP	EP	EP	ND	OK
Toxic contaminants	PP	EP	EP	ND	OK
Salinity effects	EP	OK	OK	NA	EP
Population Effects					
Fish/shellfish harvest	PP	PP	OK	NA	NA
Invasive species	PP	PP	ND	ND	NA
Habitat disruption	EP	EP	OK	OK	NA

Definitions: OK – low or no problem, NA – not applicable, ND – insufficient data to make judgment, PP – potential problem, EP – existing problem

Table ii lists the report recommendations, which are described in detail in Section D2. Briefly, we recommend that the Park Service initiate efforts to collect regular water quality information at FOPU, as a substantial data gap exists. This may best be accomplished as a partnership with existing State programs. Several enhancements and additions to standard water quality monitoring are also recommended (in terms of dissolved oxygen, nutrients, chlorophyll, suspended sediment, metals and pollutants, and radionuclides). We also recommend setting up targeted monitoring to assess the effects of perturbations such as Harbor expansion (focused on shoreline configuration, suspended sediment, and the utilization of the area by fish and other fauna). In terms of resources, surveys focused particularly on marine organisms are recommended, as well as working towards the identification of indicators. In order to better assess how various pollutant sources affect the Park, it is important to determine which portions of both the Savannah and Ogeechee watersheds influence the area. On the exposure side, information on the amount of time that water spends in the creeks and channel adjacent to the Park is also required. Suggestions are also made for improved data access from both State and Federal programs. Finally, we recommend increased NPS participation in regional-scale activities such as efforts to evaluate Harbor expansion and determine flow requirements from upstream dams.

Table ii. Recommendations.

1. Work towards improved regional cooperation
2. Initiate regular water quality monitoring at FOPU
3. Collect additional water quality information
4. Perform additional plant and animal surveys
5. Identify sentinel organisms
6. Set up targeted monitoring for Harbor expansion and other modifications
7. Assess water movement, in terms of both upstream influence and downstream drainage
8. Improve access to state and federal water quality data and improved metadata

A. Park and Regional Description
A.1. Background
A.1.a. Setting

Fort Pulaski National Monument (NM) is located in the Savannah River Estuary, approximately 15 miles east (and downstream) of the city of Savannah, in Chatham County, Georgia (**Figure 1**). Savannah is home to the 8th largest shipping port in the US (in terms of container throughput, Bailey et al. 2004), and accounts for 84% of the Georgia Ports Authority's total economic impact to the state (GPA 1998). In 1997, the Port of Savannah provided more than 67,600 jobs (either directly or indirectly) amounting to $1.5 billion in personal income and $19.5 billion in sales and revenue, annually (Booz-Allen survey analysis cited in GPA 1998), and recent trends indicate that these numbers are increasing (Georgia Ports Authority 2002b, Georgia Ports Authority 2004). Waters of the lower Savannah River also support commercially and recreationally important marine/estuarine fish and shellfish species, and thus also contribute significant economic and social value to the area.

Fort Pulaski NM is composed of a series of small islands surrounded by tidally-influenced rivers and channels that extend from the mouth of the Savannah River to about 7 miles upstream (**Figure 2**). The Park comprises a total of 5,623 acres (Meader 2003; NPS 2004), ca. 608 of which are located on Cockspur Island, with the rest distributed among Daymark Island, Cockspur Island Lighthouse Reservation, and McQueens Island (Johnstone 2004)[1]. Almost 5,000 acres of the park exist as tidal salt marsh, but the upland areas, which occur primarily on Cockspur Island[2], support a maritime forest. The park is surrounded by salty, tidally-influenced river channels and creeks of the Savannah River (**Table 1**, **Figure 3**): there are no open beaches in this area because it is sheltered from the Atlantic Ocean by Tybee Island (one of Georgia's barrier islands). According to USGS data from 1998, Fort Pulaski NM contains 4372 acres of saltmarsh, 859 acres of open water, 35 acres of cypress-gum swamp, 12 acres of shrub wetland, and 4 acres of evergreen forested wetland (USGS 2003). Although they are considered part of the Park, note that intertidal areas (i.e. salt marshes) and subtidal areas (i.e. tidal creeks and estuarine waters) are held in public trust by the state of Georgia and are managed by the Coastal Resources Division of the Georgia Department of Natural Resources.

This park is different from most other national parks in that humans have greatly altered the natural environment. Historically, Cockspur "Island" was actually a series of small marsh hammocks (small patches of upland surrounded by salt marsh), but its strategic military position at the mouth of the Savannah River prompted its fortification, which resulted in the island and habitats that now exist (Meader 2003; NPS 2004). McQueens Island was also altered: dredge spoil was used as fill in order to connect Savannah to the resort area of Tybee Island. Because it is not pristine, Fort Pulaski provides an excellent place to study human impacts on marsh systems (NPS 2004). Fort Pulaski NM is easily accessible to the public via U.S. Hwy 80.

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[1] The two largest islands, McQueens and Cockspur, are approximately 13 and 3 km (~8 and 1.8 mi) long and average 1.7 and 0.8 km (~1 and 0.5 mi) wide, respectively.
[2] About 5% of McQueens Island is upland; the remainder is salt marsh

Table 1. Water resources at Fort Pulaski NM.

Based on information in NPS 2004.

Name	Type	Freshwater or Saltwater
Bull River	Bay/Estuary	SW
Lazaretto Creek	Bay/Estuary	SW
The Moat	Artificial Canal	FW
Oyster Creek	Bay/Estuary	SW
Savannah River	Bay/Estuary	SW
South Channel	Bay/Estuary	SW
Unnamed Waterbody (n=2)	Lake/Reservoir/Pond	FW

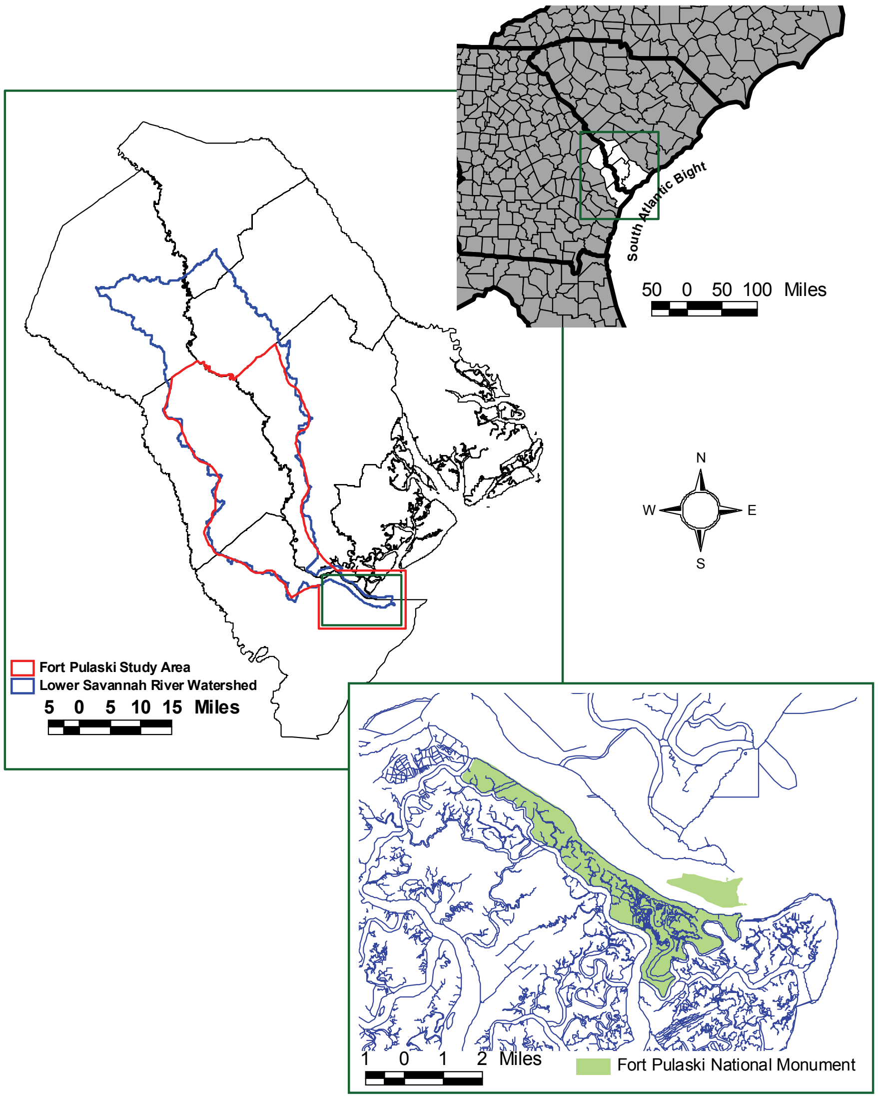
The Savannah River watershed is relatively large. With headwaters in the Blue Ridge Mountains of Georgia, North and South Carolina, the Savannah River officially begins where the Tugaloo and Seneca Rivers join in the Piedmont Region near Hartwell, Georgia, and then flows 315 miles southeastward to the Atlantic Ocean, forming the boundary between Georgia and South Carolina (Georgia - EPD 2001). The area of the entire Savannah River Basin is 10,577 mi^2, with 5,821 mi^2 in Georgia (Georgia - EPD 2001). There are 3 major multi-purpose dams along the River (Hartwell, Richard B. Russell, and Clark Hill (Thurmond Dam)), built in 1962, 1984, and 1954, respectively (U.S. ACE 1989). Although natural flow variation has been muted by flow regulation (lower maximum flows, higher minimum flows, less extensive floodplain inundation) (Meyer et al. 2003), discharge is typically higher in the winter and spring and lower in the summer and fall. Between 1930 and 2002, median flow at Clyo (located in Effingham County, USGS station # 02198500) was 11,800 cfs, with a mean monthly range of 8,112 cfs (Sept) to 18,280 cfs (Mar) (USGS 2004a). There is some indication, however, of nearly a 10% reduction in annual flow since the operation of the dams (likely due to increased evaporation in reservoirs), as compared to historical records (Meyer et al. 2003).

The study area for this report was defined in terms of both County and USGS hydrologic cataloguing units (HUCs). We included those parts of the three counties closest to Ft. Pulaski (Chatham, and Effingham County (GA) and Jasper County, (SC)) that fell within the lower Savannah River basin, (HUC 03060109) (**Figure 1**). We also included the portion of Chatham County that surrounds McQueens Island, which falls primarily in HUC 03060204 (Ogeechee Coastal, Newport River Section).

The study area includes three conservation areas: Savannah and Tybee National Wildlife Refuges and Little Tybee Island, a conservation easement owned by The Nature Conservancy of Georgia and managed by GA DNR (Georgia Ports Authority 1998; Georgia - WRD 2005) (**Figure 3**). Savannah National Wildlife Refuge includes a total of ~28,168 ac. in Chatham and Effingham Counties, GA and Jasper County, SC, which consist mostly of bottomland hardwoods, and estuarine, palustrine and tidal freshwater wetlands (U.S. FWS 2005). Tybee National Wildlife Refuge is approximately 100 ac. on Oysterbed Island in Jasper County, SC

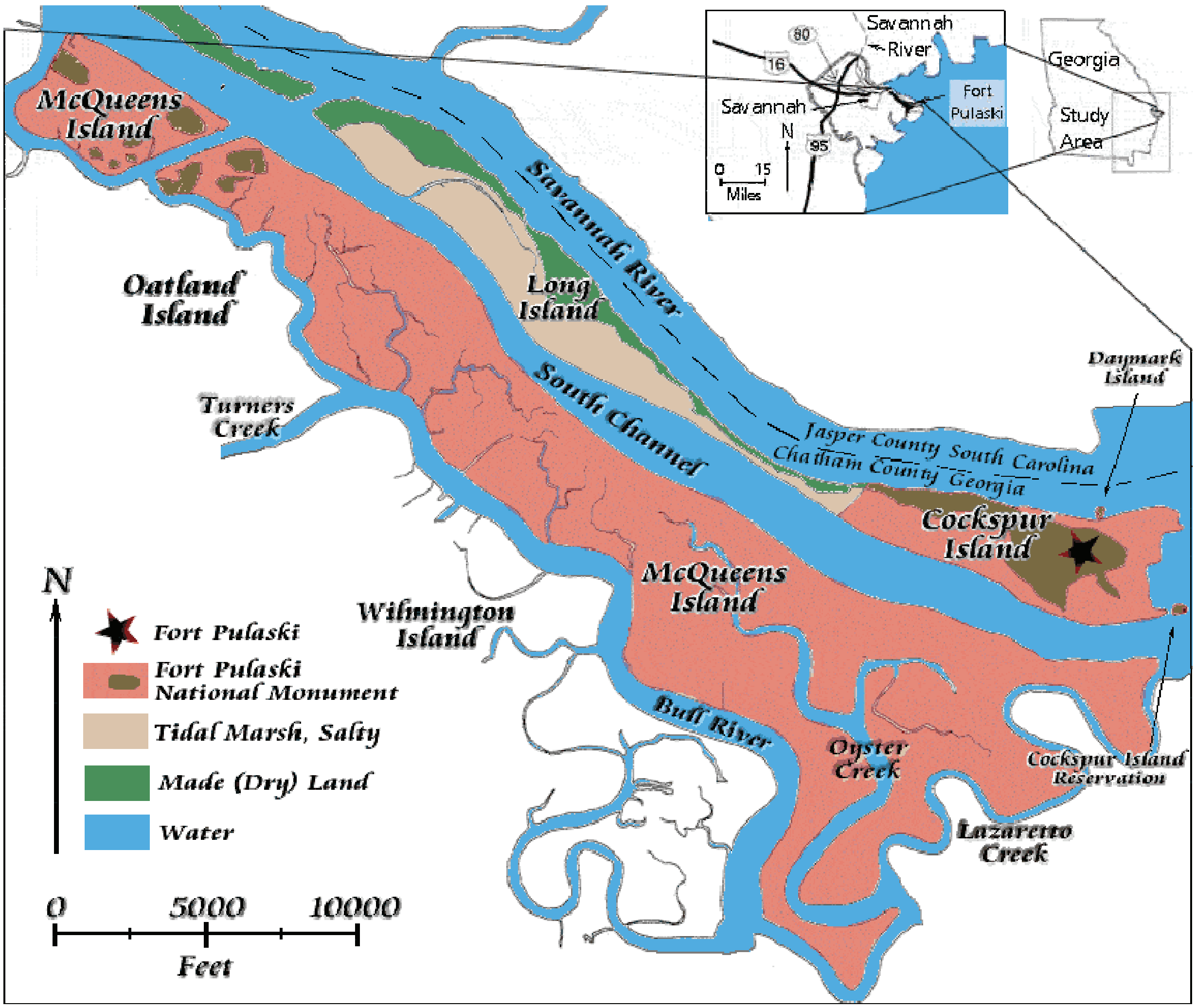
Figure 1. Location of the Fort Pulaski study area and Fort Pulaski NM within the Savannah River Basin.

The area outlined in blue denotes the lower Savannah River Basin, HUC 03060109; the area outlined in red denotes the study area for this report; and the area shaded green in the lower inset is Fort Pulaski NM.



(across from Tybee Island). It is primarily maintained as nesting and feeding habitat for least terns, neotropical songbirds, and shorebirds (it is closed to the public). Oysterbed Island is used by the US Army Corps of Engineers as a spoil disposal for harbor dredging activities, so the refuge continues to grow in size (U.S. FWS 2005). Lastly, Little Tybee Island, which is actually larger than Tybee Island (at ~6,780 ac. as compared to ~3,100 ac., although it has less upland area than Tybee), is a pristine island in Chatham County that is only reachable by boat and is home to many rare sea and shorebird species (Georgia Magazine 2005).

Figure 2. Fort Pulaski National Monument park area and surrounding bodies of water.
(source: www.cr.nps/gov/)

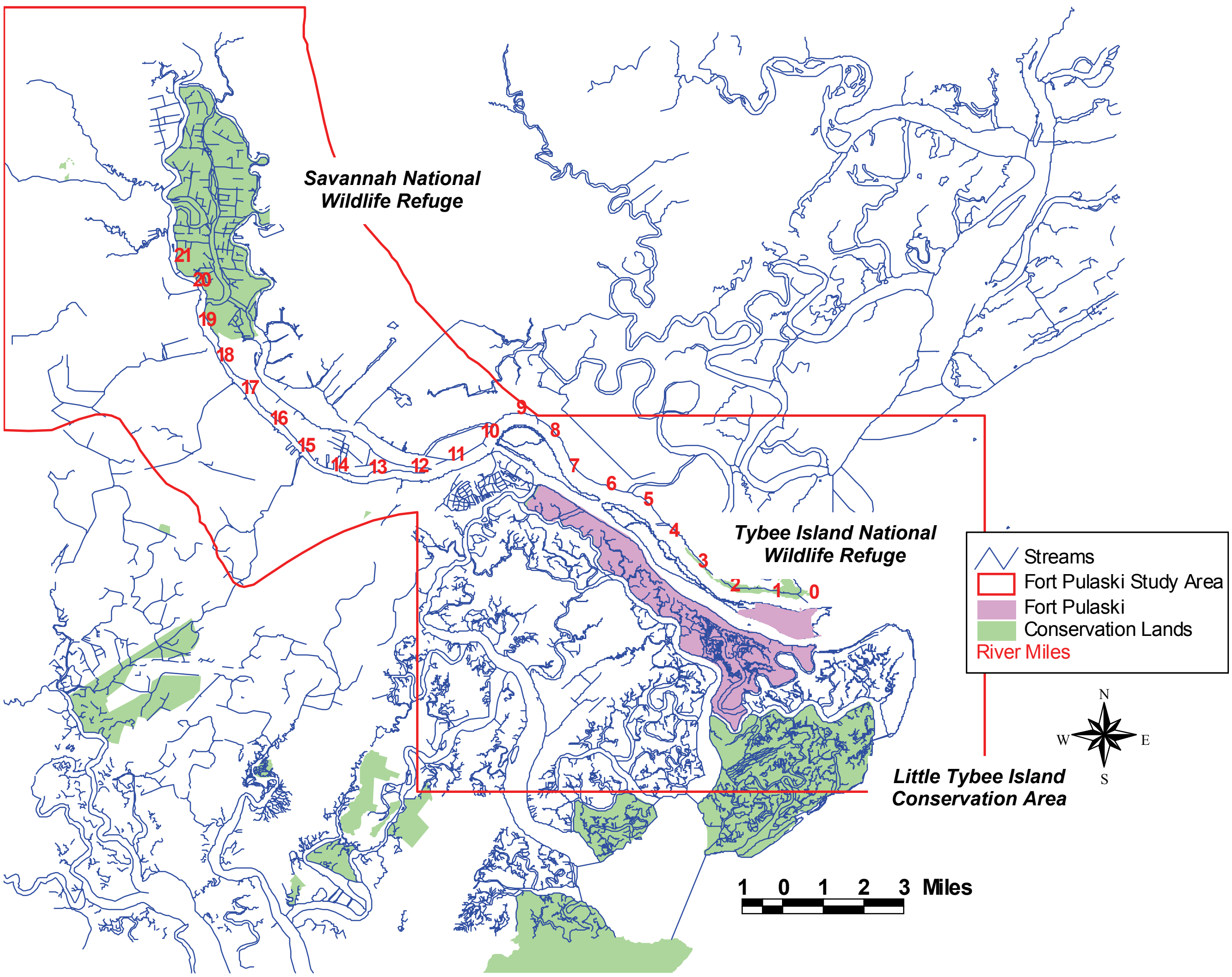


A.1.b. Site History and Management

A.1.b.i. Site History

Extensive modifications of both Cockspur and McQueens Islands have hindered archeological efforts to document prehistoric human utilization of the area. However, it is known that humans lived on nearby Whitemarsh and Wilmington Islands from ca. 500 B.C. – A.D. 1100, and the Euchee Indians inhabited Tybee Island in the early 1500's (Meader 2003; Johnstone 2004). Shell middens (mounds) are common along the Georgia coastline and barrier islands (including several located on McQueen's Island), providing evidence of the former Yamacraw Creek inhabitants (Coastal Georgia Regional Development Center 2004).

Figure 3. Lower portion of study area indicating location of conservation lands river miles along the Savannah River.



Spanish conquerors and missionaries established "mission-forts" along Georgia's coastline in the 1600s, but no permanent establishments[3] (Barber and Gann 1989). The British established the first "permanent" European establishments at Yamacraw Bluff on the Savannah River (16 miles inland of the Atlantic Ocean), and the first documented colonization of the area that is now the

[3] The British occupied land farther to the north in Jamestown, Virginia but began to encroach southward when King Charles II granted them land in the Carolinas. The Creeks and the British fought together to force the Spanish further south to St. Augustine in 1685 and the Indians reclaimed their land in Georgia until the 1730's. The English eventually expanded their territory to include the area south and west of Savannah River to the St. John's River in Florida by trading goods with the Yamacraw Creeks for land (who retained possession of the barrier islands) and by maintaining cordial relations with Chief Tomochichi (Barber and Gann 1989).

Park occurred when British General James Edward Oglethorpe landed on Cockspur Island (then "Peeper Island") in 1733 (Meader 2003). From the beginning, the English were interested in the Savannah River for commerce and trade because of the natural harbor it provided (Barber and Gann 1989). By the late 1700's and the start of the American Revolution, Savannah's population had grown from the initial 114 settlers to 2,500 and warehouses lined the waterfront of the Savannah Harbor, serving in the trade and export of crops, lumber, and Indian goods (Barber and Gann 1989).

The use of Cockspur Island for defensive purposes began in 1761 when Fort George was built to ward off potential attacks by the Spanish (who had claimed Florida and sought possession of Georgia). Never used, Fort George was soon replaced by Fort Green in 1794 as part of the "First American System of Fortifications", this time as a precautionary measure to protect Savannah against threats made by the French after the French Revolution. Fort Green fell to a hurricane in 1804, and the "Second American System of Fortifications" began in 1807, but the fort was not completed before being damaged by British attack during the War of 1812. Recognizing the ineffectiveness of the coastal defense system, Congress called for the "Third System of Defense" under the Board of Fortifications for Sea Coast Defense in 1816 (Meader 2003). These forts, characterized by greater structural durability than previous forts (as evidenced by the fact that the majority are still standing today) were built along the Atlantic, Pacific, and Gulf coasts, with Cockspur Island again chosen as a site (NPS 2003a; Johnstone 2004). Slaves from local rice plantations, military servicemen, masons, and carpenters finally completed the new fort, Fort Pulaski, in 1847[4]. The fort saw little activity for nearly 15 years, but on April 10, 1862, Union soldiers breached the southeast wall of Fort Pulaski using rifled cannons, and Confederate Colonel Olmstead surrendered. After that, several Union forces served at Fort Pulaski, and the fort served as a prison for Confederate prisoners of war until 1865. After the Civil War, U.S. Army units were stationed at the Fort until 1873 (Meader 2003).

In 1891 the city of Savannah established a quarantine station atop dredge-spoil on the northwest portion of Cockspur Island. The station was converted to a U.S. Marine Hospital Service in 1899. This was expanded in 1918-1919 to cover 130 acres (with the construction of 20 additional buildings), in anticipation of German prisoners of war, although the facility was never used for that purpose. The Fort was again used as a military base during World War II: U.S. Navy personnel were stationed there from 1941-1947. This marked the last time the Fort was used for military purposes (Meader 2003).

Dramatic changes to the landscape of Cockspur Island began as soon as 1867, when dredge-spoil material from the deepening of Savannah Harbor was placed on the north end of the Island. Later, in 1884, the U.S. Army Corps of Engineers was placed in charge of maintaining the Fort[5]. Seeking to improve navigation, they constructed jetties along the north end of Cockspur Island. Eventually, the jetties and dredge-spoil deposition caused Cockspur Island to merge with Long

[4] Planning, designing, and engineering tasks began in 1829, with task directors Major Samual Babcock and assistant Robert E. Lee, but construction did not begin until 1833, under Lieutenant Joseph Mansfield.
[5] One of their initial duties was the removal of several obstructions that had been sunk to block warships from coming into the harbor during the Civil War. About 60 vessels were sunk below Elba Island (near Fort Pulaski), an area that became known as "the obstructions"; these were a hindrance to navigation.

("Bird") Island, as the marsh that separated the two was filled in. In addition, the Central of Georgia Railroad, which traverses McQueens Island, was built to provide access to Tybee Island in 1886-1887. During the Spanish-American war (1898-1899), Battery Hambright was built along the North Channel to provide additional protection (Meader 2003).

Following transfer of the Park to the National Park Service in 1933, the Civil Works Administration (CWA), Civilian Conservation Corps (CCC), and Public Works Administration (PWA) worked on a number of projects including construction of a landing walk along the South Channel for ferry service, vegetation removal, fixing roofs of casemates, restoring the Terre plain[6], rebuilding cannon platforms on the Terre plain, restoring fort brickwork, restoring the dikes and moat (which required dirt addition and removal, respectively), mosquito control (which required ditching), maintaining ferry service for park-goers, and later, filling in marshes in preparation for and construction of the bridge across the South Channel to Fort Pulaski NM, and building the visitor parking lot. In April 1938 the park was opened to public access via automobile and the ferry service closed (Meader 2003).

In 1936, shortly after acquisition of Fort Pulaski by the NPS, Congress passed a "special-use permit" (49 Stat. 1979) that allowed unlimited use of a "strip of land extending shoreward 200 feet from the present high water line" by the U.S. Army Corps of Engineers for the deposit of dredge-spoil material (NPS 1995). By 1939, the Corps had already dredged land west of the quarantine station (northwest Cockspur), deposited the spoils to construct a new shoreline, and stabilized it with riprap. In 1942, the NPS granted the Corps a second special use permit to construct "Elba Island Cut" (running through northwest McQueen's Island) to shorten the intracoastal waterway, and spoil material was deposited on either side of the cut on McQueen's Island. Then in 1943, spoil was again deposited along the north shore of Cockspur Island, connecting it to Long ("Bird") Island (NPS 1995). Dredging activity and the placement of spoil deposits along the north shore of Cockspur Island continued through the 1970's and 1980's (Meader 2003), although various state and federal acts[7] served to restrict these activities (NPS 1995). The "special-use permit" was overturned in 1996, officially removing the Corps' right to deposit dredge-spoil along the north shore (Meader 2003).

Much-needed repairs to the Fort itself were begun in 1956, under the National Park Service's *Mission 66* initiative. Major activities funded under this initiative included repairing the drainage system, which involved digging over 7,000 feet of ditches and installing tide-gates, and building the visitor's center. Since that time, only small improvements have been made, with two important ones being the conversion of the abandoned Central of Georgia Railroad to a multi-use recreational trail through the "Rails to Trails" initiative and restoring the historic dike system to a height of 12 feet (Meader 2003).

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[6] According to Webster's 1828 dictionary, the Terre plain is "the top, platform, or horizontal surface of the rampart, upon which the cannon are placed". At Fort Pulaski, it refers to the top, grassy (*terre*, French: earth) level of the fort.

[7] National Historic Preservation Act of 1966, National Environmental Policy Act (NEPA) of 1969, Coastal Marshland Protection Act of 1970 (GA), Coastal Zone Management Act of 1972, Endangered Species Act of 1973, Clean Water Act of 1977, and Executive Order 11990, Protection of Wetlands, 1977 (NPS 1995).

A.1.b.ii. Site Management

Under the American Antiquities Act (July 17, 1915), President Calvin Coolidge established Fort Pulaski as a National Monument, initially maintained under the Departments of War and Agriculture (Johnstone 2004). The National Park Service (NPS) was not formed until President Woodrow Wilson established it within the Department of the Interior a year later (August 25, 1916), but Fort Pulaski NM did not officially become a national park until 1933 [8] (NPS 1995). The Park originally consisted of only 20 acres (areas contained between ditches and dikes), but in 1939, the State of Georgia deeded 5,000 additional acres of McQueen's Island[9] to the Park. The Park later acquired the closed Quarantine Station and the Cockspur Island Lighthouse Reservation and Daymark Island in 1954 and 1959, respectively. These additions brought Fort Pulaski NM up to the acreage that it holds today (Meader 2003).

Fort Pulaski was primarily established as a historic site, tasked to preserve and protect associated historic structures, and secondarily manage flora, fauna, and natural resources. As stated in Fort Pulaski's *Resource Management Plan* (1995, pg.4) "if there is ever a conflict between objectives, the protection and preservation of the historic scene and structures will have precedence over the preservation of natural systems". Today, primary maintenance goals are to uphold the historic character of the park by preserving historic buildings and structures and keeping the landscape representative of the time, which requires keeping a low vegetation profile to enhance visibility (Govus 1998, Kevill *pers. comm.*). There are numerous educational programs for visitors, including park ranger-guided tours, auditory stations throughout the fort, an informational sign-guided nature trail along historical sites such as the John Wesley Memorial, Battery Hambright, and the North Pier, scheduled special events, a museum, and an auditorium for videos about the fort. Recreational activities around the fort include walking/running/biking along the nature trail, dike system, or the historical "Central of Georgia Railroad" trail, bird watching (Painted Buntings are often sighted), picnicking, fishing on the South Channel bridge, or shellfish collecting at Oyster Creek. Since the 1950's, there has been a steady increase in the number of visitors to the park (**Figure 4**), although current visitation trends may indicate a slight decrease. In FY 2003, Fort Pulaski allocated $327,770 for resource preservation (including cataloguing and archiving historical artifacts, determining the status of the park's air and water quality, and conducting floral and faunal surveys), $276,629 for ground and facility maintenance, $474,049 for maintaining and improving visitor services, and $122,058 for park administration (NPS 2003b).

Both the Coast Guard and the Savannah Bar Pilots have a continuing presence at Fort Pulaski (Meader 2003). The Coast Guard established a wharf on Lazaretto Creek on McQueen's Island in 1938, ran a U.S. Naval Receiving Station from 1945-1946 on Cockspur Island (following WW II), and was then granted permission by the NPS to use an abandoned naval wharf, including 350 feet of deep-water dock, on Cockspur Island in 1949. The NPS has since granted 2 special long-term use permits: 1) in 1952, to continue use of the wharf and 2) in 1965, to occupy a 400 x 450-foot tract of land on the north shore of Cockspur Island for permanent buildings, concrete-moorings, and communication equipment. The NPS later granted administrational jurisdiction to

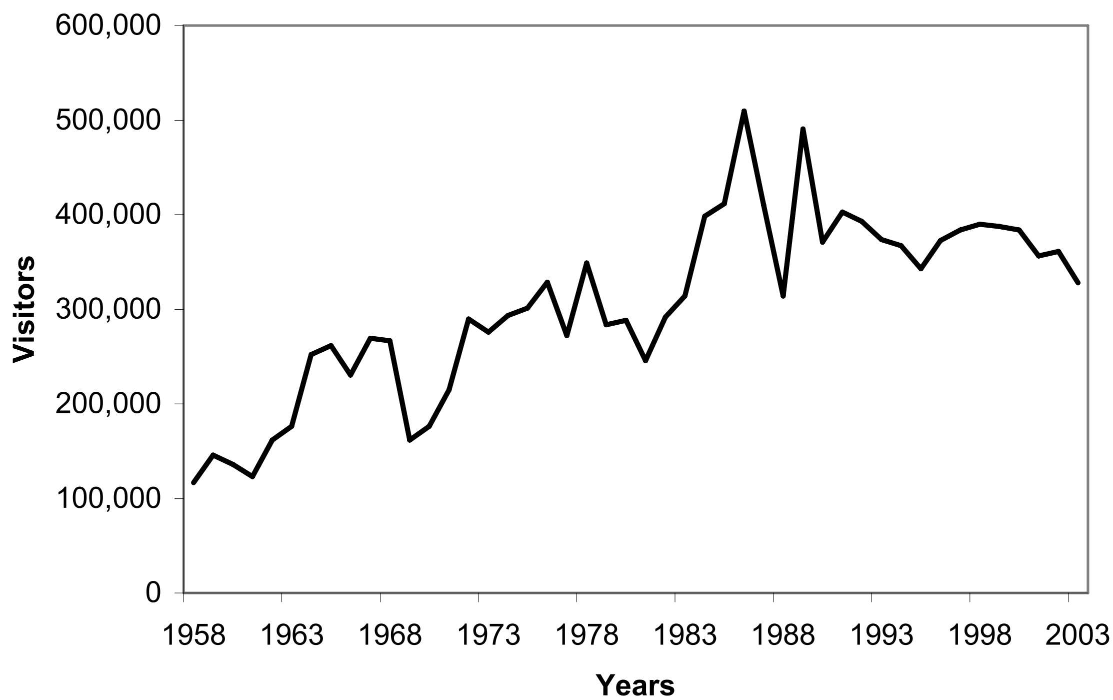
[8] Under Executive Order No. 6228, 5 U.S.C. sec. 124-135.

[9] McQueen's Island was used by the Central of Georgia Railroad (ca. 1887), and later U.S. Hwy 80 (ca. 1923) before it was acquired by the Park Service.

the U.S. Coast Guard in 1980 over an additional 1.85 ac of land, on which a Search and Rescue Station was established. Since this time, the Coast Guard has retained its involvement on Cockspur Island and worked cooperatively with the NPS (Meader 2003).

Figure 4: Visitation trends at Fort Pulaski, Years 1958-2003.

Source: (Meader 2003; NPS 2004)



Under an annually-renewed special use permit, the Savannah Bar Pilots were allowed to move into a dormitory and 2 small buildings on the west end of Cockspur Island in October, 1940. Their job is to assist ships or shipping companies in navigating up the Savannah River to the Harbor; "every commercial vessel entering or leaving the Savannah River must have a pilot on board" (Meader 2003). Cockspur Island was chosen as a place for the bar pilot's facility for the same reason it was chosen as a place of military establishments, its location in the mouth of the Savannah River. In 1973, they built a new station, dock, fuel supply system, and parking lot to replace the deteriorating facility within the 0.67-acre tract of land, as requested by NPS.

Fort Pulaski also cooperates with Chatham County (NPS 1995; Meader 2003). The Chatham County Department of Recreation and Parks Association has maintained a special use permit since 1962 allowing it to construct and oversee use of a public boat ramp, fishing pier, and parking area on Lazaretto Creek (McQueens Island). In addition, they were given the authority in 1994 to maintain the trail constructed by the "Rails to Trails" commission of Chatham County. The Chatham County Mosquito Control (CCMC) has been involved with managing the mosquitoes at the park since 1960. Mosquitoes have long been a major nuisance to park goers, and, prior to the involvement with CCMC, the U.S. Public Health Service even had to step in and aid the Park by spraying with pesticide in 1949 (Meader 2003). Spraying alone was ineffective, thus CCMC offered a combination of landscape alteration, along with natural and pesticide control. Following their successful efforts, Fort Pulaski signed a Memorandum of Understanding (MOU) with the CCMC to continue mosquito control in the Park (NPS 1995).

A.1.b.iii. Savannah River Alterations

Channel - There have been numerous historic changes to the Savannah River that have altered conditions and likely affected the natural resources of Fort Pulaski. Major modifications have been put into place for navigation, including deepening and widening of the channel, designing and filling cuts, and building stabilization structures along the banks. Modifications to both flow and sediment load due to tide gates, hydropower operations, and upstream dams have also affected conditions in the river (Barber and Gann 1989; USACE 1989).

Because the Savannah River typically carries a high sediment load, constant channel maintenance and dredging activities have been necessary in order to sustain depth and width specifications for navigation. At present, the River is maintained at a 9-foot depth and 90-foot width between Augusta (mile 202.6) and the upper end of Savannah Harbor (approx. mile 21.3). Below Savannah Harbor, the current federal project provides for 42-foot depth (MLW) at the harbor and 44-foot depth (MLW) at the entrance and an approximate bottom-channel width of 500 feet (Georgia Ports Authority 1998). Current increases in shipping traffic (up 20% from 1991-1995) and the manufacturing of larger and greater capacity container ships[10] have motivated the Georgia Ports Authority to request yet another increase in channel depth to allow for the deeper drafts required by these ships (Georgia Ports Authority 1998). As part of the so-called Harbor Expansion Project, they are also proposing widening bends at 12 bend locations to allow for easier ship navigation in an area upstream of Fort Pulaski (along Hutchinson Island, *see* Figure 4-15 of (Georgia Ports Authority 1998), which will directly affect freshwater wetlands (*see* Section **C.3.a.v.**).

Other modifications have also affected the River. In 1977, a diversion canal (New Cut), tide gate, and sediment basin were constructed to reduce dredging maintenance costs by controlling sedimentation and shoaling in the main channel (i.e. the Front River) (U.S. ACE 2005). New Cut connected the Back with the Front Rivers at river mile 18.5 (it cut across Argyle Island (just within the Savannah National Wildlife Refuge boundaries)). The tide gate was located at approximately river mile 14 of the Back River. The tide gate closed at the end of flood tide, forcing ebb tidal flow from the Back River into the Front River through New Cut. The sediment basin (dimensions: 40 feet deep, 600 feet wide, about 2 miles long with entrance channel 38 to 40 feet deep and 300 feet wide) was just below at river mile 13 (Georgia Ports Authority 1998). The tide gate and diversion canal were closed in 1991 and 1992, respectively, (Pearlstine et al. 1990 cited in Georgia Ports Authority 1998, U.S. ACE 2005, Reinert et al. 2005), due to the fact

[10] The amount of cargo passing through Savannah was 734,724 TEUs in 1997 and is projected to expand to 6 million TEUs by 2050. New ships are >6,000 TEUs (20-foot equivalent units) and larger containerships approach 8,000 TEUs Georgia Ports Authority, 1998 appendix C).

that these operations resulted in increasing salinity in the Back and Little Back Rivers, which had negative effects on tidal freshwater wetlands and striped bass (Reinert et al. 2005).

Salinity is probably the most obvious condition that has changed in the Savannah River. Prior to any major alterations in the early 1700s, there is evidence that freshwater existed as far downstream as river kilometer (RKM) 6 (~approx. river mile (RM) 4, near Long Island, just above Cockspur, *see* **Figure 3**) (historical sources cited in Reinert 2004). At present, the freshwater-saltwater interface is located above RKM 30 (~RM 19) (Reinert 2004). Shifts in the historical salinity regime are most recognizable by changes in the shoreline vegetation (Latham et al. 1993; Latham and Kitchens 1996), especially the loss of sensitive tidal freshwater marshes[11], which are confined to areas where the average annual salinity is less than 0.5 psu[12]. As the salinity gradient has become more compressed, many of these areas have been lost (Brush et al. 2004). Today, much of the remaining tidal freshwater marshes of the Savannah River exist within the Savannah National Wildlife Refuge[13], but it is likely that the area around Fort Pulaski, which is now salt marsh, was once tidal freshwater.

Additional consequences of altering the river have included reduced sediment supply to river areas downstream of the dams and reduced river sinuosity due to shoreline stabilization and the construction of straighter, more direct cuts[14] (Georgia Ports Authority 1998; Eudaly 1999; Meyer et al. 2003; Reinert 2004). The combined effects of these actions have greatly affected biological resources; these effects are discussed in Section C.3., below.

Intertidal areas - Intertidal areas along the Savannah have also been altered, primarily for agricultural purposes. Georgia's first staple crop was rice in the 1750s. The majority of rice plantations along the Savannah River were located in tidal freshwater areas. Rice cultivation in tidal marshes required an "elaborate system of irrigation works – levees, ditches, culverts, floodgates, and drains…to control and regulate the flow of water onto and off of the fields" (New Georgia Encyclopedia (NGE) 2004). Georgia had about 9,300 ha (~22,971 ac) under cultivation during its peak rice-production period, 1850-1860 (Brush et al. 2004). Although rice production in Georgia ended in the late 1800's, the impacts of rice production along the Savannah River are evident. Some dikes and impoundments still exist within the estuary, especially in the area of the Savannah National Wildlife Refuge (although these are currently maintained for waterfowl). Additionally, there are historical accounts that cypress tupelo forests were converted to marsh due to rice production (Brush et al. 2004).

By 1820, Savannah had become the 18th largest city in the U.S. and was a world leading cotton-shipping port (New Georgia Encyclopedia (NGE) 2004). Although most cotton plantations were

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[11] Though located in fresh or nearly fresh water, these marshes are still flooded by tides. They typically have high organic matter, unconsolidated sediments, and very diverse plant and animal population (as compared to salt marshes, which have higher salinities, more frequent inundation, consolidated sediments, lower organic matter, and lower plant and animal diversity).

[12] The term "psu" stands for practical salinity units and is the conventional unit for discussing salinity. Previously salinity was defined with "ppt" or parts per thousand. 1 psu = 1 ppt.

[13] The lower Savannah River holds about 6% of the remaining tidal freshwater marshes on the East Coast (Brush et al. 2004)

[14] Almost 40 cut-off bends, a total distance of approximately 26.5 miles, were constructed to straighten and shorten the navigation route between 1899-1961 (length was reduced by about 13%) (Meyer et al. 2003).

located in the area of flat land and rich soil between Augusta and Columbus (middle GA), cotton production greatly affected the lower Savannah watershed's land use, as land was cleared and drainage ditches were dug to create more cotton land. This practice, along with rice production, contributed to the loss of wetlands (New Georgia Encyclopedia (NGE) 2004).

A.1.c. Population Trends

Between 1990 and 2000, Georgia was the 10th most populous state in the country and the fastest growing state in the South[15], with an increase in population (26.4%) exactly double the national average. South Carolina's rate of population growth over the same period was 15.1% (Perry and Mackun 2001)[16]. The population within the Savannah River watershed, which was 523,000 in 1995, is expected to increase by 60% to 900,000 people by the year 2050 (Georgia - EPD 2001). Within the Savannah River watershed, *concentrated* population centers (>1600 people per sq. mi.) are located in the city of Savannah and approximately 200 miles upstream in Augusta[17]. Both of these areas, along with their surrounding suburbs, are considered Metropolitan Statistical Areas (MSAs)[18]. The cities of Savannah and Augusta had estimated populations of 129,556 and 186,206 in 1999 and their MSAs had populations of 304,325 and 488,538 in 2003. Population in the city of Savannah itself (which is located in Chatham County) is actually decreasing[19], but that in the surrounding area is increasing rapidly. Between April 2000 and July 2003 the population in Chatham County increased to 235,270, which represents a 1.4% increase in an already densely-populated area. Nearby Effingham County increased to 42,715, but it started out as relatively rural and hence this represents a growth rate of 13.8%. In contrast, Jasper County experienced a growth rate of only 1.5%, which brought its population total to 20,998. Trends in Effingham County are of particular concern as it ranked 83rd among the 100 fastest growing counties in the U.S. (July 2001-July 2002) (U.S. Census Bureau 2003).

A.1.c.i. Land Use/Land Cover

***Savannah River Basin* -** The *Savannah River Basin Plan* (Georgia - EPD 2001) compared land use and land cover for the basin in 1972-1976 with that in 1988-1990. There was no real change in wetland area (9 to 8.9%) or urban land cover (2 to 2.1%) between the two periods. However, their analysis indicated a reduction in mature forest cover over time, from 69 to 56.9%, which was coupled to an increase in clear cut/young pine cover (forestry). Agricultural land, which decreased from 18 to 8.8%, was likely converted to pasture. These changes in land cover reflect an increase in animal feeding operations[20] and a reduction in farmland. Most remaining farmland is located in Burke and Jefferson Counties in the middle Savannah River watershed, with cotton, peanuts, tobacco, and grains (wheat, sorghum, soybean, millet) being the primary commodities (Georgia - EPD 2001; USDA 2002).

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[15] Georgia is the 6th fastest growing state in the U.S.
[16] More recent data also support these trends. The average percent change in population between April 2000-July 2003 was 6.1% in Georgia and 3.4% in South Carolina as compared to a national average of 3.3%.
[17] Population density along the Savannah River Basin watershed is depicted in Figure 2-12 of the Savannah River Basin Plan (Georgia - EPD 2001).
[18] MSAs are urbanized areas, comprised of at least 50,000 people, and have a "high degree of social and economic integration with the central county as measured through commuting" (Federal Register 2000).
[19] Between 1989 and 1999, population in the City of Savannah decreased by 5.9%.
[20] About 75% of the converted pastureland are now AFOs.

Study area - Land cover classifications for the Fort Pulaski study area are shown in **Figure 5** and summarized in **Table 2**. (See **Appendix A** for an explanation of how these coverages were derived.) Of the 515,615 acres included in this analysis, the most common land cover classifications are palustrine forested wetland[21], other wetlands, and evergreen forest[22], which account for 27%, 25%, and 16% of the total area, respectively. Only 37% of the total area is considered upland[23]. Overall, cultivated and low or high intensity developed land accounts for 10% of the total area (28% of the upland area). The cultivated areas are primarily found in northern Effingham County and nearly *all* of the low and high intensity developed land is associated with the downtown Savannah area, located along the Harbor. The majority of the freshwater (palustrine) wetland and forested area is located in Jasper County, SC, in the area of the SNWR, and Effingham County, GA.

Table 2. Land cover in the Fort Pulaski study area.

Based on 1998 Georgia Gap Analysis Program (GAP) and 1995 South Carolina Coastal Change Analysis Program (C-CAP) data (NOAA - CSC 1997; 2001).

Land Cover Classification	Acres	% of Total
Palustrine Forested Wetland	138215	26.8
Evergreen Forest	80327	15.6
Scrub/Shrub	49908	9.7
Water	43898	8.5
Grassland	36581	7.1
Estuarine Emergent Wetland	34793	6.8
Palustrine Scrub/Shrub Wetland	26750	5.2
Cultivated Land	23789	4.6
Low Intensity Developed	17129	3.3
Bare Land	16090	3.1
Palustrine Emergent Wetland	15771	3.0
High Intensity Developed	12445	2.4
Deciduous Forest	9361	1.8
Mixed Forest	9249	1.8
Unconsolidated Shore	1309	<1

Fort Pulaski (FOPU) - The land that comprises Fort Pulaski National Monument falls completely within the estuary of the Savannah River. Land cover classifications for the Park, which are shown in **Figure 6** and summarized in **Table 3,** were derived from the 1997 Georgia

[21] These are wetlands with salinities <0.5 psu; they may be tidal or nontidal (Mitsch and Gosselink 2000).
[22] Nearly all of the evergreen forest is Loblolly-Slash Pine.
[23] In this analysis, upland was considered to include the following classifications: evergreen forest, grassland, cultivated land, low and high intensity developed, bare land, deciduous/mixed forest, and unconsolidated shore.

C-CAP data set (NOAA - CSC 2001). Out of a total of 6,312 acres[24] included in the analysis, estuarine emergent wetland (i.e. salt marsh) is the dominant classification, accounting for almost 66% of the area, and open water is second, accounting for 16%. As seen in **Figure 6,** very little of the upland is on McQueen's Island: the only upland areas are those associated with Hwy 80 (shown as low/high intensity developed), the Lazaretto Creek public access (shown as low/high intensity developed), and very small patches near Elba Island Cut (shown as forest, surrounded by scrub/shrub). Upland areas on Cockspur Island are primarily grassland and mixed/evergreen forest; a small amount of upland is associated with the roads, the visitor center, and the Fort itself (shown as low/high intensity developed). Overall, only about 2.6% of the Park area is classified as low or high intensity developed, which represents about 23% of the total upland area. The remaining upland area at the park is classified as unconsolidated shore (27%), forest (all categories, 23%), grass (22%), scrub/shrub (15%), and bare land (9%).

Table 3. Land cover of Fort Pulaski National Monument.

Based on 1997 Georgia C-CAP data (NOAA - CSC 1997).

Land Cover Classification	Acres	% of Total
Estuarine Emergent Wetland	4185.0	66.3
Water	1023.7	16.2
Palustrine Scrub/Shrub Wetland	332.0	5.3
Unconsolidated Shore	165.9	2.6
Low Intensity Developed	147.7	2.3
Evergreen Forest	139.9	2.2
Grassland	134.8	2.1
Scrub/Shrub	93.2	1.5
Palustrine Emergent Wetland	55.6	0.9
High Intensity Developed	17.6	<0.5
Bare Land	14.7	<0.5
Palustrine Forested Wetland	1.3	<0.5
Deciduous Forest	0.4	<0.5
Mixed Forest	0.2	<0.5

A.2. Hydrologic Information

A.2.a. Park Setting

Fort Pulaski lies at the mouth of the Savannah River estuary. The area is protected by Tybee Island, such that wave action is minimal. Tides are semidiurnal (i.e. two highs, two lows each day), with a mean tidal range of 2.1 m (~7 ft) and a maximum tidal range (the difference during Spring tides) of 2.3 m (~7.5 ft) (NOAA CO-OPS 2004). The outflow from the Savannah River forms a salt wedge estuary, with fresh water from upstream floating over the top of denser, salty water that enters from the ocean (Brush et al. 2004). The waters surrounding Fort Pulaski have

[24] This acreage is greater than that reported for Fort Pulaski under Part A.1.a. (Setting) because some surrounding open water (Lazaretto Creek and Elba Island Cut) was included in this analysis.

salinities that typically range from near 20 psu (practical salinity units) at the northernmost tip (~RM 7) to full strength seawater (30-33 psu) at the mouth (RM 0) (Richardson and Sajwan 2001; 2002; Jennings and Weyers 2003).

Figure 5. Land cover in the Fort Pulaski study area.

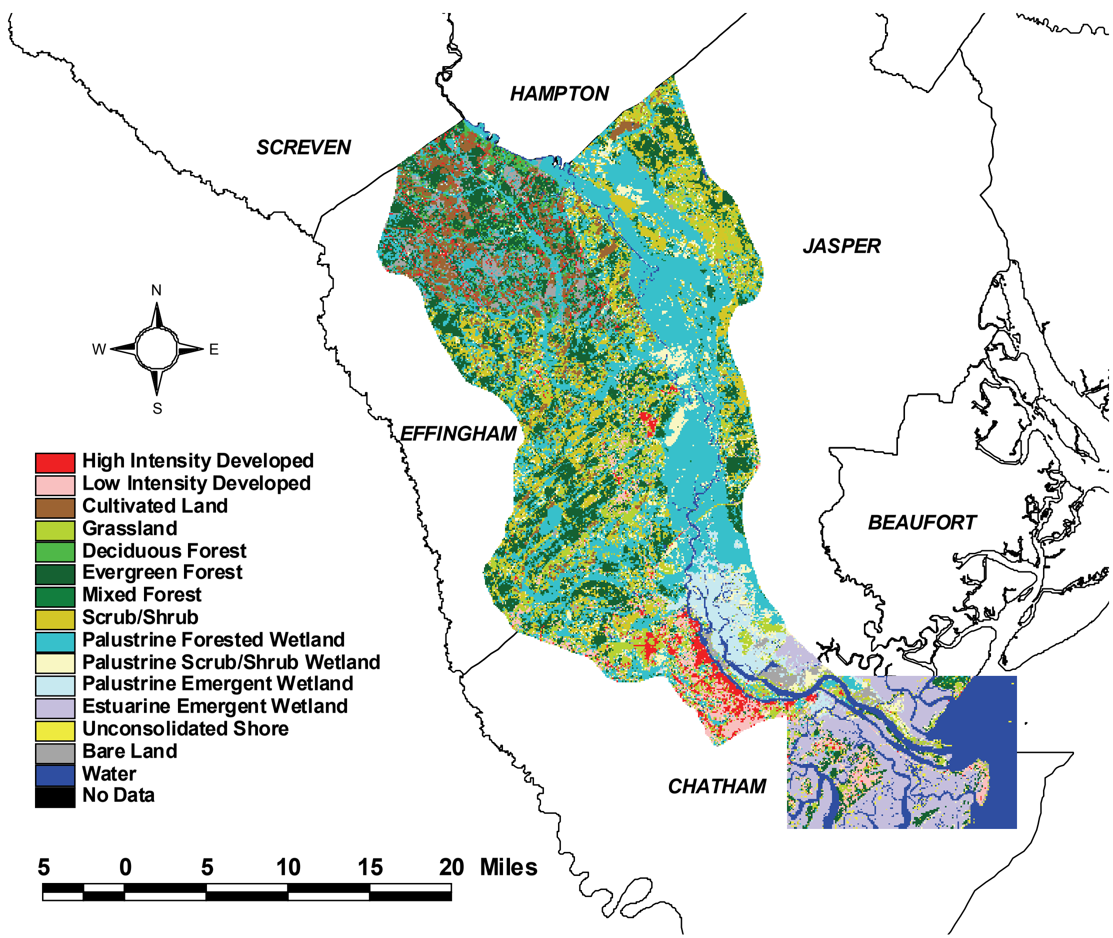
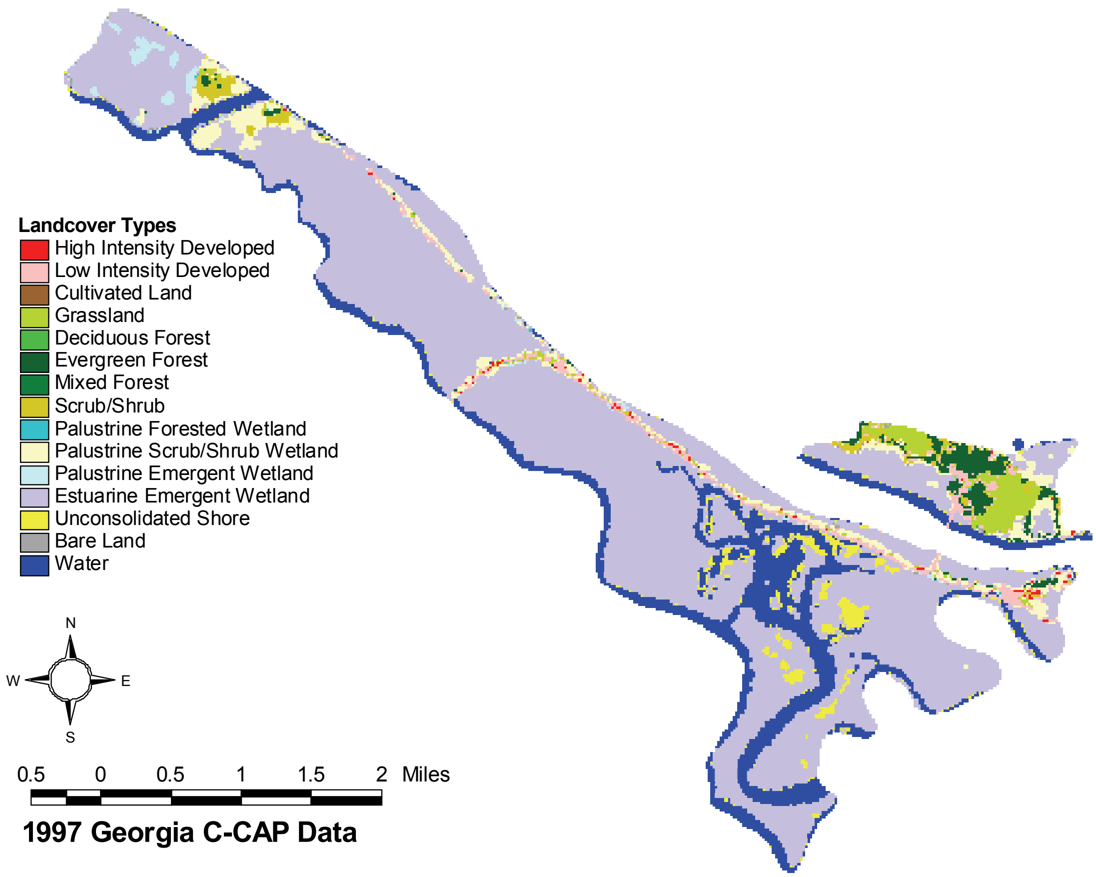


Figure 6. Land cover at Fort Pulaski National Monument.



Northeasterly winds dominate the area during the winter, and southwesterly winds during the rest of the year (NOAA CO-OPS 2004). The area is characterized by mild winters and hot summers, with high humidity (75%) throughout the year (Georgia - EPD 2001; NPS 2004). Temperatures may range from 20° to 100° F, but mean seasonal temperatures are as follows: winter, 51° F; spring, 64° F; summer, 80° F, and fall, 66° F (Georgia Ports Authority 1998; NPS 2004). The average annual precipitation is 49.41 inches; snow is rare (1951-2003, reported for Savannah International Airport, (GAEMN 2005)). Hurricanes are only an occasional threat to the area (Georgia Ports Authority 1998).   The only hurricane that has had direct landfall on this area of Georgia over the past 50 years was Hurricane David, a category 1 (winds at 80 mph) storm that hit Savannah in 1979, but caused no major damage (NOAA - CSC 2005).

A.2.b. Groundwater and Aquifers

The principal source of freshwater for public use (i.e. drinking water, etc) at Fort Pulaski NM and the rest of Chatham county is the Upper Floridan aquifer (Clarke et al. 1990; Fanning 2003). Along the Georgia coastline, the Floridan aquifer is the shallowest (ca. 110 ft. below the land surface) and thinnest (ca. 250-260 ft.) at Fort Pulaski NM: it becomes deeper (max. 530 ft. at Kings Bay) and thicker (max. 460 ft. in Brunswick) further south, and it is most productive where it is thickest (Clarke et al. 1990). Recharge areas are in southwestern Georgia (significant areas are in Brooks, Echols, and Lowndes counties) where the overlying strata is thin and/or sinkholes breach the upper confining layers to allow rain and riverine water to infiltrate the aquifer (see Fig. 3-12 inches (Donahue 2003).

Secondary sources of groundwater in Chatham County are not widely used for public supply. The lower Floridan aquifer is rarely used, except for a few municipal and industrial wells, because it is deeply buried (Clarke et al. 1990). The upper Brunswick aquifer, which lies above the upper Floridian aquifer, is about 88 ft. below the surface and about 20 ft thick at Fort Pulaski. The surficial aquifer lies above the upper Brunswick aquifer (Clarke et al. 1990; Georgia Ports Authority 2002a). It ranges in depth from 10-90 ft. below the surface and is about 65 ft. thick nearest Fort Pulaski (Clarke et al. 1990; Georgia Ports Authority 2002a). Recharge to the surficial aquifer occurs by local rainfall. Groundwater in the surficial aquifer moves laterally to streams and rivers, and consequently has a very low water yield due to a low hydraulic gradient (Georgia Ports Authority 2002a).

A.3. Biological Resources

The plants and animals present on Fort Pulaski have been described in a number of previous studies. An extensive vegetation survey by Govus (1998) documented 256 species of plants within the various habitats in the park (81 newly reported). When combined with information from other surveys, it brought the total number of plant species at Fort Pulaski to 292. Rabolli and Ellington (1998) surveyed the vertebrate population, including birds, fish, amphibians, reptiles, and mammals, within most of these habitats. Their report included species observed during their survey, those previously observed by park officials, and those that potentially occur on Fort Pulaski. Numerous species of wading birds, waterfowl, and shorebirds are either residents or seasonal or migratory visitors to the Park (**Table 4**) and several species inhabit the maritime forests (**Table 5**). About 50% (~200 species) of the *total* bird species[25] in Georgia can be seen in the Park some time during the year (Georgia - WRD 2005). Rabolli and Ellington sited 82 species of birds during their survey (1998). An extensive list of species that occur throughout Coastal Georgia, along with information describing their seasonal occurrences and preferred habitat, is also available (Southeastern Wildlife Management 1981). There have been fewer studies identifying invertebrate species within the park (but see Southeastern Wildlife Management 1981[26]), and this is one area that the park has identified for a potential future project (Kevill *pers comm*.). Currently, a more extensive amphibian and reptile survey is being conducted by the Herpetology Program at the UGA Savannah River Ecology Lab (Savannah River Ecology Lab 2004). Thus far, they have generated a potential species list for amphibians (**Table 6**) and reptiles (**Table 7**); there are not expected to be many species due to the scarcity of freshwater in the area.

[25] According to the Georgia Ornithological Society, there are 407 well-documented (and regular) bird species in Georgia (*Annotated Checklist of Georgia Birds*) (Beaton et al. 2003).
[26] This study primarily identified noxious insect and other arthropod species within the park and made recommendations for their management. There was no formal identification/enumeration of other invertebrate fauna.

Below we provide a brief overview of the organisms that are associated with the different habitats found in and around the Park.

Table 4. Wading birds, waterfowl, and shorebirds commonly seen at Fort Pulaski NM. Based on data in NPS 2004.

Category	Common Name	Scientific Name
Wading Birds	Brown Pelican	*Pelecanus occidentalis*
	Double-creasted Cormorant	*Phalacrocorax auritus*
	Great Blue Heron	*Ardea herodias*
	Great Egret	*Casmerodius albus*
	Snowy Egret	*Egretta thula*
	Little Blue Heron	*Egretta caerulea*
	Cattle Egret	*Bubulcus ibis*
	Great-backed Heron	*Butorides striatus*
	White Ibis	*Eudocimus albus*
Waterfowl	Lesser Scaup	*Aythya affinis*
	Hooded Merganser	*Lophodytes cucullatus*
	Turkey Vulture	*Cathartes aura*
	Osprey	*Pandion haliaetus*
	American Kestrel	*Falco sparverius*
Rails, Gulls, Shorebirds	Northern Bobwhite	*Colinus virginianus*
	Clapper Rail	*Rallus longirostris*
	Black-bellied Plover	*Pluvialis squatarola*
	Semipalmated Plover	*Charadrius semipalmatus*
	Killdeer	*Charadrius vociferus*
	Willet	*Catoptrophorus semipalmatus*
	Red Knot	*Calidris canutus*
	Dunlin	*Calidris alpina*
	Dowitcher (mostly short-billed)	*Limnodromus griseus*
	Common Snipe	*Gallinago galllinago*
	Laughing Gull	*Larus atriculla*
	Ring-billed Gull	*Larus delawarensis*
	Herring Gull	*Larus argentatus*
	Royal Tern	*Sterna maximus*
	Common Tern	*Sterna hirundo*
	Forster's Tern	*Sterna forsteri*

Table 5. Birds commonly seen in maritime forests at Fort Pulaski NM. Based on data in NPS 2004.

Category	Common Name	Scientific Name
Doves, Owls, Swifts, Hummingbirds, Kingfishers, Woodpeckers	Rock Dove	*Columba livia*
	Mourning Dove	*Zenaida macroura*
	Chimmey Swift	*Chaetura pelagica*
	Belted Kingfisher	*Ceryle alcyon*
	Red-bellied Woodpecker	*Melanerpes carolinus*
	Nothern Flicker	*Colaptes auratus*
	Common Barn Owl	*Tyto alba*
	Ruby-throated Hummingbird	*Archilochus colubris*
Buntings, Sparrows, Blackbirds, Orioles, Finches	Nothern Cardinal	*Cardinalis cardinalis*
	Painted Bunting	*Passerina ciris*
	Savannah Sparrow	*Passerculus sandwichensis*
	Swamp Sparrow	*Melospiza georgiana*
	Song Sparrow	*Melospiza melodia*
	White-throated Sparrow	*Zonotrichia albicollis*
	Red-winged Blackbird	*Agelaius phoeniceus*
	Boat-tailed Grackle	*Quiscalus major*
	Brown-headed Cowbird	*Molothrus ater*
	Orchard Oriole	*Icterus spurius*
	American Goldfinch	*Carduelis tristis*
Starlings, Vireos, Wood Warblers	American Robin	*Turdus migratorius*
	Gray Catbird	*Dumetella carolinensis*
	Northern Mockingbird	*Mimus polyglottos*
	Cedar Waxwing	*Bombycilla cedrorum*
	European Starling	*Sturnus vulgaris*
	White-eyed Vireo	*Vireo griseus*
	Yellow-rumped Warbler	*Dendroica coronata*
	Pine Warbler	*Dendroica pinus*
	Prairie Warbler	*Dendroica discolor*
	American Redstart	*Setophaga ruticilla*

Table 6. Species of amphibians occurring or likely to occur within or near Fort Pulaski NM.

Based on data in Savannah River Ecology Lab 2004. Those species marked with an "X" have been confirmed within the park.

Scientific name	Common name	Record for park
FROGS		
Acris crepitans	Northern cricket frog	
Acris gryllus	Southern cricket frog	X
Bufo terrestris	Southern toad	X
Bufo quercicus	Oak toad	
Gastrophryne carolinensis	Eastern narrowmouth toad	X
Hyla chrysoscelis/versicolor	Gray/Cope's gray treefrog	
Hyla cinerea	Green treefrog	X
Hyla femoralis	Pine woods treefrog	
Hyla gratiosa	Barking treefrog	
Hyla squirella	Squirrel treefrog	X
Pseudacris brimleyi	Brimley's chorus frog	
Pseudacris crucifer	Spring peeper	
Pseudacris nigrita	Southern chorus frog	
Psuedacris ocularis	Little grass frog	X
Pseudacris ornata	Ornate chorus frog	
Pseudacris triseriata	Upland chorus frog	
Rana catesbeiana	Bullfrog	
Rana clamitans	Green frog	
Rana grylio	Pig frog	
Rana utricularia	Southern leopard frog	X
Scaphiopus holbrookii	Eastern spadefoot toad	
SALAMANDERS		
Ambystoma opacum	Marbled salamander	
Ambystoma talpoideum	Mole salamander	
Amphiuma means	Two-toed amphiuma	
Desmognathus auriculatus	Southern dusky salamander	
Eurycea cirrigera	Southern two-lined salamander	X
Eurycea guttolineata	Three-lined salamander	
Eurycea quadridigitata	Dwarf salamander	
Notophthalmus viridescens	Red spotted newt	
Plethodon glutinosus complex	Slimy salamander	
Pseudotriton montanus	Mud salamander	
Siren intermedia	Lesser siren	
Siren lacertina	Greater siren	
TOTALS	**33**	**8**

Table 7. Species of reptiles occurring or likely to occur within or near Fort Pulaski NM.

Based on data in Savannah River Ecology Lab 2004. Those species marked with an "X" have been confirmed within the park.

Scientific name	Common name	Record for park
ALLIGATORS		
Alligator mississippiensis	Alligator	X
TURTLES		
Apalone ferox	Florida softshell turtle	
Chelydra serpentina	Common snapping turtle	
Clemmys guttata	Spotted turtle	
Deirochelys reticularia	Eastern chicken turtle	
Kinosternon baurii	Striped mud turtle	
Kinosternon subrubrum	Eastern mud turtle	
Malaclemys terrapin	Diamondback terrapin	X
Pseudemys concinna	Eastern river cooter	
Pseudemys floridana	Florida cooter	
Sternotherus odoratus	Common musk turtle	
Terrapene carolina	Eastern box turtle	X
Trachemys scripta	Yellow-bellied slider	X
LIZARDS		
Anolis carolinensis	Green anole	X
Cnemidophorus sexlineatus	Six-lined racerunner	
Eumeces egregius	Mole skink	
Eumeces fasciatus	Five-lined skink	
Eumeces inexpectatus	Southeastern five-lined skink	X
Eumeces laticeps	Broadhead skink	
Ophisaurus attenuatus	Slender glass lizard	
Ophisaurus compressus	Island glass lizard	
Ophisaurus mimicus	Mimic glass lizard	
Ophisaurus ventralis	Eastern glass lizard	X
Sceloporus undulatus	Fence lizard	
Scincella lateralis	Ground skink	X
SNAKES		
Agkistrodon contortrix	Copperhead	
Agkistrodon piscivorus	Cottonmouth	X
Carphophis amoenus	Worm snake	

Cemophora coccinea	Scarlet snake	
Coluber constrictor	Black racer	X
Crotalus adamanteus	Eastern diamondback rattlesnake	X
Crotalus horridus	Canebrake rattlesnake	
Diadophis punctatus	Ringneck snake	
Drymarchon corais	Eastern indigo snake	
Elaphe guttata	Corn snake	X
Elaphe obsoleta	Rat snake	X
Farancia abacura	Mud snake	
Farancia erytrogramma	Rainbow snake	
Heterodon platirhinos	Eastern hognose snake	
Heterodon simus	Southern hognose snake	
Lampropeltis getula	Eastern kingsnake	X
Lampropeltis triangulum	Scarlet kingsnake or milksnake	
Masticophis flagellum	Coachwhip	
Micrurus fulvius	Coral snake	
Nerodia erythrogaster	Plainbelly water snake	
Nerodia fasciata	Banded water snake	X
Opheodrys aestivus	Rough green snake	X
Pituophis melanoleucus	Pine snake	
Rhadinaea flavilata	Pine woods snake	
Sistrurus miliarius	Pigmy rattlesnake	
Storeria dekayi	Brown snake	
Storeria occipitomaculata	Redbelly snake	
Tantilla coronata	Southeastern crowned snake	
Thamnophis sauritus	Ribbon snake	
Thamnophis sirtalis	Garter snake	
Virginia striatula	Rough earth snake	
Virginia valeriae	Smooth earth snake	
TOTALS	**57**	**16**

A.3.a. Estuarine Areas

Fort Pulaski is located within the estuary of the Savannah River. Both the main channels of the estuary and the shallower tidal creeks that drain into them provide subtidal habitat to numerous aquatic organisms. Closer to shore, intertidal habitat includes oyster reefs, salt marshes, and mud flats.

A.3.a.i. Subtidal

Main Channel - Jennings and Weyers (2003) sampled ichthyoplankton upstream of the Park along 8 transects within the Front, Middle, and Back Rivers of the estuary (between RKM 12-45, i.e. RM ~8-28). Stations were located in the main channel, marsh-edge, and tidal creek and sampled monthly over 2 years (September 2000-August 2002). They found a total of 91 fish species, >80% of which were considered estuarine-generalists (tolerant of a wide variety of salinities). The greatest number of species were found in polyhaline waters (>15 psu), and included Bay anchovy (*Anchoa mitchelli*), Atlantic menhaden (*Brevoortia tyrannus*), Atlantic croaker (*Micropogonias undulatus*), and spot (*Leiostomus xanthurus*) (Jennings and Weyers 2003). A second study showed that the area where the Front, Middle, and Back Rivers converge (RKM 15, ~RM 9, just above Fort Pulaski) is home to the most diverse fish and crustacean population in the estuary (Collins et al. 2002). Combined, these 2 studies documented 116 species occurring in the estuary (**Table 8)**. Other studies have indicated that the channels of the Savannah River and estuary provide habitat for several anadromous, catadromous, and resident fish species, some of which are threatened or endangered (Part C).

Other organisms found in the estuary include dolphins (primarily Atlantic bottle-nosed, *Tursiops truncatus*) and occasional manatees (*Trichechus manatus*) (Rabolli and Ellington 1998; Deutsch et al. 2003). Various species of whales (Right (*Eubalaena glacialis*), Hump-back (*Megaptera novaengliae*), Sperm (*Kogia breviceps)*, Pilot (*Globicephala macrorhyncha*)) are potential visitors to the area (Georgia Museum of Natural History and Georgia Department of Natural Resources 2000). Conspicuous reptilian inhabitants include alligators (*Alligator mississippiensis*), terrapins (diamondback, *Malaclemys terrapin*), and to a lesser extent, diamondback terrpins (especially loggerheads, *Caretta caretta*).

There have been a few studies that looked directly at the fish species found in the portion of the estuary that borders FOPU. Rabolli and Ellington (1998) surveyed fish in May 1998 along the edge of the South Channel using a beach seine. They recovered 11 species, with over 50% represented by Bay Anchovies, and Atlantic Croaker[27]. Three sites were sampled in 1995 as part of the EPA's Environmental Monitoring and Assessment Program (EMAP)[28], recovering 23 species (see **Appendix B, Table B-1**) (U.S. EPA 1999). The most abundant species were white

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[27] Other fish were alewife (*Alosa pseudoharengus*), Atlantic needlefish (*Strongylura marina*), longnose gar (*Lepisosteus osseus*), mummichog, sailfin molly, sheepshead minnow, striped killifish (*Fundulus majalis*), striped mullet, and western mosquitofish (*Gambusia affinis*).

[28] This program was specifically designed to assess the conditions of estuarine resources through in-depth sampling at a few locations each year, and includes information on water quality (DO, salinity, temperature, depth, pH, nutrients, chlorophyll), sediment quality (grain size, TOC, sediment chemistry, sediment toxicity), and biota (community structure, external pathology, tissue analyses).

shrimp (*Penaeus setiferous*), *Stellifer lanceolatus,* and *Callinectes similes*, comprising 53%, 18%, and 6% of the total catch, respectively (U.S. EPA 1999). All species were different than those captured by Rabolli and Ellington (1998), likely because of the different habitats sampled and methods employed, i.e. channel edge (seine) vs. channel bottom (trawl). Collins et al. (2001) conducted acoustic surveys 3 times per week over 10 months (during Sciaenid spawning seasons, Aug-Nov and Feb-June) and found that the recreationally important fish spotted seatrout (*Cynoscion nebulosus*), red drum (*Sciaenops ocellatus*), weakfish (*Cynoscion regalis*), and black drum (*Pogonias cromis*) used the area located between RKM 0- 16 extensively for habitat (RM 0-10, at Elba Island). In addition, all but red drum were found to be actively spawning in these areas, as well. Notably, the *only* spawning sites located in the estuary (from ~RM 24 to RM 0) for black drum and weakfish were at the mouth of the Savannah River near Cockspur Island (RM 0).

***Tidal creeks* -** Rabolli and Ellington (1998) observed 5 species of fish in the drainage canals at FOPU: mummichogs (*Fundulus heteroclitus*), sailfin mollies (*Poecilia latipinna*), sheepshead minnows (*Cyprinodoi variegates*), western mosquitofish (*Gambusia affinis*), and striped mullet (*Mugil cephalus*). Although these canals are manmade, these same species are commonly observed in tidal creeks throughout the area (Wiegert and Freeman 1990). Tidal creeks serve as important nursery grounds for several fish species (Kneib 1997; Malloy 2004). White shrimp and blue crabs are also commonly found in these creeks and likely use them for marsh access (Williams 1984). Note also that other nektonic organisms that do not directly access the marsh can indirectly benefit by eating marsh residents or juveniles that move across the landscape from the marsh to the estuary and open water as they mature (Kneib 1997).

Benthos - The sediment around Fort Pulaski supports a variety of infaunal and epifaunal species. A composite sample of several cores from Fields Cut (which connects the Wilmington River to the South Channel, above McQueen's Island ~RM 7 to RM 0) consisted of 81.6% sand, 10.5% clay, and 3.3% silt (Georgia Ports Authority 1998). Benthic trawl surveys conducted in 1995 under the EMAP program documented a total of 67 species (1605 individuals) from sediment grab samples at 3 stations near Fort Pulaski. The most abundant species collected were *Oligochaeta* (602), *Streblospio benedicti* (321), *Parapionosyllis longicirrata* (126), *Nematoda* (71), and *Batea catharinensis* (70) comprising 37.5%, 20%, 7.9%, 4.4%, and 4.4% of the total individuals collected, respectively. The remaining species caught made up less than 3% each of the total individuals surveyed (*see* **Appendix B, Table B-2**).

Table 8. Fish species inhabiting the Savannah River Estuary.

Based on data in Collins et al. 2002 and Jennings and Weyers 2003. Species identified as "near Fort Pulaski" occurred at the lowermost Savannah River Site sampled by Collins et al. (2002) (site SR01, ~RM 9).

Species	Common Name	Near Fort Pulaski
Trichiurus lepturus	Altantic cutlassfish	
Anguilla rostrata	American eel	
Alosa sapidissima	American shad	X
Chloroscombrus chrysurus	Atlantic bumper	X
Micropogonias undulatus	Atlantic croaker	X
Brevoortia tyrannus	Atlantic menhaden	X
Selene setapinnis	Atlantic moonfish	X
Strongylura marina	Atlantic needlefish	
Rhizoprionodon terraenovae	Atlantic sharpnose shark	X
Menidia menidia	Atlantic silverside	
Dasyatis sabina	Atlantic stingray	
Acipenser oxyrinchus	Atlantic sturgeon	
Opisthonema oglinum	Atlantic thread herring	X
Elassoma zonatum	Banded pygmy sunfish	
Anchoa mitchilli	Bay anchovy	X
Citharichthys spilopterus	Bay whiff	
Prionotus tribulus	Bighead searobin	
Pomoxis nigromaculatus	Black crappie	
Pogonias cromis	Black drum	
Centropristis striata	Black sea bass	
Symphurus plagiusa	Blackcheek tonguefish	X
Ictalurus furcatus	Blue catfish	
Alosa aestivalis	Blueback herring	
Pomatomus saltatrix	Bluefish	X
Lepomis macrochirus	Bluegill	
Albula vulpes	Bonefish	
Myliobatis freminvillei	Bullnose ray	X
Peprilus triacanthus	Butterfish	X
Cyprinus carpio	Carp	
Syngnathus louisianae	Chain pipefish	
Ictalurus punctatus	Channel catfish	
Hypleurochilus geminatus	Crested blenny	X
Gobionellus boleosoma	Darter goby	
Hypsoblennius hentzi	Feather blenny	X
Lepisosteus platyrhincus	Florida gar	
Gobionellus shufeldti	Freshwater goby	
Etropus crossotus	Fringed flounder	X
Bagre marinus	Gafftopsail catfish	

Dorosoma cepedianum	Gizzard shad	
Lutjanus griseus	Gray snapper	
Microgobius thalassinus	Green goby	
Syngnathus scovelli	Gulf pipefish	
Peprilus alepidotus	Harvestfish	X
Alosa mediocris	Hickory shad	
Trinectes maculatus	Hogchoker	X
Morone saxatilis X chrysops	Hybrid striped bass	
Synodus foetens	Inshore lizardfish	X
Diapterus auratus	Irish pompano	
Caranx hippos	Jack crevalle	X
Scomberomorus cavalla	King mackerel	X
Elops saurus	Ladyfish	X
Micropterus salmoides	Largemouth bass	
Heterandria formosa	Least killifish	
Oligoplites saurus	Leatherjacket	
Lepisosteus osseus	Longnose gar	X
Selene vomer	Lookdown	X
Evorthodus lyricus	Lyre goby	
Eucinostomus sp.	Mojarra	
Gambusia affinis	Mosquitofish	
Fundulus heteroclitus	Mummichog	
Gobiosoma bosci	Naked goby	
Menticirrhus saxatilis	Northern kingfish	
Syngnathus fuscus	Northern pipefish	
Astroscopus guttatus	Northern stargazer	X
Ancylopsetta quadrocellata	Ocellated flounder	X
Ooestehus brachyurus	Oppossum pipefish	
Orthopristis chrysoptera	Pigfish	
Lagodon rhomboides	Pinfish	
Monacanthus hispidus	Planehead filefish	X
Lucania parva	Rainwater killifish	
Sciaenops ocellatus	Red drum	
Lepomis auritus	Redbreast sunfish	
Membras martinica	Rough silverside	
Poecilia latipinna	Sailfin molly	
Prionotus sp.	Sea robin	
Gobiosoma ginsburgi	Seaboard goby	
Gobionellus hastatus	Sharptail goby	
Archosargus probatocephalus	Sheepshead	X
Cyprinodon variegatus	Sheepshead minnow	
Acipenser brevirostrum	Shortnose sturgeon	
Bairdiella chrysoura	Silver perch	X
Cynoscion nothus	Silver seatrout	X
Gobiesox strumosus	Skilletfish	

Paralichthys lethostigma	Southern flounder	X
Menticirrhus americanus	Southern kingfish	X
Scomberomorus maculatus	Spanish mackerel	X
Sardinella aurita	Spanish sardine	
Myrophis punctatus	Speckled worm eel	
Leiostomus xanthurus	Spot	X
Eucinostomus argenteus	Spotfin mojarra	
Notropis hudsonius	Spottail shiner	
Ameiurus serracanthus	Spotted bullhead	
Urophycis regius	Spotted hake	X
Cynoscion nebulosus	Spotted seatrout	X
Minytrema melanops	Spotted sucker	
Citharichthys macrops	Spotted whiff	
Stellifer lanceolatus	Star drum	X
Anchoa hepsetus	Striped anchovy	
Morone saxatilis	Striped bass	
Chilomycterus schoepfi	Striped burrfish	
Mugil cephalus	Striped mullet	X
Paralichthys dentatus	Summer flounder	X
Megalops atlanticus	Tarpon	
Dorosoma petenense	Threadfin shad	X
Menidia beryllina	Tidewater silverside	
Fundulus sp.	Unid killifish	
Anchoa Sp.	Unidentified anchovy	X
Carangidae	Unidentified jack	
Cyprinidae	Unidentified minnow	
Lepomis sp.	Unidentified sunfish	
Cynoscion regalis	Weakfish	X
Ictalurus catus	White catfish	
Pomoxis annularis	White crappie	
Mugil curema	White mullet	
Morone americana	White perch	
Total	**116**	**41**

A.3.a.ii. Intertidal Habitat

Oyster reefs - The only approved location for recreational oyster harvest in Chatham County is Oyster Creek on McQueen's Island; fishers gain access through the Park and require NPS approval. Oyster reefs are also conspicuous habitats along the North Channel (Cockspur) and at Lazaretto Creek (McQueen's). Georgia oyster reefs are dominated by the American oyster *Crassostrea virginica* (>87%). Studies conducted throughout the southeast have shown that oyster reefs exert important physical influences, which in turn, create habitat for many organisms (Bahr and Lanier 1981). They stabilize banks, reduce erosion, aid in sedimentation, modify tidal stream flow and overall marsh physiography, and provide hard substrate in an area with an otherwise soft bottom. Numerous species of sessile suspension-feeding epifauna, invertebrates, small fish, mussels, mud crabs, polycheates, barnacles, metazoa, protozoa, and bacteria make their home on oyster reefs (Bahr and Lanier 1981). An estimated 40 species of animals are found on Georgia and South Carolina tidal reefs, and the density of individuals may vary from 25 to 2949 per m^2 (Wells 1961; Dame 1979). Some studies have indicated that oysters reefs and the associated fauna are rich sources of food for several valuable species, including blue crabs and black drum (Bahr and Lanier 1981; Zimmerman et al. 1989). In addition, they are important sources of nutrients for primary producers because they mineralize organic carbon, releasing N and P (Bahr and Lanier 1981).

Salt marshes and mud flats - Polyhaline (>18 psu) salt marsh communities are the dominant intertidal habitats on both Cockspur and McQueen's Island (Govus 1998). The dominant grass within the marsh is salt marsh cordgrass (*Spartina alterniflora*). Black needlerush (*Juncus roemerianus*) is not widely developed on either island, but is often interspersed with the cordgrass or located along the salt marsh fringe. Associated with these marsh communities are hypersaline salt flats on eastern Cockspur Island, which support halophytic shrub and herbaceous vegetation, typically seaside oxeye (*Borrichia frutescens*), saltwort (*Batis maritima*), woody-glasswort (*Salicornia virginica*), salt grass (*Distichlis spicata*), sea lavender (*Limonium carolinianum*), sea-blite (*Sueda linearis*), sea purslane (*Sesuvium portulacastrum*), and dwarfed saltmarsh cordgrass. At the upland edge of the marsh, dominant plant species are groundsel-tree (*Baccharis halimifolia*), marsh-elder (*Iva frutescens*), and wax myrtle (*Myrica cerifera*) (Govus 1998)

Although no surveys have been conducted specifically on Fort Pulaski's salt marsh fauna, an extensive study by the Fish and Wildlife Service, *Tidal Salt Marshes of the Southeastern Atlantic Coast: A Community Profile* provides a comprehensive list of fauna found in southeastern marshes(Wiegert and Freeman 1990). In addition, there is also a species list for Sapelo Island and its environs on the web site of the Georgia Coastal Ecosystems LTER project (http://gcelter.marsci.uga.edu/lter/asp/db/species_list.asp). Rabolli and Ellington surveyed small mammals at one site in the high marsh over 15 days (between January-October 1988) using a single trap line (consisting of 31 total traps) and reported only the marsh rice rat (*Orzyomys palustris*).

A.3.b. Upland Areas

Govus (1998) described the flora associated with the upland habitats of Cockspur and McQueen's Island. On Cockspur Island, upland areas consist of maintained grassland as well as forested areas found associated with higher ground (on the edge of the marsh; on the tops of the dikes; on shell mounds; and on dredge spoil deposits). It should be noted that live oak (*Quercus virginiana*), which is typically found in Georgia maritime forests, is not present at the Park, most likely because the upland is largely man-made and was kept free of vegetation until the 1920's. During the Civil War Period and during the army's subsequent occupation of the Fort, vegetation was removed and/or kept in early successional stages in order to enhance visibility for military purposes. On McQueen's Island there are a few shell mounds as well as ruderal areas adjacent to US Hwy 80 and the abandoned Central of Georgia Railroad.

A.3.b.i. Planted Areas

The most abundant upland habitat on Cockspur Island is maintained grasslands, which are located on the central portion of the area and surrounding the fort and dike system. Grasses are primarily cultivated species such as bermuda (*Cynodon dactylon*), dallis (*Paspalum dilataum*), vasey (*Paspalum urvillei*), and bahai (*Paspalum notatum*), but native and exotic grass and herbaceous species are also present (Govus 1998). Slash pine (*Pinus elliotti*) was planted by the NPS in the picnic area, and this area is used by nesting birds (Carolina Chikadee and Pine Warbler) and non-nesting birds (Mourning Dove, Yellow-shafted Flicker, Fish Crow, Red-Breasted Nuthatch, Blue Gray-Gnatcatcher, Cardinal, and White-throated Sparrow) (Southeastern Wildlife Management 1981).

A.3.b.ii.Maritime Forest

Marsh edge - Communities adjacent to the high marsh consist of almost pure stands of cabbage palmettos (*Sabel palmetto*) in the canopy. Shrubs consist of yaupon holly (*Ilex vomitoria*) or wax myrtle (*Myrica cerifera*), winged sumac (*Rhus coppalina*), and Spanish-bayonet (*Yucca aloifolia*), with nearly pure communities of yaupon holly and/or wax myrtle just above the high-tide line (Govus 1998).

Dike and dredge spoil areas - The canopy associated with the dike and spoil deposits[29] primarily consists of cabbage palmetto, coastal red-cedar (*Juniperus virginiana* var. *silicicola*), sugarberry (*Celtis laevigata*), and a few American elms (*Ulmus americana*). Exotic species Chinese tallow (*Sepium sebiferum*) and Chinaberry (*Melia azederach*) are occasionally present on old spoil sites. Shrubs present in the understory of these areas include dense stands of yaupon holly, laurel holly (*Prunus caroliniana*), wax myrtle, and beauty-berry (*Callicarpa americana*). Few ground-cover herbaceous species are present due to the dense woody vegetation, but vines, such as Virginia-creeper (*Parthenocissus quinquefolius*), pepper-vine (*Ampelopsis arborea*), smilax (*Smilax auriculata*), and muscadine (*Vitis rotundifolia*), are well-represented (Govus 1998).

A.3.b.iii. Shell Mounds

The overstory in these areas consists of nearly-pure stands of coastal red cedar. Calciphilic shrubs dominate the understory, including Hercules' club (*Zanthoxylum clava-herculis*), tough bumelia (*Sideroxylon tenax*), wild-olive (*Osmanthus americanus*), and Florida privet (*Forestiera segregata*, one of Georgia's "special concern" species) (Govus 1998).

A.3.b.iv. Ruderal

This habitat, found alongside U.S. Hwy 80 and the old railroad grade, parallel to the adjacent marsh on McQueen's Island, has the most diverse vegetation of the upland habitats. During the

[29] Areas of the most recently deposited dredge-spoil material (about 22-24 years ago), located on the north central and southwestern portions of Cockspur Island, support younger successional communities of primarily coastal red cedar, a few maritime shrubs, and a diverse herbaceous layer.

1998 study, special attention was paid to this area due to proposals to widen Hwy 80. Common tree and shrub/understory species are typical of the maritime forest and tidal shrubland species already discussed. Conspicuous herbaceous species are wildflowers, Indian blanket (*Gaillardia pulchella*), gaura (*Gaura angustifolia*), gerardia (*Agalinis fasiculata*), butterfly-pea (*Clitoria mariana*), wild bean (*Strophosyles helvola*), blue-curls (*Trichostema dichotomum*), camphorweed (*Heterotheca subaxilaris*), and flat-topped goldenrod (*Euthamia tenuifolia*) (Govus 1998).

A.3.c. Freshwater

The only bodies of freshwater located within the park's boundaries are manmade; there are 2 small ponds maintained near the monument that were originally dug for mosquito control in the 1990's, and the water in the moat surrounding the fort has been fresh since 1962 (Meader 2003). Although Govus (1998) did not include these areas in his vegetation survey, the two small mosquito ponds contain freshwater wetland species (Rabolli and Ellington 1998), with cattail (*Typha angustifolia*) being the most obvious. Rabolli and Ellington (1998) surveyed the fish fauna of one of the mosquito control ponds, and only mosquitofish (*Gambusia affinis*) were present. The moat fauna were not sampled, but there are several fish species and alligators present (Kevill *pers comm.*).

B. Water Resources Assessment

B.1. Water Quality

B.1.a. Data Sources

Horizon Systems Corporation was contracted by the NPS to retrieve, format, and analyze surface water quality data from 6 government databases[30] for the Park and surrounding area (between 3 miles upstream and 1 mile downstream). The "Horizon report," Baseline Water Quality Data Inventory and Analysis for Fort Pulaski National Monument (NPS 2001), represents the most comprehensive data inventory on water quality collected for Fort Pulaski and its immediate vicinity. The query yielded a total of 68 stations (9 located within the park)[31] containing data between 1960 and 1998. A summary of their results can be found in **Table 9**.

Most of the more recent water quality data that are discussed in this report come from the Coastal Resources Division (CRD) of the Georgia Dept. of Natural Resources. CRD collects samples from within the Fort Pulaski Study Area as a part of two ongoing programs: the State's shellfish monitoring and EPA's National Coastal Assessment Program (NCA). CRD samples 4 shellfish stations immediately adjacent to Fort Pulaski on a monthly basis, whereas approximately 1-3 sites randomly selected each year in the Chatham County-Wassaw Sound area for the NCA program fall adjacent to Fort Pulaski (n=9 sites total, 2000-2003) and are sampled once during the summer months (**Figure 7**). Parameters measured and the period of record varies, but they include measurements of fecal coliform, temperature, pH, DO, salinity, and dissolved nutrients. Sediment contaminants are also measured at NCA stations.

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[30] US EPA Databases: STORET (Storage and Retrieval water quality database management system), RF3 (River Reach File), IFD (Industrial Facilities Discharge), DRINKS (Drinking Water Supplies), GAGES (Water Gages), and DAMS (Water Impoundments).

[31] Location of these stations are on pages 34-37 of the Horizon report, which can be download at http://nrdata.nps.gov/FOPU/data/nrdata/water/wq/docs/FOPUwqaa.pdf.

Table 9. Summary of Horizon Report results (NPS 2001).

Parameter	Dissolved Oxygen	pH	Turbidity	Fecal Coliform
Water Use Designation	Aquatic Life	Aquatic Life	Aquatic Life	Bathing (Fresh or Marine)
EPA Criteria[1]	≥4 mg/L	≥6.5, ≤8.5 (M) ≥6.5, ≤9.0 (FW)	≤50 NTU	≤200 CFU/100 ml
By Station:				
# Stations	25	23	10	20
# Exceeding Criteria	18	19	8	14
% Exceeding Criteria	72	83	80	70
By Observation[2]**:**				
# Observations	4148	4685	2322	2245
# Exceeding Criteria	793	599	162	769
% Exceeding Criteria	19	13	7	34
Date of Record	02/15/68-12/10/98	03/07/60-12/10/98	02/15/68-12/10/98	02/17/68-12/10/98

[1]M=Marine, FW=Freshwater

[2]Represents the number of observations comparable to EPA criteria (not necessarily the total number of observations).

Additional data sources for nutrients include sampling conducted as part of several specific projects, including the EPA Environmental Monitoring and Assessment Program (EMAP); the NSF-sponsored Georgia Rivers Land Margin Ecosystem Research (LMER) Program at the University of Georgia; USGS sampling, and data collected for the Georgia Ports Authority. The EMAP program was the precursor to NCA, and was specifically designed to assess the conditions of estuarine resources through in-depth sampling at a few locations during each year. EMAP samples were taken in the Savannah River during August 1995, and include information on water quality, sediment quality, and biota[32] (Hyland et al. 1998). The LMER program measured nutrient concentrations in the Savannah River during cruises conducted between 1994 and 1996 (Wiebe and Sheldon Unpublished data) and the USGS sampled stations in the channel between 2002 and 2003 (USGS 2005). The Georgia Ports Authority has sponsored studies in preparation for the Environmental Impact Statement associated with their proposal to deepen the Harbor. A recent report, Hydrodynamic and Water Quality Monitoring of the Lower Savannah River Estuary (Applied Technology & Management (ATM) 2000), included water quality observations from the summer of 1999 at stations that spanned the Savannah River from Fort Pulaski at river mile 0 to Clyo at river mile 61. Additional data sources are discussed below.

[32] EMAP water quality data were not used in this report, as there were only limited observations (one sampling date at only 3 stations.)

B.1.b. Water Quality Data

Water quality data were compared to Georgia standards (**Appendix C)**. Note that, where applicable, information on ecosystem effects and human health issues related to water quality are also included in this section.

Nutrients

One focus of the Georgia Rivers LMER project was to characterize the transport of materials from upstream and through the estuary. Between 1994 and 1996 the project conducted longitudinal transects down the main channel of the river in a series of 4 cruises that spanned the calendar year (Wiebe and Sheldon Unpublished data). Stations were located at 2-km increments along the main channel, and spanned from river mile 0 to approximately river mile 29. Although there are seasonal changes in nutrient dynamics, their results show that dissolved nitrogen (NO_3+NO_2) and phosphorus (PO_4) concentrations are always highest at the upstream end of the estuary and decrease downstream as the river water becomes increasingly diluted by salt water from the ocean (**Figure 8**). For this reason, the discussion below focuses only on nutrient measurements taken directly adjacent to Fort Pulaski (RM 0 to 8). Note that near Fort Pulaski tidal mixing can sometimes increase nutrient concentrations, as is shown in the example plotted here.

We obtained recent dissolved nutrient concentrations for the tidal creeks and estuarine channel adjacent to Fort Pulaski from the USGS (n = 2 stations in the channel), GA-DNR CRD shellfish monitoring (n = 4 stations located in Oyster Creek) and NCA stations distributed in both the channel and tidal creeks (n=6) (**Figure 7**). USGS stations were sampled sporadically between January 2002 and December 2003. Monthly CRD sampling began in summer 2001 at the shellfish monitoring stations and yearly sampling began in 2000 at NCA stations[33]. Average dissolved nutrient concentrations at Fort Pulaski as measured by each of these programs as well as the LMER are summarized in **Table 10**. These observations represent surface water only, as there are only limited observations of nutrient concentrations with depth[34]: samples for the LMER, USGS, and shellfish monitoring programs are averaged across seasons, whereas NCA represents summer observations only. The measurements from the various programs show quite a range: lowest average DIN concentrations were reported by the CRD shellfish program (0.079 mg L^{-1} ± 0.044) and the highest by the LMER program (0.203 mg L^{-1} ± 0.072). Average phosphate concentrations were lowest in the NCA observations (0.023 mg L^{-1} ± 0.011) and highest in the USGS data set (0.073 mg L^{-1} ± 0.040). It is difficult to know how to compare these observations, since the station locations, sampling dates, and analytical methodology varied among the different programs. However, the overall averages are generally in line with past observations of dissolved inorganic nutrients as reported in the Horizon Report: NH_4 (mean ± sd) averaged 0.095 mg L^{-1} ± 0.019 (n=209, 1973-1999), NO_3 + NO_2 concentrations averaged 0.115 mg L^{-1} ± 0.043 (n=209 obs, 1973-1998), and TDP averaged 0.030 mg L^{-1} ± 0.019 (n=5, 1985-1986). Nutrient concentrations

[33] CRD data are still being checked for quality assurance so we have based this discussion on observations made through October 2003 at the shellfish stations and through August 2002 for NCA stations. Note that NCA stations included in this analysis were: GA00-0030, GA00-0031, GA01-0009, GA02-0007, GA02-0008, and GA02-0011.
[34] The NCA data suggest there is a mid-depth peak in dissolved inorganic nitrogen (notably in NH_4), but similar concentrations in surface and bottom water.

reported for South Carolina during the summers of 1999 and 2000 at stations located in both tidal creeks (n=30) and open water (n=30) are also presented for comparison (Van Dolah et al. 2002). The dissolved nutrient concentrations observed at Fort Pulaski are similar with the concentrations reported in South Carolina waters, although maximum concentrations in the Savannah River are always lower.

There are no EPA standards for dissolved nutrient concentrations, so we compared the NCA observations to the criteria developed by the EPA for the National Coastal Condition Report II (NCCRII) (U.S. EPA 2004d). For nitrogen, dissolved inorganic nitrogen (DIN) concentrations less than 0.1 mg N/L were considered "Good;" those between 0.1 and 0.5 were considered "Fair;" and those above 0.5 were considered "Poor" for the southeast (U.S. EPA 2004d). For phosphorus, dissolved inorganic phosphorus (DIP) concentrations less than 0.01 mg P/L were considered "Good;" those between 0.01 and 0.05 were considered "Fair;" and those above 0.05 were considered "Poor." By these criteria, 63% of the total DIN observations in the Fort Pulaski region of the Savannah River (n = 119) are Good and 37% are Fair (none are Poor). In terms of PO_4, 93% of the total DIP observations (n = 115) are considered Fair; 5% are Good, and 2% are Poor. By these criteria, 71% of the DIN observations at the USGS stations were considered Fair and all of the PO_4 observations were either Poor or Fair. Taken together, these observations indicate that nutrients warrant continued observation.

It would also be useful to obtain measurements of dissolved organic nitrogen (DON) for the region. Long-term measurements at Skidaway Island, just outside the study area, show evidence of linear increases in DON concentration over the past 10 y, along with smaller, less obvious increases in DIN (Verity 2002b). Between 1987 and 1996, average DON concentrations increased from 0.28 mg N L^{-1} to 0.72 mg N L^{-1}. DON calculated from LMER measurements near Fort Pulaski averaged 0.20 mg N L^{-1} (n=10 obs, 11/94-7/96) in surface water, well below the measurements reported at Skidaway. More recent observations of DON (calculated as TKN-NH_4) at the study site comes from one station (GPA26) monitored during an ATM study (2000). There, DON averaged 0.41 ± 0.30 mg N L^{-1} (n=14 obs, August-September 1999)[35], which is higher than the LMER average but again lower than that observed at Skidaway. It is therefore unclear whether DON is in fact increasing in the Savannah the way it appears to be doing at the Skidaway site. However, given that DON comprises approximately 80% of total dissolved nitrogen, additional measurements of DON would be informative.

[35] When reported values for TKN or ammonium were below the lab detection limit, we used half the detection limit to calculate DON.

Figure 7. Map of U.S. EPA (EMAP), GA-DNR CRD (NCA and Shellfish), and USGS sampling stations near Fort Pulaski.

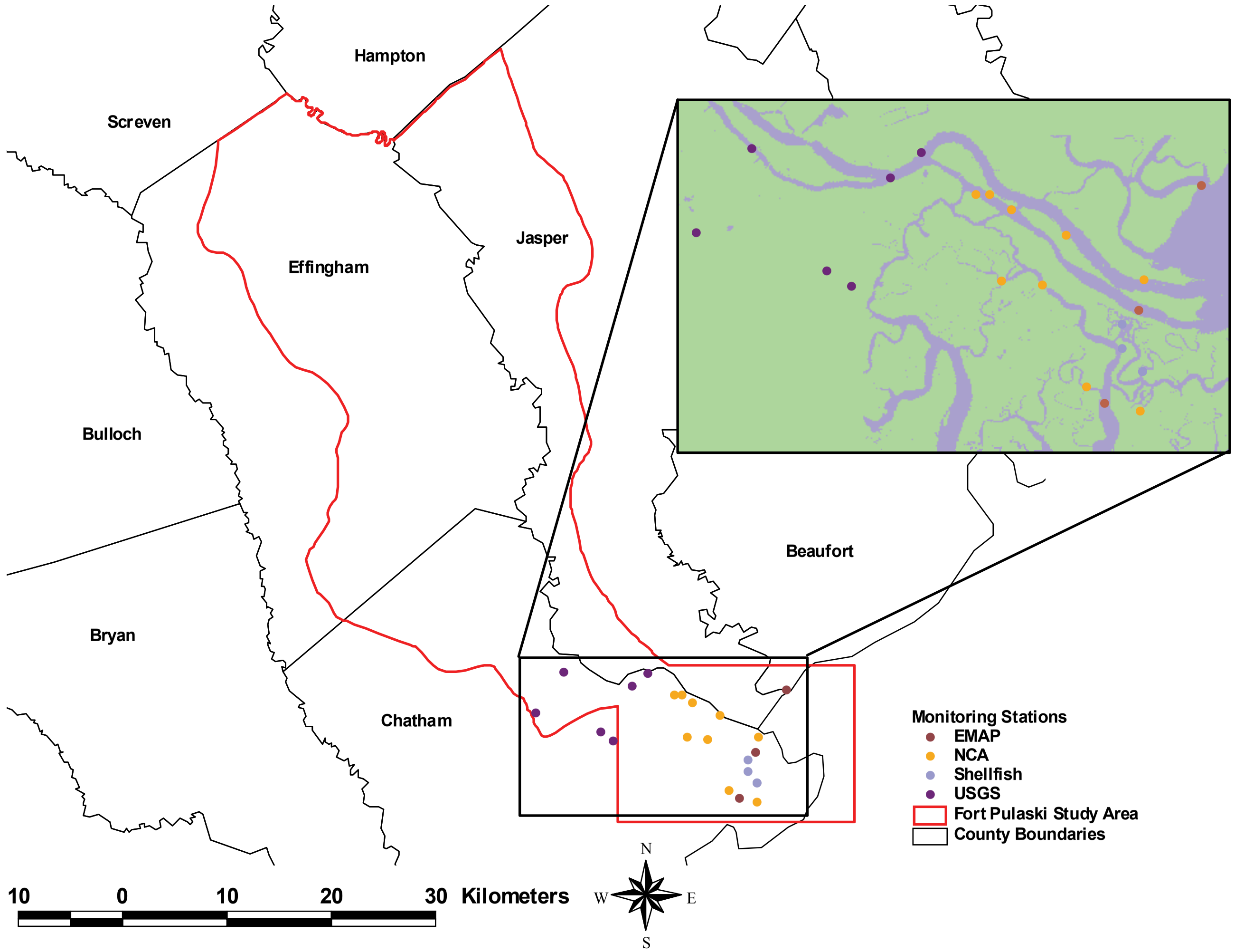
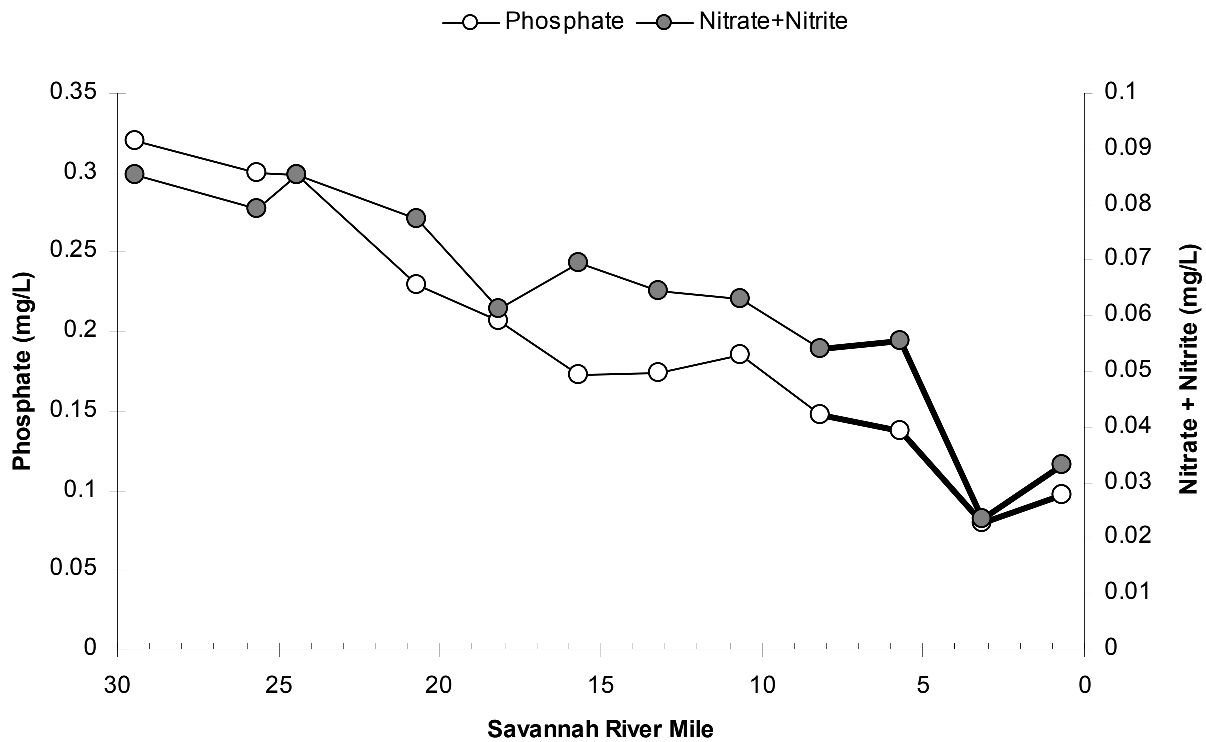


Figure 8. Nitrogen and Phosphorus concentrations along a transect in the Savannah River, shown from upstream to downstream.

*portions of the river surrounding Fort Pulaski are in bold
(based on data from GA Rivers-LMER, July 1996 cruise, Wiebe and Sheldon, unpublished data)



Dissolved Oxygen

19% of the 4,148 dissolved oxygen (DO) observations compiled in the Horizon report violated US EPA standards for aquatic life (NPS 2001). The majority (76%) of the stations with low DO were upstream of Fort Pulaski. On the basis of these types of observations as well as their own measurements, DO in the lower Savannah River was identified as a potential problem in the Savannah Harbor Environmental Impact Statement (EIS) by Applied Technology Management (ATM), a consultant to the Ports Authority.

In an effort to better characterize DO conditions in the Savannah River, ATM measured longitudinal profiles of DO at a series of stations along the River during a one-day sampling effort in September as a part of their 1999 Hydrodynamic and Water Quality Monitoring (Applied Technology & Management (ATM) 2000). DO measurements were made at 4 cross-channel sites at 10 pre-established Georgia EPD stations using a handheld YSI probe. DO concentrations at all stations ranged from 2.38 to 6.93 mg L^{-1} (**Table 11**). Thirty-one of the 336 observations fell below the GA water quality standard (< 4.0 mg L^{-1}). When the data from the survey are separated by

Table 10. Nutrient concentrations (mg L^{-1}) reported for the Savannah River at stations adjacent Fort Pulaski, GA and in South Carolina tidal creeks and open water (data are means ± SD).

Program	**GA Rivers LMER***	**USGS**	**GA-CRD Shellfish Monitoring**	**NCA Monitoring**	**South Carolina****
# Stations	Transect, ~RM 0-8	2	4	6	60
Dates of Observations	year-round (1994-1996)	year-round (2002-2003)	year-round (2001-2003)	Summer (2000-2002)	summer (1999)
Nitrogen (mg N L^{-1})					
NH_4 (# obs)	n=15	n=48	n=578	n=6	n=53
mean ± SD	0.072 ± 0.025	0.049 ± 0.033	0.044 ± 0.028	0.064 ± 0.035	0.051 ± 0.064
min-max	0.014 – 0.105	0.015 – 0.14	0.007 – 0.131	0.022 – 0.103	0 - 0.280
NO_2 + NO_3 (# obs)	n=15	n=48	n=98	n=6	n=57
mean ± SD	0.131 ± 0.054	0.103 ± 0.049	0.035 ± 0.026	0.110 ± 0.121	0.035 ± 0.049
min-max	0.023 – 0.194	0.025 – 0.23	0.001 – 0.130	0.004 – 0.291	0 – 0.305
DIN (# obs)	n=15	n=48	n=98	n=6	n=50
mean ± SD	0.203 ± 0.072	0.152 ± 0.066	0.079 ± 0.044	0.174 ± 0.124	0.094 ± 0.087
min-max	0.079 – 0.294	0.045 - 0.31	0.008 – 0.211	0.065 – 0.349	0.006 – 0.380
TDN*** (# obs)	n=10		---	---	n=59
mean ± SD	0.391 ± 0.062		---	---	0.594 ± 0.146
min-max	0.282 – 0.471		---	---	0.361 – 0.950
Phosphorus (mg P L^{-1})					
PO_4 (# obs)	n=15	n=48	n=578	n=2	n=60
mean ± SD	0.027 ± 0.010	0.073 ± 0.040	0.023 ± 0.011	0.014 ± 0.001	0.023 ± 0.034
min-max	0.013 – 0.042	0.03 – 0.19	0.003 – 0.072	0.014 – 0.021	0 – 0.209
TDP* (# obs)	---		n=572	---	n=60
mean ± SD	---		0.035 ± 0.020	---	0.039 ± 0.035
min-max	---		0.018 – 0.100	---	0.006 – 0.255

* Wiebe and Sheldon, unpublished data.
** Reported in Van Dolah et al., 2002.
*** Inorganic + organic.

depth[36] and plotted by river mile, it can be seen that surface and bottom oxygen concentrations are similar above RM 20 (where it is nearly all fresh), but in downstream areas where the river is vertically stratified there is lower DO in bottom than surface water (**Figure 9**) (Applied Technology & Management (ATM) 2003). As seen in **Figure 9**, DO concentrations near Fort Pulaski (below RM 8) and closer to the ocean increase steadily in both the surface and bottom water, an observation that is also supported by the 1997 and 1999 ATM continuous DO station datasets (Applied Technology & Management (ATM) 2004).

The location of the lowest DO concentrations is upstream of Fort Pulaski. ATM did an initial report, Hydrodynamic and Water Quality Monitoring of the Lower Savannah River Estuary, July-September 1997, in which lowest DO concentrations were observed ~RM 10-19[37]. Almost all of the exceedances in the ATM dataset (84%) occurred in bottom water at the 2 stations between river miles 13 and 15, and minimum DO was observed at RM 15 (**Table 11**, **Figure 9**). More recently, modeling of DO based on continuous observations collected in1999 suggest that the region with the lowest bottom water DO is located between RM 15 and 20 (Applied Technology & Management (ATM) 2003)[38].

Although some areas in the Georgia rivers are naturally low in oxygen, the low DO observed in the Savannah is likely due to discharges of organic matter and/or nutrients associated with industrial activity. The areas of low DO in the Savannah River are located adjacent to the Ocean Terminal (~RM 15) and heavily developed downtown area, and just downstream of the Garden City Terminal (~RM 18) and major industrial sources. As a part of the data collected for input to the Hydrodynamic and Water Quality Model, ATM (Applied Technology & Management (ATM) 2004) quantified biological oxygen demand (BOD) along the river from Clyo, located at ~RM 60 in Effingham County, to the Atlantic Ocean. Estimated BOD from marshes, sediment, and upstream loads remained relatively steady and did not fluctuate much throughout the Harbor. In comparison, BOD from point source loads varied with time and space, from 10,000-120,000 lbs/day. Their analysis showed that the DO deficit[39] in the reach between RM 13 and 20 was most strongly correlated to the BOD of point source dischargers (see Figure 2-21 of ATM 2004). ATM identified 10 major point source dischargers spanning the Harbor, 6 of which occurred between RM 13 and 20 (see section B.3.a. *NPDES*). However 85% of the total point source BOD came from a single discharger located between RM 16.6 and 18.7 (Applied Technology & Management (ATM) 2004). At station GPA-06 (RM 16.6), which is closest to this area, bottom water had the greatest mean DO deficit (~4.2 mg L^{-1}) and the lowest mean DO concentration (~3.3 mg L^{-1}) (Applied Technology & Management (ATM) 2004).

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[36] For each station, "surface" water was the top 4-5 DO measurements (all were at depths ≤1.5 m) and "bottom" water was the bottom 3-4 DO measurements (depth depended on how deep that portion of the river was at that station, typically >10 m).
[37] Although we were unable to obtain the report and its associated data, it was summarized in the 1998 EIS (see Figures 4-11 through 4-13 "pre-project" DO concentrations in (Georgia Ports Authority 1998).
[38] Data were extrapolated from two continuous monitoring stations located within RM 15-20, GPA-06 at RM 16.6 and GPA-22 at RM 18.7. The model was calibrated to the 1999 Hydrodynamic and Water Quality monitoring data and validated to the 1997 data (Applied Technology & Managemen (ATM) 1998; Applied Technology & Management (ATM) 2000).
[39] The DO deficit is equal to the DO saturation concentration minus the observed DO concentration. It is used, rather than the raw DO concentration, because it removes the effects of salinity and temperature on DO.

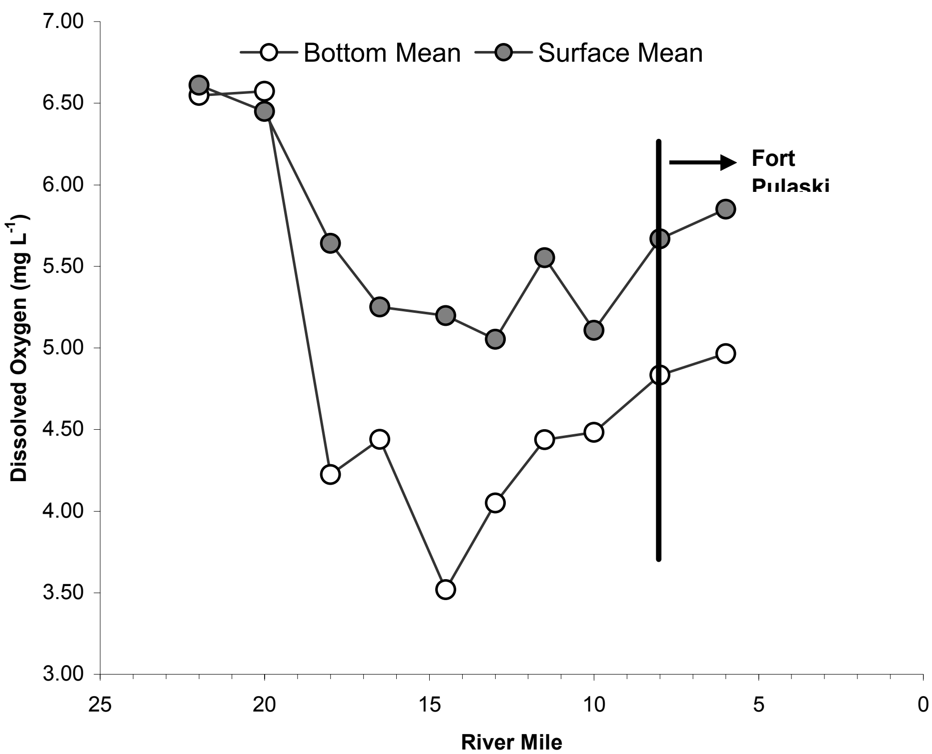
Table 11. Summary of July-September 1999 dissolved oxygen data collected by Applied Technology and Management, Inc. at pre-established EPD stations (Applied Technology Management (ATM) 2000).

EPD Station	Min	Max	Mean	# of Obs	% of Obs Exceeding	Approx River Mile
1	4.78	6.12	5.15	42	0	6.0
2	4.77	5.80	5.03	35	0	8.0
3	2.38	5.30	4.64	35	6	10.0
4	3.61	6.10	4.72	45	4	11.5
5	3.90	5.23	4.40	41	27	13.0
6	3.24	5.29	4.35	39	38	14.5
7	4.44	5.25	4.95	8*	0	16.5
8	4.15	6.12	5.12	36	0	18.0
9	6.29	6.61	6.46	39	0	20.0
10	6.38	6.93	6.63	19	0	22.0

- Few observations due to shipping activity.

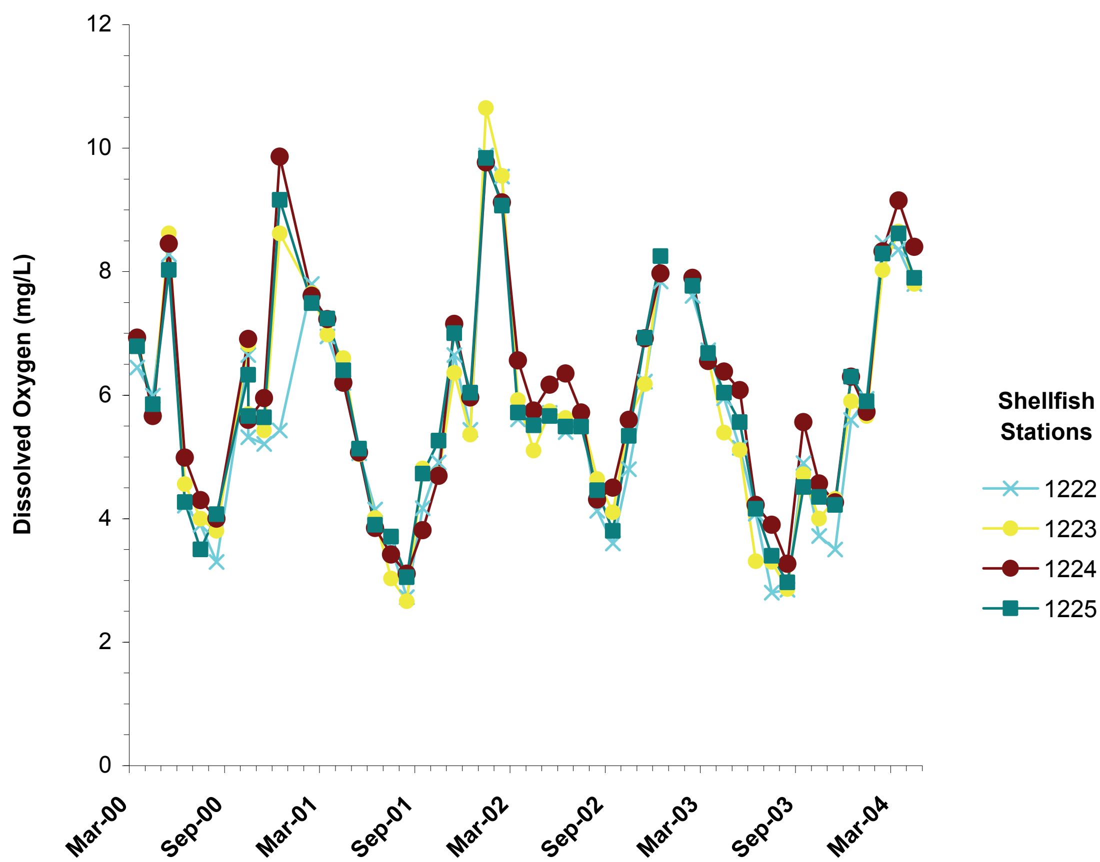
Figure 9. Mean dissolved oxygen concentrations of surface and bottom water along a transect in the Savannah River (sampled 9/13/99), shown from upstream to downstream.

(source data: Applied Technology Management (ATM) 2000, 10 pre-established EPD stations)



Recent DO measurements near Fort Pulaski were obtained from CRD's Shellfish Monitoring Program. These are instantaneous measurements taken in surface water using an oxygen probe. DO concentrations at stations near Fort Pulaski ranged from 2.7 to 10.7 mg L^{-1} and averaged 5.8 ± 1.7 mg L^{-1}. Low concentrations (less than or equal to the GA criterion of 4 mg L^{-1}) occurred 16% of the time (31 out of 196 observations). Examination of the period of record reveals similar trends at different sites (**Figure 10**). Not surprisingly, there was a distinct seasonal cycle in these observations, with summertime minima and wintertime maxima. The seasonal cycle for all stations is shown in **Figure 11**. In the entire data set, values <4 mg L^{-1} were most common during warm months, with all observations occurring between May and October (these were nearly equally distributed across the 4 stations). Concentrations were below 3 mg L^{-1} 6 times, but never fell below 2 mg L^{-1}; the minimum observation was 2.7 mg L^{-1}. Note that these measurements were generally taken at mid-day. They therefore do not necessarily reflect the average concentration at a given site, and are almost certainly higher than the daily minimum (which usually occurs just before dawn).

Figure 10. Dissolved oxygen concentrations over time (March 2000-April 2004) at stations near Fort Pulaski.



Observations of DO concentrations in bottom water come from samples taken by Georgia CRD for the National Coastal Assessment Program (NCA). Oxygen concentrations are sampled during the late summer (either in August or September), when DO minima occur. The range of DO observations at 8 stations sampled directly adjacent to Fort Pulaski during 2000, 2002, and 2003 (**Figure 1**) was 3.32 to 5.23 mg L^{-1}, with surface water (<1 m) averaging 4.38 ± 0.57 and bottom water (the lowest measurement in a profile) averaging 4.03 ± 0.62. Two stations near Elba Island Cut (~RM 6 in the North Channel) and two near the intersection of Turners Creek and the Bull River (**Figure 7**) had average concentrations below 4 mg L^{-1}. When the wider study area (i.e. the area denoted by red outline in Part A, Figure 1) is considered (n=21 stations), 27 out of 46 of the observations in water not considered surface water (>1 m) were less than or equal to 4 mg L^{-1}. When plotted by depth of observation (regardless of station location), mean DO concentrations decreased to less than 4 mg L^{-1} below a depth of only 2 meters (**Figure 12**). Although these values do not approach hypoxic conditions (defined as < 2 mg L^{-1}), they are less than the State standard and may indicate a problem for benthic species that cannot move to a more favorable environment.

Figure 11. Seasonal variation in mean dissolved oxygen averaged across stations near Fort Pulaski. (based on Shellfish program data from Georgia-DNR-CRD)

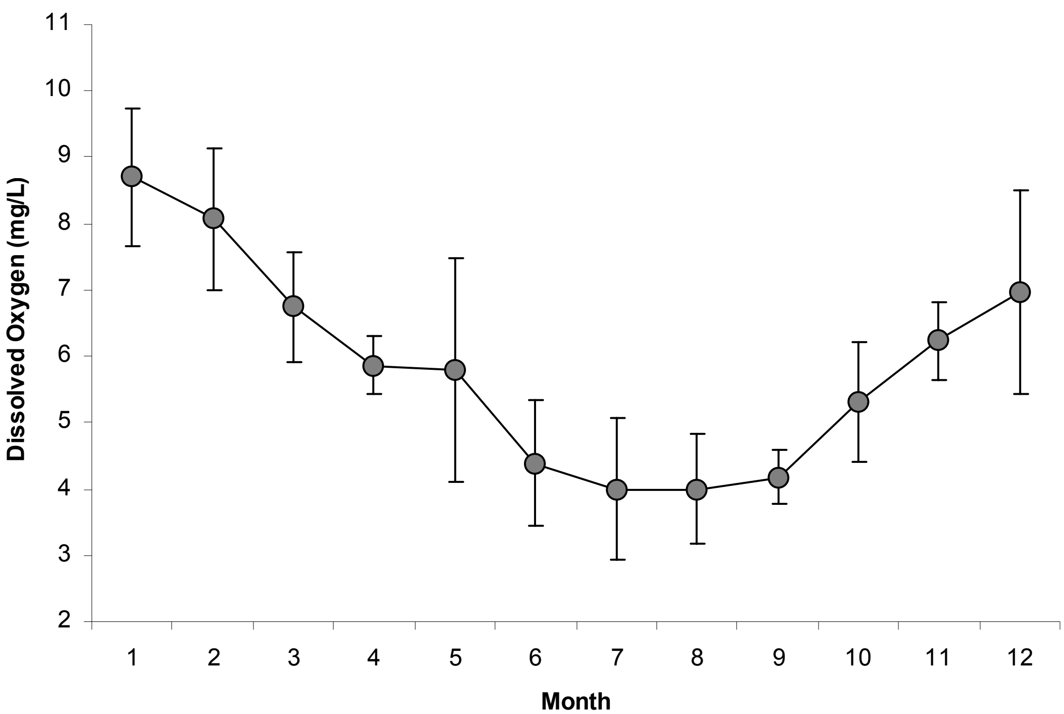
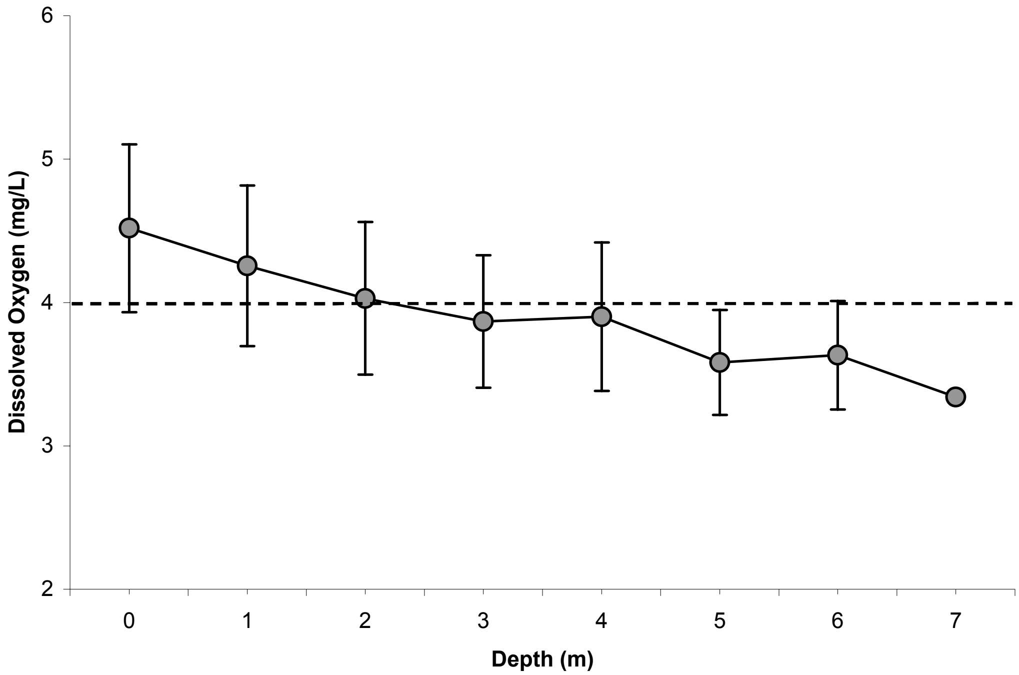


Figure 12. Dissolved oxygen concentrations (± SD) versus depth of observation in the Study Area. Data are averaged across stations (n=21) in the Study Area. The reference line denotes 4 mg/L. (based on NCA program data from Georgia-DNR-CRD)



Bacterial Contamination

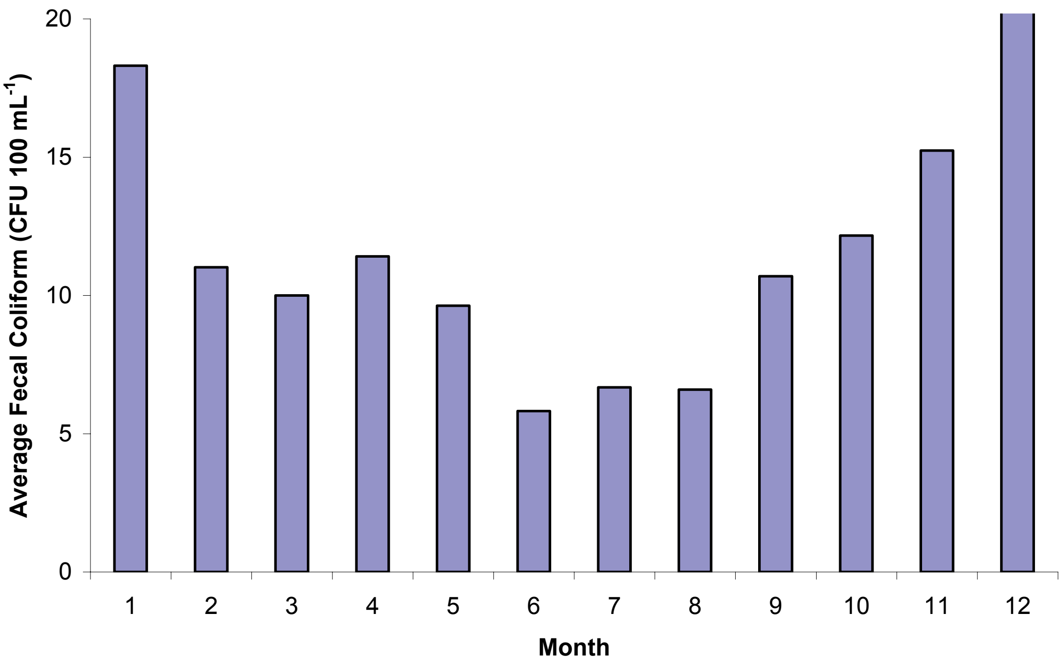
Fecal coliform bacteria may arise from point and nonpoint sources, such as wastewater treatment plants, agricultural nonpoint sources, leaking septic systems, and storm water runoff. In the Horizon report, a total of 769 of 2,245 observations of fecal coliform violated EPA standards for bathing water (200 colony forming units (CFU) per 100 mL) taken between 1986 and 1997, with most exceedances (64%) occurring upstream of Fort Pulaski. However, three stations in the North Channel directly adjacent to Fort Pulaski accounted for nearly all (77%) of the remaining 277 exceedances. Current information within the main channel of the Harbor was available from 5 USGS stations located at river miles 2, 5, 10, 11, and 15.5, sampled sporadically over 2 years, from January 2002 to December 2003 (**Figure 7**). There were 32 observations per station, except for the station at RM 11, which had 31 observations. A total of 21 of 159 observations across all stations exceeded bathing water criteria; all but one exceedance occurred upstream of Fort Pulaski (between RM 10-15.5).

Current information on fecal coliform concentrations in the Park itself was available from four CRD Shellfish stations located on Oyster Creek, which is the only approved site for shellfish harvest in Chatham County. In the Horizon Report, only 1 of 374 observations in this area (Stations 021, 022, 015, 017) exceeded the EPA bathing standard. We compiled a total of 584 fecal coliform observations (n =145-147 at each station) collected between 1991 and 2004.

Fecal coliform concentrations (based on most probable number (MPN)) were again much lower than the EPA standard, averaging between 26 and 36 CFU per 100 ml over the period of record. In terms of temporal patterns, 1991 and 2000 had much higher overall concentrations (> 10 x) than all other years due to exceptionally high measurements in June 1991 (1100 CFU per 100 ml at all stations) and July 2000 (2400 CFU per 100 ml at all but station 1222). The specific cause(s) of these high readings are unclear[40]. Average monthly concentrations (with June 1991 and July 2000 values omitted) are presented in **Figure 13**. The concentration of fecal coliform was highest from late fall through early winter and lowest during the summer[41].

Figure 13. Seasonal pattern of mean fecal coliform concentration near Fort Pulaski.

(based on Shellfish data from Georgia DNR-CRD)



Fewer than 2% of these observations (n = 9)[42] were above the Georgia criterion of 100 CFU per 100 ml for coastal recreational water. Given that these are single observations and State standards are written to reflect geometric mean concentrations sampled over a 30-d period, they cannot be used for regulatory purposes. In order to evaluate similar one-time observations, the South Carolina Estuarine Coastal Assessment Program (SCECAP) considered 43 colonies per 100 ml as representative of marginal conditions and >400 colonies per 100 ml as degraded

[40] We obtained precipitation information for Savannah during the June 1991 and July 2000 sampling events from the Georgia State Climatology Office website (http://climate.engr.uga.edu/, 2005) to see if the high coliform observations were associated with increased runoff. Although rain was associated with each sampling date: 0.42 in., 6/8/91 (sampled 6/10/91); 0.32 in., 7/12/00; 0.28 in., 7/8/00 (sampled 7/12/00), these rain events were not particularly large.

[41] If those 7 values are included, the concentration of fecal coliform shows a strong peak only during the months of June and July, exactly opposite the pattern seen without those observations.

[42] All 9 observations were > 200 CFU, with 7 > 1000 CFU.

conditions. By these criteria, 18 observations out of the total (584) are considered marginal, and the 7 extremely high observations from June 1991 and July 2000 are considered degraded (**Table 12**). Nearly half of these observations were at the most upstream station (1222), which may reflect reduced flushing at this site. No recent observations (2002-2004) are considered marginal or degraded.

Shellfishing standards are more stringent than those for recreational waters. The National Shellfish Sanitation Program standard is a geometric mean value >14 CFU over the course of 30 observations (which translates to 2.5 y in this data set because observations are made monthly[43]). Values over this standard were only observed at station 1222, which had exceedances over 19 consecutive months between 2/94 and 5/96[44]. However, the geometric mean at station 1222 has not exceeded 6 CFU since November 2000 and the most recent measurements taken in 2004 were ≤5 CFU, indicating improved conditions. The geometric mean at the other 3 stations never exceeded 10 CFU over the period of record. Overall, these observations indicate low fecal coliform concentrations in Oyster Creek, and shellfishing is permitted in this area.

Table 12. Number of fecal coliform observations exceeding SCECAP criteria*, summed by month and station.

Station locations are shown in **Figure 7**.

	Station ID				
Month	**1222**	**1223**	**1224**	**1225**	**Monthly Total**
1	1		1		2
2	1				1
4	2				2
5	2				2
6	1	1	1	1	4
7	1	1	1	1	4
8	1				1
9			1	1	2
10	1				1
11	2				2
12			3	1	4
Station Total	12	2	7	4	25

*Observations exceeding 400 CFU per 100 ml are highlighted. All others exceeded 43 CFU per 100 ml. (based on GA-CRD Shellfish data)

43 The earliest observation in this data set is February 1991, so the soonest possible date that can be examined for shellfishing exceedance is July 1993.

44 Samples were taken every other month in 1995 and 1996.

Contaminants

Information on contaminants in the Savannah Harbor area and Fort Pulaski comes primarily from the 1998 EIS, the EMAP and NCA programs, an independent study by Loganathan et al. (2001), and studies conducted for the Park Service by investigators at Savannah State University (Richardson and Sajwan 2001; 2002). In each case, sediments and/or fish tissue was analyzed for a suite of EPA recommended priority and non-priority pollutants (~150), which include metals and organic compounds (PAHs, PCBs, pesticides, phenols) (www.epa.gov/waterscience/criteria/wqcriteria/). The EIS provided information on contaminants found in sediment spanning the Harbor from RM 20 (above the Kings Island Turning Basin) to about 14 miles offshore, near dredge-disposal facilities sites. Sediments were collected for the EMAP program from 3 sites in summer 1995 (CP95161, CP95162, and CP95163) and for the NCA program from 3 sites during the summers of 2000 and 2001 (GA00-0030, GA00-0031, GA01-0009). Contaminant concentrations and sediment toxicity tests were performed on these samples. Composite samples of shrimp tissue (*Penaeus setiferus*) were collected for EMAP in August 1995 (CP95162) and for NCA in August 2000 (GA00-0031). Loganathan et al. (2001) analyzed sediments and 6 different species of fish for PCBs and pesticides in July 1997. Sediments were sampled at 2 sites in the Park, one in the North Channel near Cockspur Island and one in the Bull River near McQueens Island; the fish were composited from these 2 sites plus 6 others located in Wassaw Sound. Lastly, Richardson and Sajwan (2001, 2002) conducted 2 studies at the Park (November 2000 and 2001) during which they analyzed sediment and oyster tissue for several heavy metals and organic compounds at 9 sites within the salt marsh-estuarine system, 3 of which were in Oyster Creek. In addition, several independent studies that provide relevant historic and background information are included in this section.

Concentrations of contaminants in sediment were compared to effects range-low (ERL) and effects range-median (ERM) values (Long et al. 1995)[45]. These values and information regarding their derivation are provided in **Appendix E**. In addition, the 1998 EIS used EPA sediment quality guideline values and threshold effects levels to evaluate contaminant concentrations reported by the U.S. Army Corps of Engineers. Concentrations of contaminants in seafood tissue were compared to the EPA Risk Guidelines as in the National Coastal Condition Report (see Table 1-20 in U.S. EPA 2004c). Individual sites were rated “good” if contaminant concentrations fell below screening values, “fair” if they were within the range of screening values, and “poor” if they were greater than screening values. The report gave the southeast an overall rating of “good”, but did not give details on individual sites.

Sediments - Historic information on sediment contamination in the Savannah River Harbor comes from Goldberg et al. (1979) and Alexander et al. (1994), each of whom utilized radiolabeled sediment cores to analyze trends in sediment pollution over time (geochronology). Goldberg et al. (1979) reported a trend toward increasing heavy metal concentrations - lead,

[45] The effects-based method estimates the percent incidence at which adverse biological effects occur to aquatic organisms at specific contaminant concentrations. For each chemical, effects range-low (ERL) and effects range-medium (ERM) are used that correspond to the likelihood of adverse effects: when concentrations are less than the ERL, adverse effects are rare; when they fall between the ERL and ERM, adverse effects are occasional, and when they are greater than the ERM, adverse effects are frequent.

chromium, and vanadium - from mid-1940 to mid-1970 and suggested this was due to increased anthropogenic activity during that period (Goldberg et al. 1979). Alexander et al. (1994) also observed high concentrations of heavy metals (mainly mercury and chromium), as well as PAHs and PCBs (especially just below Hwy 17, ~RM 15) in sediments corresponding to the period from 1950 to 1960, the time of greatest port and industrial development in the city of Savannah. However, they noted that sediment contaminants were in much lower concentration than found by studies in more populous areas that used similar methods. The most recent sediments of the core suggested a gradual decline in contamination over time (Alexander et al. 1994).

Sediment quality in the Harbor was investigated as part of the 1998 EIS. They summarized data from the Savannah District of the Army Corps of Engineers, which indicated that sediments in both the channel and the sediment basin (located in the Back River, ~RM 13, downstream of the former tide gate and just upstream (~2 mi) of the convergence with the Front River), were elevated in chromium, copper and arsenic. Channel sediments were elevated in cadmium as well. Concentrations of each of these contaminants exceeded ERL values, although none were greater than ERM values (Georgia Ports Authority 1998). The report also looked at contaminant bioavailability along the 4 major river reaches to be deepened (Upper Harbor, Lower Harbor, Jones/Oysterbed, Nearshore), the middle two of which are closest to Fort Pulaski (RM 5-15 and 0-5, respectively). Although concentrations of some metals and PAHs were enriched in the middle two reaches, they were either not considered high enough to cause adverse benthic effects or had low bioaccumulation potential[46]. Pesticides, PCBs, and phenolic compounds were not detected in any samples (Georgia Ports Authority 1998).

Sediments removed either during deepening and expansion projects or during routine operation and maintenance dredging are placed in eight confined and two unconfined upland disposal facilities within the Savannah Harbor, and in one unconfined open water site[47]. Three of these sites are in the immediate vicinity of Fort Pulaski[48] (listed in Table C-3 of Georgia Ports Authority 1998). Contaminants from these disposal sites may leach into the water and sediments, posing a potential risk to marine organisms. Winger et al. (2000) looked specifically at heavy metals in sediments near dredge-disposal sites in the Savannah Harbor, upstream of Fort Pulaski. They reported concentrations of arsenic, cadmium, chromium, nickel, mercury, and zinc above the ERL values and elevated levels of manganese (>1,000 mg/L) and molybdenum (>1 mg/L), and suggested that drainage from disposal sites was a likely source of these contaminants. Water samples eluted from sediment collected at disposal sites located in the Lower Harbor and Nearshore Reach were evaluated for the EIS (no samples were collected from

[46] Cadmium, Chromium, Manganese, Nickel, and Zinc were elevated, but below EPA's Sediment Quality Guidelines. Acenaphthene, Flourene, Phenanthrene, and Low and High Molecular Weight PAHs exceeded EPA's Threshold Effects Levels in the Lower Harbor Reach, but their bioaccumulation potentials were lower than those of the reference stream (Wright River). Note that butyltin was also elevated, but toxicity and bioavailability information is currently limited.

[47] The Savannah Ocean Dredged Material Disposal Site (ODMDS) is located just outside of the entrance channel to the harbor, 3.7 nautical miles offshore of Little Tybee Island.

[48] All three are located on the South Carolina side of the river. Two are upland confined disposal facilities: a section of Jones/Oysterbed Island, spanning ~RM 0-5, and a section beyond Fields Cut, spanning from ~RM 5-7. The third is an upland unconfined section located just upstream of the two confined sections, spanning from ~RM 7-8, although this has been inactive for some time as South Carolina now prohibits placement of dredge-spoil at undiked sites (Georgia Ports Authority 1998).

the Jones/Oysterbed reach, which is adjacent to Fort Pulaski). Copper and nickel concentrations exceeded Georgia Water Quality Standards (*see* **Appendix A**). Ammonia (max. 34,000 µg/L) and manganese (max. 2,130 mg/L) were also elevated. Neither of these has an established standard, but EPA has previously used 35 µg/L (chronic) and 233 µg/L (acute) as criteria for ammonia at ocean dredged material sites, and a NMFS study has noted that manganese toxicity in marine organisms occurs at levels >2,500 µg/L (Georgia Ports Authority 1998). Arsenic was also elevated (~6.6 µg/L), but well below the Georgia Water Quality Standard.

Neither the EMAP nor the NCA analyses from sites near Fort Pulaski yielded any metal or organic contaminant concentrations that exceeded their respective ERL values, although arsenic was elevated at one NCA site (GA00-0030 had a concentration of 7 ppm, compared to the ERL value ~8 ppm) (**Appendix F**). Sediment toxicity tests performed as part of these programs were also negative, which is in keeping with the low sediment contaminant concentrations observed[49]. Loganathan et al. (2001), whose study looked at persistant organic pollutants, reported concentrations of total DDTs (2.11 ppb) in sediments above ERL values in the North Channel at Cockspur Island, and suggested that this may represent recent inputs to the area. However, no other organic pollutants (including PCBs) exceeded ERL values at either this site or the other one located in the Park. In the tidal creeks at Fort Pulaski, Richardson and Sajwan (2001; 2002) reported arsenic concentrations above ERL values at all sites sampled over two years (2000 and 2001), with a few observations (3 of 30) exceeding ERM values. These observations should be followed up on, as they suggest a potential problem at the Park. Sediment toxicity tests would also be useful.

Seafood - The GA EPD has issued fish consumption guidelines for various portions of the Savannah River basin based on the detection of mercury and PCBs, including restrictions in the Fort Pulaski study area (**Table 13**). The detection frequency of mercury and PCBs in composites of fish tissue from the lower Savannah River basin during sampling years 1992-2002 was 82% and 20%, respectively, with a mean concentration of 0.27 µg mercury and 0.02 µg PCBs per g fish tissue[50] (Georgia - EPD 2004a). It was also noted that radioactive elements Cs-137 and Sr-90 were detected in some fish in the Savannah River below Augusta. In addition, there is a regional advisory pertaining to the consumption of King Mackerel due to mercury in the entire southeast[51]. All of these contaminants may cause health problems to humans, and should be monitored.

We compiled tissue contaminant information collected from sites near Fort Pulaski under both the EMAP and NCA programs. A total of 47 contaminants were detected in shrimp tissue by the 2 programs (**Appendix D**). None of the contaminants detected exceeded FDA guidelines (action

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[49] However, one station about 2 miles upstream of FOPU (GA00-0029) tested significantly for sediment toxicity, although the specific chemical(s) present was not identified.

[50] The database was also searched for: 4'4 DDT, a-BHC, aldrin, chlordane (technical), a-chlordane, g-chlordane, dieldrin, endrin, lindane, heptachlor, lead, mercury, PCB (total), and toxaphene (all detection frequencies were below 25%).

[51] NC, SC, FL, GA have issued a joint statement for King Mackerel consumption: 1 meal /week recommended limit for fish with fork length of 33-39 inches (1 meal /month for pregnant women, nursing mothers and children aged 12 and younger). Fish over 39 inches should not be eaten. Fish with a fork length of 24-32 inches have no consumption restrictions.

or tolerance levels). However, arsenic and PAHs[52] were elevated in samples from both programs according to EPA Risk Guidelines, although concentrations did decrease between EMAP (sampled in 1995) and NCA (sampled in 2000): arsenic decreased from 0.26 to 0.04 ppm and total PAHs decreased from 0.15 to 0.008 ppm. Despite the decrease, these sites would still be rated "poor" according to the NCCRII criteria.

Loganathan et al. (2001) sampled edible portions of 6 species of fish collected by GA-DNR trawls (spot, silver sea trout, summer flounder, spotted sandbass, Atlantic croaker, and Atlantic menhaden) for PCBs and pesticides from 8 sites in Wassaw Sound (including the 2 sites near Fort Pulaski). Concentrations of PCBs were above the EPA risk guideline range associated with cancer for all species except for summer flounder and spotted sandbass[53]. Richardson and Sajwan (2001, 2002) sampled oyster meat collected primarily from tidal creeks at Fort Pulaski, and they also observed elevated levels of PAHs (range 0.003-0.210 ppm, wet wt.) and arsenic (range <0.2-3 ppm, dry wt.). The highest levels of PAHs were found in samples from Oyster Creek sites (which were only sampled in 2000), and the highest levels of arsenic were from a site located in the Savannah River (only sampled in 2001). In addition, PCBs were detected at elevated levels (0.008-0.012 ppm, wet wt.) in 2001[54]. All of these values are above the EPA risk guideline range associated with cancer (0.0059-0.012 ppm).

These high concentrations of arsenic and PAHs in both shrimp and oyster tissue are evidence of a problem. Although neither the EMAP nor the NCA program measured high concentrations of contaminants in the sediment, and sediment toxicity tests were negative, the animals were likely feeding in areas of the river where sediments are contaminated. Elevated levels of both arsenic and PAHs were reported in the EIS (Georgia Ports Authority 1998), and the Richardson and Sajwan studies (2001; 2002) observed high concentrations of arsenic. Although the fact that shrimp tissue concentrations decreased between the EMAP and NCA sampling is a positive sign, continued observation of tissue contaminants is warranted.

B.2. Water Quality Impairments

The Environmental Protection Division of the State of Georgia prepares Management Plans for each River Basin in the State. These plans provide information on the major sources of both point and non-point pollutants within a River Basin, as well as information on point source pollution control efforts that have been undertaken in the region. The Savannah River Basin Management Plan is based on water quality observations from 1998-1999 (Georgia - EPD 2001). In addition, the Clean Water Act requires states to prepare and submit a list of those navigable waters that do not attain the standards and conditions outlined by the designated use for that water body. This 303(d) list (named for the section of code outlining the mandate) is prepared biennially by the state EPD. Here we summarize information from the 2000, 2002 and draft 2004 lists.

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[52] In addition, some individual PAH concentrations were elevated (shaded in Appendix B): naphthalene in both NCA and EMAP, and C3-naphthalenes, fluoranthene, fluorene, and pyrene in the EMAP program.
[53] Samples of summer flounder were 0.005 ppm and that of spotted sandbass was 0.0058, whereas the other species' ranged from 0.0071 to 0.016 ppm. The EPA cancer concentration range is from 0.0059 to 0.012 ppm.
[54] PCBs were not detected in samples from 2000, but these were run with a higher lab detection limit (>0.01 ppm).

Only one stream within those portions of Chatham and Effingham Counties that fall within HUC 03060109 (the lower Savannah River watershed which contains Fort Pulaski) was listed in 2000 as *fully supporting* its designated uses (fishing): the 7 mile portion of St. Augustine Creek that runs from Walthour Swamp to the Front River segment of the Savannah River near Port Wentworth (Georgia - EPD 2001). A total of 4 stream branches (2 not supporting, 2 partially supporting) and 1 estuarine area (not supporting) have been listed on 303 (d) lists for the past 3 report years (**Table 14**). Together, these streams account for a total of 144 miles and the estuarine area for 6 square miles *not* fully supporting designated uses. Two of the areas listed on the 303 (d) list for HUC 03060109 were cited for violating fish consumption guidelines, 3 for low dissolved oxygen, 2 for high fecal coliform bacteria, and 1 for low pH.

Over the entire Savannah River Basin, a total of 35 streams were listed in 2004 for *not supporting* their designated uses, which is up from a total of 26 reported in the 2 previous years (2000, 2002). It is difficult to tell whether this is a result of the EPD assessing more streams in 2004 or because the status of streams in the Savannah River Basin is worsening. In addition, because all stream segments are not assessed (the 305 (b) lists a total of 5 stream segments/ estuarine areas only for the lower Savannah River watershed), their current status is unknown. Recommendations for ways to make this database more useful are provided in section D.

B.3. Sources of Pollutants

B.3.a. Point Sources

There are no federally regulated point sources of pollution within the boundary of Fort Pulaski NM. There are, however, numerous point sources in the surrounding watershed, particularly upstream in the city of Savannah. Discharges from industrial and municipal facilities (organic matter, nutrients, and contaminants) are monitored under the National Pollutant Discharge Elimination System (NPDES). Information on NPDES permit-holders can be obtained through the Savannah River Basin Management Plan and the U.S. EPA Envirofacts database. In addition, the EPA maintains information in the Envirofacts database under various programs: the Enforcement and Compliance History Online program, which provides many details to the public on water, air, and hazardous waste facilities; the Toxic Release Inventory (TRI) Program, which provides information on toxic releases as reported by industrial facilities; and the Comprehensive Environmental Response, Compensation, and Liability Information System program, which provides information on Superfund Sites. The Georgia EPD also has information pertaining to NPDES permittees and other point sources on their "Georgia's Environment" web page, which includes links to a hazardous site inventory, radiation monitoring reports, and information on environmental releases (which includes toxics release inventory reports as well as data on industrial spills[55]). The Enforcement Order search page allows one to access a list of the proposed and executed EPD enforcement orders[56], and the Regulated

[55] A table of these events including the date, spill number, facility/incident name, location, material spilled, waterway impacted, type of action, and to which agency the incident was referred can be downloaded from the website.

[56] EPD enforcement orders resulting from action under the Water Quality Control Act (including Surface Water Allocation), Air Quality Act, Comprehensive Solid Waste Management Act, Erosion and Sedimentation Act, Safe Drinking Water Act, Surface Mining Act, or Underground Storage Tank Act (Georgia - EPD 2002a) can all be found. A recent search turned up 58 executed enforcement orders in Chatham County and 12 in Effingham County.

Table 13. Georgia-EPD recommendations for consuming contaminated fish in the Savannah River.

Lakes ≥ 500 acres	Species	Less than 12"	12"-16"	Over 16"	Chemical
Lake Burton	Largemouth Bass			1 meal/week	Mercury
	Spotted Bass		1meal/week		Mercury
Clarks Hill	Largemouth Bass			1 meal/week	Mercury
Lake Hartwell/Tugaloo Arm	Largemouth Bass		1meal/week	1 meal/month	Mercury
	Hybrid/Striped Bass		1 meal/month	Do Not Eat	PCBs
	Channel Catfish			1 meal/month	PCBs
	Carp			1 meal/week	Mercury
Lake Hartwell: Main Body	Largemouth Bass		1 meal/month	1 meal/month	PCBs
	Hybrid/Striped Bass	Do Not Eat	Do Not Eat	Do Not Eat	PCBs
	Channel Catfish	1 meal/month	1 meal/month	1 meal/month	PCBs
Lake Rabun	Largemouth Bass			1 meal/week	Mercury
	White Catfish			1 meal/week	Mercury
Lake Richard B. Russell	Largemouth Bass		1 meal/week	1 meal/week	Mercury
Lake Tugaloo	Largemouth Bass		1 meal/month	1 meal/month	Mercury
Lakes and Ponds <500 acres	**Species**	**Less than 12"**	**12"-16"**	**Over 16"**	**Chemical**
Bush Field Airport, Augusta: Unamed Pond	Largemouth Bass		1 meal/week		Mercury
McDuffie PFA (West Watershed Pond)	Largemouth Bass *		1 meal/week *	1 meal/week	Mercury
Yonah Lake	Largemouth Bass		1 meal/week		Mercury
	Catfish (mixed sp.)		1 meal/week		Mercury
Freshwater Streams	**Species**		**General Recommendation**		**Chemical**
Brier Creek (Burke County) @ Hwy 56	Largemouth Bass		1 meal/month		Mercury
Brier Creek (Burke County) @ Hwy 57	Spotted Sucker		1 meal/week		Mercury
Chattooga River @ Hwy 24 (Rabun County)	Northern Hog Sucker		1 meal/week		Mercury
Chattooga River @ Above Lake Tugaloo (Rabun County)	Silver Redhorse		1 meal/week		Mercury
Little River, Above and Below Rocky Creek (Wilkes County)	Largemouth Bass		1 meal/week		Mercury
Pipe Makers Canal (Savannah, Chatham County)	Largemouth Bass		1 meal/week		Mercury
Savannah River, Above New Savannah Bluff Lock and Dam (Columbia County)	Largemouth Bass		1 meal/week		Mercury
Savannah River, Above New Savannah Bluff Lock and Dam (Columbia County)	Spotted Sucker		1 meal/week		Mercury
Savannah River, Downstream of New Savannah Bluff Lock and Dam (Richmond/Burke County)	Largemouth Bass		1 meal/week		Mercury
Savannah River @ US Hwy 301 (Screven County)	Largemouth Bass		1 meal/week		Mercury
Savannah River @ GA Hwy 119 (Effingham County)	Largemouth Bass		1 meal/month		Mercury
Savannah River @ Fort Howard (Near Rincon)	Largemouth Bass		1 meal/month		Mercury
Savannah River @ Fort Howard (Near Rincon)	White Catfish		1 meal/week		Mercury
Savannah River @ Fort Howard (Near Rincon)	Bowfin		1 meal/month		Mercury
Savannah River @ Hwy 17 (Chatham County)	Largemouth Bass		1 meal/week		Mercury
Savannah River @ Tidal Gate (Chatham County)	White Catfish		1 meal/week		Mercury
Tributary to Hudson River (Banks County)	Redeye Bass		1 meal/week		Mercury

*Minimum size is 14 inches unless posted otherwise.

Table 14. List of streams and estuarine areas located within HUC 3060109 (the Lower Savannah River watershed) that are not fully supporting their designated uses.

(Based on 2000, 2002, and 2004 EPD 305(b)/303(d) Lists)

BASIN STREAM	LOCATION	WATER USE CLASSIFICATION	CRITERION VIOLATED	POTENTIAL CAUSE(S)	ACTIONS TO ALLEVIATE	MILES AFFECTED	STATUS
Pipemaker Canal	Walthhour Creek to confluence with Savannah River (Effingham/Chatham Co.)	Fishing	Fish Consumption Guidelines	Nonpoint Sources/Unknown	EPD will address nonpoint sources through a watershed protection stragegy. Fish consumption guidelines due in part to natural source of mercury.	13	Partially Supporting
Savannah River	Brier Creek to Tide Gate (Screven/Effingham/Chatham Co.)	Fishing/Drinking Water	Fish Consumption Guidelines	Nonpoint Sources/Unknown	EPD will address nonpoint sources through a watershed protection stragegy. Fish consumption guidelines due in part to natural source of mercury.	84	Partially Supporting
Ebenezer Creek	Long Bridge to Savannah River near Springfield (Effingham Co.)	Fishing	Dissolved Oxygen, pH	Nonpoint Sources/Unknown	Impairment will be addressed by implementing a locally developed plan that includes the remedial actions necessary for problem resolution. Multi-agency study ongoing to address issues and implement solutions.	6	Not Supporting
Runs Branch (Ebenezer Creek)	Cowpen Creek to Little Ebenezer Creek near Clyo (Effingham Co.)	Fishing	Dissolved Oxygen,Fecal Coliform Bacteria	Nonpoint Sources/Unknown	EPD will address nonpoint sources through a watershed protection stragegy.	11	Not Supporting
Savannah Harbor	SR25 (Old US Hwy 17) to Elba Island Cut Savannah (Chatham Co.)	Coastal Fishing	Fecal Coliform Bacteria,Dissolved Oxygen	Urban Runoff, Municipal Facility, Industrial Facility	None listed.	4*	Partially Supporting

* Square miles affected

Community pages include a listing of Leaking Underground Storage Tanks and Industrial Stormwater Permittees.

B.3.a.i. OM and Nutrients

Organic matter and nutrients increase the biological oxygen demand (BOD) and thus decrease oxygen concentrations in the water. Wastewater treatment plants and pulp and paper mills, and stormwater permittees are the primary point sources of organic matter and nutrient loading in the lower Savannah River watershed[57]. There are 82 federally-regulated industrial and municipal NPDES permittees within the study area that may contribute to organic matter and nutrients (**Appendix G, Table G-1**). Together, more than half of the permittees (51) are located in Chatham County, 25 permittees are in Jasper County and 6 in Effingham County. Fourteen of these are classified as "major" permitees, which include municipal wastewater treatment plants (8) that discharge ≥ 1 million gallons per day (mgd) and industrial facilities (6) that discharge organic material and oxygen-demanding loads (such as pulp and paper mills), non-contact cooling water (power plants), and various pollutants (such as from chemical and textile manufacturing, metal finishing, etc.) at quantities that could cause localized stream impacts. The largest permitted municipal discharge is the President St. wastewater treatment plant in Savannah, which can discharge up to 27 mgd (all other municipal discharge permits are for ≤ 4.5 mgd). The largest permitted industrial discharge is the Savannah Electric Company (108 mgd) in Effingham County, followed by 2 pulp and paper companies, International Paper (42 mgd) and Weyerhaeuser (38 mgd) in Chatham County. **Appendix A, Table A-1** also includes any EPA- or EPD-listed events (violations, toxic releases, known hazards, enforcement orders, spills and leaking underground storage tanks) associated with the NPDES permittees: 7 have been cited for EPA violations, 15 for releasing toxins, 6 are on the GA Hazardous Site List, 10 have EPD enforcement orders, 9 have reported spills that affect streams, and 12 have leaking underground storage tanks. Chatham County permittees account for all but 1 of the EPA violations, enforcement orders, and toxic releases, and account for all of the hazardous sites, spills, and leaking underground storage tanks within the study area. USGS HUC code and receiving stream information is also included when it is available online.

Stormwater is also a source of organic material and nutrients, along with other types of contaminants. The water quality and quantity of stormwater discharges varies depending upon the amount of precipitation and length of rain events, the nature of industrial activities, and the degree of surface imperviousness. There are a total of 159 federally regulated storm water dischargers in Chatham County, 9 are classified as MS4s (storm sewer systems in cities and counties with > 100,000 people) and 151 are industrial. These are listed along with receiving streams in **Appendix G, Table G-2**. MS4s are located in Chatham County, Garden City, Savannah, Thunderbolt, Tybee, Bloomingdale, Pooler, and Port Wentworth.

As part of their Water Quality Monitoring Report, ATM identified the top 10 sources (NPDES permittees) of oxygen-demanding materials in the Savannah River (Applied Technology & Management (ATM) 2004). These facilities and their approximate river mile location, along with measured (August 1999) and estimated (based on NPDES permitted flow rate) BOD loading rates, are listed in **Table 15**. The cumulative BOD loading rate measured at these 10

[57] There are no combined sewer overflows in the lower Savannah River watershed.

Table 15. Discharge characteristics of major point sources (NPDES permittees) of organic matter in the Savannah River (Applied Technology Management (ATM) 2004).

BOD and NH_3 loading rates were measured during Aug-Sep 1999. Permitted (potential) loading rates were estimated based on NPDES discharge limits. All measurements are reported in grams per second (g/s).

CBOD = Cabonaceous Biological Oxygen Demand

Station Name	RM	Permit #	---Measured BOD (g/s)---			---Measured NH_3 (g/s)---			---Permit Limits (g/s)---			
			Min	**Avg**	**Max**	**Min**	**Avg**	**Max**	**CBOD avg**	**CBOD max**	**NH_3 avg**	**NH_3 max**
Kerr-McGee Pigments/Kemira	10	GA0003646	1.38	4.77	6.15	0.02	0.06	0.07	n/a	n/a	n/a	n/a
Engelhard	13	GA0048330	0.05	0.13	0.21	0.20	0.56	0.88	n/a	n/a	4.63	13.89
President Street WPCP	13	GA0025348	2.20	24.79	53.66	0.63	1.11	1.77	87.69	109.58	15.28	19.10
Wilshire WPCP	15	GA0020443	0.15	1.16	3.77	0.04	0.73	2.28	13.04	16.22	3.44	4.27
International Paper	17	GA0001998	53.94	322.49	612.33	0.34	1.41	1.76	1404.11	2808.23	n/a	n/a
Garden City WPCP	19	GA0031038	0.30	0.55	1.87	0.002	0.003	0.011	6.31	18.94	1.53	1.91
Travis Field WPCP (City of Savannah)	19	GA0020427	0.26	0.48	0.99	0.001	0.002	0.004	3.04	3.83	0.76	0.97
Weyerhaeuser /Stone Container /Smurfit	21	GA0002798	0.47	3.06	12.77	0.01	0.03	0.09	158.26	n/a	n/a	n/a
Georgia Pacific (Fort James /Fort Howard)	>28	GA0046973	0	15.25	48.31	0.14	0.28	0.38	342.39	2068.49	n/a	n/a
Hardeeville Church Road Plant	>28	SC0034584	0.08	0.15	0.41	0.001	0.001	0.004	4.78	n/a	n/a	n/a

facilities averaged 373 grams/second, with International Paper Company comprising 86% of the total. The study also estimated loads of ammonia. In this case, the two largest contributors were International Paper and the President Street Wastewater Treatment Plant, which contributed an estimated 34% and 27%, respectively.

B.3.a.ii. Contaminants

Point source contributions of contaminants to streams may be either discharging (direct) or non-discharging (non-direct). In the lower Savannah River watershed, discharging sources include several NPDES permittees (municipal, industrial, and storm water) that release contaminants directly to surface water and non-discharging sources include superfund sites, landfills, and industries that release contaminants to the groundwater, soil, or air. In addition, 2 major nuclear facilities located upstream of the Fort Pulaski study area and the Port of Savannah are also discussed in this section. **Table 16** gives an overall summary of regional environmental releases of contaminants for the Fort Pulaski study area.

Surface Water - A total of 14 industries releasing 25 different chemicals to surface waters in the FOPU study area are included in the EPA TRI Program database. Thirteen of the industries are in Chatham County, 1 is in Effingham County, and none are in Jasper County. All but 2 of the industries are NPDES permittees (discharge or stormwater) - Eastman Chemical Resins, Inc. and Conocophillips Co. Savannah Lubricants Plant. **Table 17** provides the total amount of each chemical listed in the inventory, as well as a breakdown by industry. The International Paper Company of Savannah releases the greatest number of chemicals (n=14) and Kerr-McGee Pigments (Kemira) releases the largest amount (more than half) of all chemicals by weight (1,096,583 lbs). By industrial classification, chemical industries account for the greatest discharges of contaminants to surface waters. Manganese and nitrate compounds are released in the largest quantities (Mn primarily by Kerr-McGee), comprising 91% of all chemicals released. In addition, several industries report releases of PAHs (Weyerhaeuser and International Paper), chromium (Kerr-McGee), nickel (Kerr-McGee), mercury (Fort James), and zinc (International Paper, Conocophillips), which (along with Mn) were all found at elevated levels in the study area (*see* section **B.1.b.**). However, there are no reported releases of arsenic, which was also detected at the site. When taken together, there is a total of 1.9 million lbs of chemicals released into the study area, which account for 19% of GA's total industrial toxic releases to surface water.

Atmosphere - A total of 21 industries releasing 42 different chemicals to the air in the FOPU study area are reported to the TRI database. Eighteen of the industries are located in Chatham County, 3 are in Effingham County, and none are in Jasper County (**Table 18**). The International Paper Company of Savannah (Chatham Co) releases the greatest number of chemicals (n=26) and the largest amount by weight (1,574,861 lbs). This company plus the Savannah Electric, McIntosh Plant in Effingham County, account for 58% of all point source air emissions by weight in the FOPU study area. By industrial classification, electric industries account for the greatest emissions of contaminants to air. Hydrochloric acid (aerosols), methanol, ammonia, and sulfuric acid (aerosols) are released in the largest quantities, accounting for 42%, 18%, 11%, and 10% of all chemicals released as point source air emissions, respectively. Although several companies report air emissions of the chemicals found at elevated levels in the study area, including PAHs, arsenic, copper, manganese, mercury, nickel and zinc, the International Paper Company is of special note because it is a source of all of these. All together, there are 4.7 million lbs of chemicals released via air emissions in the study area, which account for 5% of GA's total industrial toxic releases to air.

Table 16. Number of facilities reporting environmental releases of contaminants in the lower Savannah River watershed.

(based on data reported to the TRI database (U.S. EPA 2002))

	Chatham	**Effingham**	**Jasper**
AIR	189	13	28
TOXICS	26	3	0
HAZARDOUS WASTE	500	30	39
SUPERFUND	20	0	0
NPL	0	0	0
WATER (NPDES)	50	6	25

Table 17. Chemical releases to surface waters from industries in the FOPU study area.

(based on data reported to the TRI database (U.S. EPA 2002))

Chemical	**Facility**	**lbs**
ACETALDEHYDE		***2666***
	WEYERHAEUSER CO	*2316*
	INTERNATIONAL PAPER CO SAVANNAH COMPLEX	*350*
AMMONIA		***24822***
	ENGELHARD CORP SAVANNAH OPERATIONS	*9500*
	WEYERHAEUSER CO	*4304*
	INTERNATIONAL PAPER CO SAVANNAH COMPLEX	*1700*
	FORT JAMES OPERATING CO SAVANNAH RIVER MILL	*3250*
	CITGO ASPHALT REFINING CO.	*6055*
	INTERCAT SAVANNAH INC.	*3*
	GEORGIA-PACIFIC RESINS INC	*10*
BARIUM COMPOUNDS		***15375***
	WEYERHAEUSER CO	*4575*
	INTERNATIONAL PAPER CO SAVANNAH COMPLEX	*10800*

BIPHENYL		***1***
	INTERNATIONAL PAPER CO SAVANNAH COMPLEX	*1*
CATECHOL		***2130***
	WEYERHAEUSER CO	*43*
	INTERNATIONAL PAPER CO SAVANNAH COMPLEX	*2087*
CHLOROFORM		***946***
	FORT JAMES OPERATING CO SAVANNAH RIVER MILL	*946*
CHROMIUM COMPOUNDS		***12800***
	KERR-MCGEE PIGMENTS (SAVANNAH) INC	*12800*
CREOSOTE		***3***
	ATLANTIC WOOD INDUSTRIES INC	*3*
DIOXIN AND DIOXIN-LIKE COMPOUNDS		***0.002***
	KERR-MCGEE PIGMENTS (SAVANNAH) INC	*0.002*
EPICHLOROHYDRIN		***5***
	CHEMICAL RESINS INC	*5*
FORMALDEHYDE		***3662***
	WEYERHAEUSER CO	*3371*
	INTERNATIONAL PAPER CO SAVANNAH COMPLEX	*280*
	GEORGIA-PACIFIC RESINS INC	*11*
FORMIC ACID		***2196***
	WEYERHAEUSER CO	*2196*
LEAD COMPOUNDS		***169***
	KERR-MCGEE PIGMENTS (SAVANNAH) INC	*103*
	WEYERHAEUSER CO	*66*
	NEW NGC INC	*0.4*
MANGANESE COMPOUNDS		***1066027***
	KERR-MCGEE PIGMENTS (SAVANNAH) INC	*1010000*
	WEYERHAEUSER CO	*32110*
	INTERNATIONAL PAPER CO SAVANNAH COMPLEX	*23900*
	SAVANNAH ELECTRIC PLANT KRAFT	*17*

MERCURY COMPOUNDS		***0.2***
	FORT JAMES OPERATING CO SAVANNAH RIVER MILL	*0.2*
METHANOL		***32558***
	WEYERHAEUSER CO	*9168*
	INTERNATIONAL PAPER CO SAVANNAH COMPLEX	*23100*
	FORT JAMES OPERATING CO SAVANNAH RIVER MILL	*290*
METHYL ETHYL KETONE		***145***
	WEYERHAEUSER CO	*125*
	INTERNATIONAL PAPER CO SAVANNAH COMPLEX	*20*
NICKEL COMPOUNDS		***7200***
	KERR-MCGEE PIGMENTS (SAVANNAH) INC	*7200*
NITRATE COMPOUNDS		***691608***
	KERR-MCGEE PIGMENTS (SAVANNAH) INC	*380*
	ENGELHARD CORP SAVANNAH OPERATIONS	*412750*
	WEYERHAEUSER CO	*120089*
	EMD CHEMICALS INC	*103700*
	FORT JAMES OPERATING CO SAVANNAH RIVER MILL	*54600*
	INTERCAT SAVANNAH INC.	*89*
PHENOL		***1***
	GEORGIA-PACIFIC RESINS INC	*1*
POLYCYCLIC AROMATIC COMPOUNDS		***21***
	WEYERHAEUSER CO	*9*
	INTERNATIONAL PAPER CO SAVANNAH COMPLEX	*12*
TOLUENE		***160***
	INTERNATIONAL PAPER CO SAVANNAH COMPLEX	*160*
VANADIUM COMPOUNDS		***68572***
	KERR-MCGEE PIGMENTS (SAVANNAH) INC	*66100*
	INTERNATIONAL PAPER CO SAVANNAH COMPLEX	*730*
	FORT JAMES OPERATING CO SAVANNAH RIVER MILL	*1720*
	INTERCAT SAVANNAH INC.	*13*

	SAVANNAH ELECTRIC PLANT KRAFT	*9*
XYLENE (MIXED ISOMERS)		***10***
	INTERNATIONAL PAPER CO SAVANNAH COMPLEX	*10*
ZINC COMPOUNDS		***1861***
	INTERNATIONAL PAPER CO SAVANNAH COMPLEX	*1650*
	CONOCOPHILLIPS CO SAVANNAH LUBRICANTS PLANT	*211*
GRAND TOTALS (ALL CHEMICALS)		***1932938***
	KERR-MCGEE PIGMENTS (SAVANNAH) INC	*1096583*
	ENGELHARD CORP SAVANNAH OPERATIONS	*422250*
	WEYERHAEUSER CO	*178372*
	EMD CHEMICALS INC	*103700*
	INTERNATIONAL PAPER CO SAVANNAH COMPLEX	*64800*
	FORT JAMES OPERATING CO SAVANNAH RIVER MILL	*60806*
	CITGO ASPHALT REFINING CO.	*6055*
	CONOCOPHILLIPS CO SAVANNAH LUBRICANTS PLANT	*211*
	INTERCAT SAVANNAH INC.	*105*
	SAVANNAH ELECTRIC PLANT KRAFT	*26*
	GEORGIA-PACIFIC RESINS INC	*22*
	EASTMAN CHEMICAL RESINS INC	*5*
	ATLANTIC WOOD INDUSTRIES INC	*3*

Table 18. Chemicals released in air emissions from industries in the FOPU study area. (based on data reported to the TRI database (U.S. EPA 2002))

Chemical	Facility	lbs
1,1-DICHLORO-1-FLUOROETHANE		**5286**
	GREAT DANE TRAILERS	5286
ACETALDEHYDE		**127031**
	INTERNATIONAL PAPER CO SAVANNAH COMPLEX	84000
	FORT JAMES OPERATING CO SAVANNAH RIVER MILL	27300
	WEYERHAEUSER CO	15731
AMMONIA		**536857**
	INTERNATIONAL PAPER CO SAVANNAH COMPLEX	178000
	WEYERHAEUSER CO	104356
	ENGELHARD CORP SAVANNAH OPERATIONS	213710
	INTERCAT SAVANNAH INC.	28520
	CITGO ASPHALT REFINING CO.	12271
ARSENIC COMPOUNDS		**130**
	INTERNATIONAL PAPER CO SAVANNAH COMPLEX	130
BARIUM COMPOUNDS		**2095**
	INTERNATIONAL PAPER CO SAVANNAH COMPLEX	660
	SAVANNAH ELECTRIC PLANT MCINTOSH	484
	WEYERHAEUSER CO	493
	SAVANNAH ELECTRIC PLANT KRAFT	458
BENZO(G,H,I)PERYLENE		**1**
	INTERNATIONAL PAPER CO SAVANNAH COMPLEX	1
	CITGO ASPHALT REFINING CO.	0.0003
	BUILDING MATERIALS MFG. CORP.	0.001
BIPHENYL		**51600**
	INTERNATIONAL PAPER CO SAVANNAH COMPLEX	1700
	FORT JAMES OPERATING CO SAVANNAH RIVER MILL	49900
CARBONYL SULFIDE		**200000**
	KERR-MCGEE PIGMENTS (SAVANNAH) INC	200000
CERTAIN GLYCOL		**8**

ETHERS		
	ASHLAND DISTRIBUTION CO.	8
CHLORINE		**1174**
	FORT JAMES OPERATING CO SAVANNAH RIVER MILL	439
	WEYERHAEUSER CO	65
	KERR-MCGEE PIGMENTS (SAVANNAH) INC	670
CHLORINE DIOXIDE		**103**
	WEYERHAEUSER CO	103
CHLORODIFLUOROMETHANE		**20699**
	GREAT DANE TRAILERS	20699
CHLOROFORM		**56400**
	FORT JAMES OPERATING CO SAVANNAH RIVER MILL	56400
COPPER COMPOUNDS		**230**
	INTERNATIONAL PAPER CO SAVANNAH COMPLEX	230
CREOSOTE		**1400**
	ATLANTIC WOOD INDUSTRIES INC	1400
CYCLOHEXANE		**387**
	CITGO ASPHALT REFINING CO.	387
DIISOCYANATES		**8**
	GREAT DANE TRAILERS	8
DIOXIN AND DIOXIN-LIKE COMPOUNDS		**0.008**
	INTERNATIONAL PAPER CO SAVANNAH COMPLEX	0.004
	FORT JAMES OPERATING CO SAVANNAH RIVER MILL	0.001
	WEYERHAEUSER CO	0.002
	KERR-MCGEE PIGMENTS (SAVANNAH) INC	0.001
	ATLANTIC WOOD INDUSTRIES INC	0.000
EPICHLOROHYDRIN		**134**
	EASTMAN CHEMICAL RESINS INC	134
FORMALDEHYDE		**41808**
	INTERNATIONAL PAPER CO SAVANNAH COMPLEX	28600
	WEYERHAEUSER CO	12016

	GEORGIA-PACIFIC RESINS INC	440
	GEORGIA-PACIFIC CORP SAVANNAH PLYWOOD	752
FORMIC ACID		**15110**
	INTERCAT SAVANNAH INC.	15110
HYDROCHLORIC ACID (1995 AND AFTER 'ACID AEROSOLS' ONLY)		**1970142**
	INTERNATIONAL PAPER CO SAVANNAH COMPLEX	384000
	SAVANNAH ELECTRIC PLANT MCINTOSH	1085314
	FORT JAMES OPERATING CO SAVANNAH RIVER MILL	154000
	WEYERHAEUSER CO	31458
	SAVANNAH ELECTRIC PLANT KRAFT	315370
HYDROGEN FLUORIDE		**70758**
	INTERNATIONAL PAPER CO SAVANNAH COMPLEX	2200
	SAVANNAH ELECTRIC PLANT MCINTOSH	44717
	SAVANNAH ELECTRIC PLANT KRAFT	23841
LEAD COMPOUNDS		**415**
	INTERNATIONAL PAPER CO SAVANNAH COMPLEX	180
	SAVANNAH ELECTRIC PLANT MCINTOSH	108
	FORT JAMES OPERATING CO SAVANNAH RIVER MILL	19
	WEYERHAEUSER CO	42
	SAVANNAH ELECTRIC PLANT KRAFT	55
	INTERNATIONAL PAPER MELDRIM LUMBER MILL	11
	BUILDING MATERIALS MFG. CORP.	0.004
	NEW NGC INC	1
MALEIC ANHYDRIDE		**426**
	INTERNATIONAL PAPER CO SAVANNAH COMPLEX	426
MANGANESE COMPOUNDS		**2837**
	INTERNATIONAL PAPER CO SAVANNAH COMPLEX	2200
	WEYERHAEUSER CO	211
	SAVANNAH ELECTRIC PLANT KRAFT	426
MERCURY COMPOUNDS		**108**
	INTERNATIONAL PAPER CO SAVANNAH COMPLEX	31
	SAVANNAH ELECTRIC PLANT MCINTOSH	28

	FORT JAMES OPERATING CO SAVANNAH RIVER MILL	15
	SAVANNAH ELECTRIC PLANT KRAFT	34
METHANOL		**860645**
	INTERNATIONAL PAPER CO SAVANNAH COMPLEX	550000
	FORT JAMES OPERATING CO SAVANNAH RIVER MILL	58500
	WEYERHAEUSER CO	243245
	GEORGIA-PACIFIC RESINS INC	8900
METHYL ETHYL KETONE		**15851**
	INTERNATIONAL PAPER CO SAVANNAH COMPLEX	12400
	WEYERHAEUSER CO	3451
M-XYLENE		**49**
	CITGO ASPHALT REFINING CO.	49
N-HEXANE		**7084**
	CITGO ASPHALT REFINING CO.	7084
NICKEL COMPOUNDS		**450**
	INTERNATIONAL PAPER CO SAVANNAH COMPLEX	350
	FORT JAMES OPERATING CO SAVANNAH RIVER MILL	100
NITRATE COMPOUNDS		**10424**
	INTERCAT SAVANNAH INC.	10424
PENTACHLOROPHENOL		**4**
	ATLANTIC WOOD INDUSTRIES INC	4
PHENOL		**11884**
	INTERNATIONAL PAPER CO SAVANNAH COMPLEX	9350
	WEYERHAEUSER CO	2467
	GEORGIA-PACIFIC RESINS INC	67
POLYCYCLIC AROMATIC COMPOUNDS		**236**
	INTERNATIONAL PAPER CO SAVANNAH COMPLEX	143
	WEYERHAEUSER CO	87
	SAVANNAH ELECTRIC PLANT KRAFT	1
	ATLANTIC WOOD INDUSTRIES INC	2
	OWENS CORNING FIBERGLAS SAVANNAH	4

	PLANT	
	BUILDING MATERIALS MFG. CORP.	0.23
SULFURIC ACID (1994 AND AFTER 'ACID AEROSOLS' ONLY)		**461309**
	INTERNATIONAL PAPER CO SAVANNAH COMPLEX	116000
	SAVANNAH ELECTRIC PLANT MCINTOSH	42397
	FORT JAMES OPERATING CO SAVANNAH RIVER MILL	85700
	SAVANNAH ELECTRIC PLANT KRAFT	43382
	KERR-MCGEE PIGMENTS (SAVANNAH) INC	164000
	SOUTHERN STATES PHOSPHATE & FERTILIZER CO	9830
TOLUENE		**211677**
	INTERNATIONAL PAPER CO SAVANNAH COMPLEX	197000
	GREAT DANE TRAILERS	10613
	CITGO ASPHALT REFINING CO.	319
	GULFSTREAM AEROSPACE CORP.	3078
	ASHLAND DISTRIBUTION CO.	667
VANADIUM COMPOUNDS		**8161**
	INTERNATIONAL PAPER CO SAVANNAH COMPLEX	670
	SAVANNAH ELECTRIC PLANT MCINTOSH	171
	FORT JAMES OPERATING CO SAVANNAH RIVER MILL	7000
	SAVANNAH ELECTRIC PLANT KRAFT	225
	INTERCAT SAVANNAH INC.	95
XYLENE (MIXED ISOMERS)		**6090**
	INTERNATIONAL PAPER CO SAVANNAH COMPLEX	6000
	ASHLAND DISTRIBUTION CO.	90
ZINC COMPOUNDS		**590**
	INTERNATIONAL PAPER CO SAVANNAH COMPLEX	590
GRAND TOTAL		**4699599**
	INTERNATIONAL PAPER CO SAVANNAH COMPLEX	1574861
	SAVANNAH ELECTRIC PLANT MCINTOSH	1173219
	FORT JAMES OPERATING CO SAVANNAH RIVER MILL	439373
	WEYERHAEUSER CO	413724
	SAVANNAH ELECTRIC PLANT KRAFT	383791

KERR-MCGEE PIGMENTS (SAVANNAH) INC	364670
ENGELHARD CORP SAVANNAH OPERATIONS	213710
INTERCAT SAVANNAH INC.	54149
GREAT DANE TRAILERS	36606
CITGO ASPHALT REFINING CO.	20110
SOUTHERN STATES PHOSPHATE & FERTILIZER CO	9830
GEORGIA-PACIFIC RESINS INC	9407
GULFSTREAM AEROSPACE CORP.	3078
ATLANTIC WOOD INDUSTRIES INC	1406
ASHLAND DISTRIBUTION CO.	765
GEORGIA-PACIFIC CORP SAVANNAH PLYWOOD	752
EASTMAN CHEMICAL RESINS INC	134
INTERNATIONAL PAPER MELDRIM LUMBER MILL	11
OWENS CORNING FIBERGLAS SAVANNAH PLANT	4
BUILDING MATERIALS MFG. CORP.	0.23

***Land disposal* –** Contaminants that are stored or disposed of on land may in turn reach the study site either via groundwater or overland runoff. The TRI data base lists three companies that dispose of toxic material on land in the FOPU study area: Kerr-Mcgee Pigments, Savannah Electric, Kraft (Chatham) and McIntosh (Effingham) Plants. The major toxins released by these companies are manganese, vanadium, chromium, barium, nickel, and lead compounds and ethylene glycol. Together, these companies discharged approximately 1.1 million lbs onto the land (2002 data), equating to 10% of GA's total toxic releases to land.

Georgia's Hazardous Site Inventory (HSI) lists sites with known or suspected releases of regulated contaminants in groundwater or soil. The HSI list began in 1994 in Georgia and is updated annually[58]. Chatham and Effingham County have a total of 44 sites, each of which is given a "class designation" ranging from I (top priority for EPD cleanup) to V (low priority) (**Table 19).** Only 2 sites in the study area are classified as Class I (139 Brampton Road and Abercorn & Largo Development of Chatham County), each of which release tetrachloroethane to groundwater. Abercorn & Largo also releases lead to soil. Of the remaining sites, 29 are Class II, 1 is Class III, 9 are Class IV, and 3 are Class V. Overall, lead is the primary regulated contaminant exceeding sate standards in groundwater and soil. In addition, several industries are sources of cadmium, PAHs, chromium, and nickel to groundwater and soil.

Superfund sites may also be a source of contaminants to groundwater and soil. Twenty out of a total of 392 Superfund sites in Georgia are located in Chatham County (there are none in Jasper or Effingham Counties) (**Table 20**). It is difficult to obtain information on the identity of the contaminants at these sites as the EPA database only provides this information for sites associated with the National Priorities List, and none of the sites in Chatham County have this

[58] Sites may be removed from the HSI list when EPD finds that applicable clean-up standards have been met. Since 1994, a total of 104 sites have been removed from GA's HSI list

designation. However, portions of nine superfund sites[59] are listed on GA's HSI list (**Table 19**), which provides information on the release of contaminants to groundwater and soil. Three companies are also listed in the TRI database as releasing chemicals to surface water or air: EMD chemicals (nitrate to surface water), Gulfstream (toluene to air), and Kerr-McGee (Kemira) (chromium, dioxins, lead, manganese, nickel, nitrate, and vanadium to surface water; carbonyl sulfide, chlorine, dioxins, and sulfuric acid to air).

The Savannah International Airport (Travis Field) is also a Superfund site. Airports are exempt from reporting chemicals to the TRI database, however a study by the NRDC (1996) showed that they are significant sources of toxic compounds that can enter the surface water as runoff or through atmospheric deposition. Departing and arriving planes release benzene, 1,3-butadiene, and formaldehyde, and chemicals such as ethylene- and propylene-glycol mixtures for deicing and other solvents and metals for aircraft maintenance are used on the tarmac and can enter the watershed as runoff (Natural Resources Defense Council (NRDC) 1996). Airports that use toxic deicing chemicals at rates of 100,000 gallons per year are required to monitor their outflows under the NPDES stormwater program (Savannah International is regulated under this program).

Landfills are another potential source of contaminants to soil or groundwater. There are 7 landfills in the FOPU study area: 6 are in Chatham County and 1 is in Effingham County (**Figure 14**). However, none of the operative landfills currently fall under the GA HSI list. Under the provisions of the Hazardous Site Response Act (which also governs HSI sites), all landfills operating after 1988 are required to be lined and have a leachate collection system. Thus, contamination of groundwater and surface water is more likely to come from older landfills that are unlined.

***Other* –**

***Nuclear Facilities* -** Upstream of the Fort Pulaski study area, there are 2 nuclear facilities, the Savannah River Site and the Vogtle Electric Plant. The Savannah River Site borders the Savannah River along a 30 mile stretch in Aiken, SC[60] (approximately ~160 RM upstream of the Atlantic Ocean). In the 1950's it was primarily used to produce uranium, tritium, and plutonium for the National Defense Program (U.S. DOE 2005). Although the facilities' production of nuclear chemicals are currently stopped or placed on standby (1992 marks the last time of radioactive materials (tritium) were produced, (U.S. DOE 2005)), radioactive elements and their waste-products[61] may persist for some time. In addition, a new mission to produce "replacement-tritium" (H-3) has recently begun: commissioning of the facility is expected sometime in 2006 (Slotts and Wilkes 2005). The Savannah River Site is listed on the National Priority List[62] under the federal Superfund program. A second nuclear facility, Vogtle Electric Power, is a 2-unit commercial Pressurized Water Reactor plant located directly across the Savannah River from the Savannah River Site in Burke County[63]. The plant uses uranium and has been in operation since 1985 (Southern Company 2005).

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[59] Bernuth-Lembcke, Colonial Terminals, Hunter Army Airfield, Kerr-McGee (Kemira), McKenzie Tank Lines, Powell Duffryn, Savannah International-Travis Field, Truman Parkway-Phase II, and Union Camp.

[60] Latitude 33°20'56"; Longitude: -81°44'16".

[61] Waste-products include ^{14}C, $^{89,90}Sr$, ^{99}Tc[4], $^{129}I^{-}$[5], and $^{134,137}Cs$.

[62] Savannah River Site: NPL ID # SC1890008989

[63] Latitude: 32°08'08" N; Longitude: 81°45'53" W.

EPD monitors both facilities for potential human health hazards. The results are reported to the US Nuclear Regulatory Commission, and are also reported biannually in the Georgia Environmental Radiation Surveillance Report (Georgia - EPD 2002b). In the 2000-2002 surveillance report, EPD detected numerous isotopes above background levels in sediment samples from both the Savannah River Site (Cobalt-60 (22x above background), Strontium-90 (3x), Cesium-137 (540x), Plutonium-238 (3x) and Plutonium-239 (6x)) and from Vogtle (Cobalt-60 (7x)). Water-borne emissions are believed to originate from 5 streams at the Savannah River Site (Georgia - EPD 2002b). A study of these 5 streams (branches of the Savannah River) found elevated levels of tritium and its by-products, Technetium-99 and Iodine-129, in water samples collected in 1992-1994 (i.e. following the final production of radioactive materials) (Beals and Hayes 1995). These elevated levels may be a cause for concern for both animals and humans because they can be concentrated in the thyroid and/or GI tract. However, radionuclides were below EPA regulatory limits further downstream after mixing with the Savannah River (i.e. Lower Three Runs Stations) (Beals and Hayes 1995).

Tritium (H-3) is the most common radioisotope detected above background levels in the Savannah River (Fledderman et al. 2004). During the EPD monitoring study conducted in 2000-2002 along a 130-mile river stretch near the Savannah River Site, concentrations of tritium in tributaries adjacent to the site were 300x background levels, whereas concentrations in downstream tributaries were 16x background levels (Georgia - EPD 2002b). In addition, Iodine-129 (a waste product of tritium) was detected at 8x the background level at a tributary near the middle of the site (Four Mile Creek), likely due to groundwater seepage from a closed radioactive-waste treatment basin. H-3 was also detected in one river water sample downstream of Vogtle Electric Plant at 50x the background level (Georgia - EPD 2002b), although this was attributed to an unusual acute chemistry problem in one reactor (which was shutdown for cleanup). According to the EPD, the Savannah River Site accounts for over 90% of the H-3 detected in waters of the Savannah River, primarily through migration of groundwater to streams, although that percentage is likely >95% when wet deposition via precipitation of H-3 is also considered (Georgia - EPD 2002b).

Tritium concentrations in fish samples along the Savannah River were 230x background levels in tributaries adjacent to the site and 9x background levels further downstream (Fledderman et al. 2004). Strontium-90 (5x) and Cs-137 (220x) were also elevated above background levels in fish samples downstream of the Savannah River Site (Georgia - EPD 2002b).

In terms of conventional pollutants, both nuclear facilities are listed in the TRI Explorer database as releasing toxic material into surface water: the Savannah River Site releases lead (20 lbs/year) and mercury (1 lb/year) and the Vogtle Electric Plant releases zinc compounds (11,103 lbs/year) [64](Georgia - EPD 2002b).

[64] In addition, the Savannah River Site is cited for releasing Hydrochloric Acid (acid aerosols, after 1995), lead, mercury, and sulfuric acid into the air and lead into surface impoundments.

Table 19. Industries in the Fort Pulaski Study area that are listed on Georgia's Hazardous Site Inventory (HSI) List for releasing significant quantities of contaminants to groundwater and/or soil (Georgia - EPD 2004b).

HSI sites that are also listed as (or portions of) Superfund sites are shaded.

HSI ID	Site Name	County	Class	Major Groundwater Contaminant	Major Soil Contaminant
10208	139 Brampton Road	Chatham	I	Tetrachloroethene	Lead
10579	Abercorn & Largo Development	Chatham	I	Tetrachloroethene	
10091	Travis Field/Savannah International Airport	Chatham	II	Chomium	Lead
10095	Central of GA RR/Bernuth-Lembcke Site	Chatham	II	Naphthalene	Benzo(b)fluoranthene
10098	Colonial Terminals, Plant #2	Chatham	II	Lead	
10179	Kerr McGee - Deptford Tract	Chatham	II	Lead	Benzo(b)fluoranthene
10255	Union Camp Corp - Hwy 17 Disposal Site	Chatham	II		Nickel
10351	ARAMARK Uniform Services	Chatham	II	Tetrachloroethene	
10364	Circle K Store #7703 (Former)	Chatham	II	Lead	Lead
10371	Southern States Phosphate & Fertilizer Co.	Chatham	II	Lead	Lead
10372	Truman Parkway, Phase II	Chatham	II	Lead	Lead
10395	Hunter Army Airfield, Fire Training Area	Chatham	II	Vinyl Chloride	
10403	Futch Wire	Effingham	II	Lead	Lead
10415	Savannah Electric - Plant Kraft	Chatham	II	Benzo(a)pyrene	Benzo(a)pyrene
10434	Savannah Paint Manufacturing	Chatham	II	Naphthalene	Toluene
10440	Blue Ribbon Dry Cleaners	Chatham	II	Tetrachloroethene	Tetrachloroethane
10464	Vopak Terminal Savannah	Chatham	II	Tetrachloroethene	
10465	Rhodes Air National Guard Station Areas A & B	Chatham	II	Beryllium	
10497	Southeastern Family Homes, Inc.	Chatham	II	Tetrachloroethene	
10503	Reese & Co., Inc. Tract	Chatham	II	Lead	
10521	Hunter Army Airfield - MCA Barracks	Chatham	II	Benzene	
10553	Georgia Air National Guard/Savannah/Site 8	Chatham	II	Lead	
10555	Georgia Air National Guard/Savannah/Site 10	Chatham	II	Lead	
10590	Central of Georgia Railroad Company - Battlefield Park	Chatham	II	Lead	
10591	Southern Motors of Savannah, Inc.	Chatham	II	Tetrachloroethene	
10600	Colonial Terminals, Inc.- 1100 West Lathrop Property	Chatham	II	Beryllium	

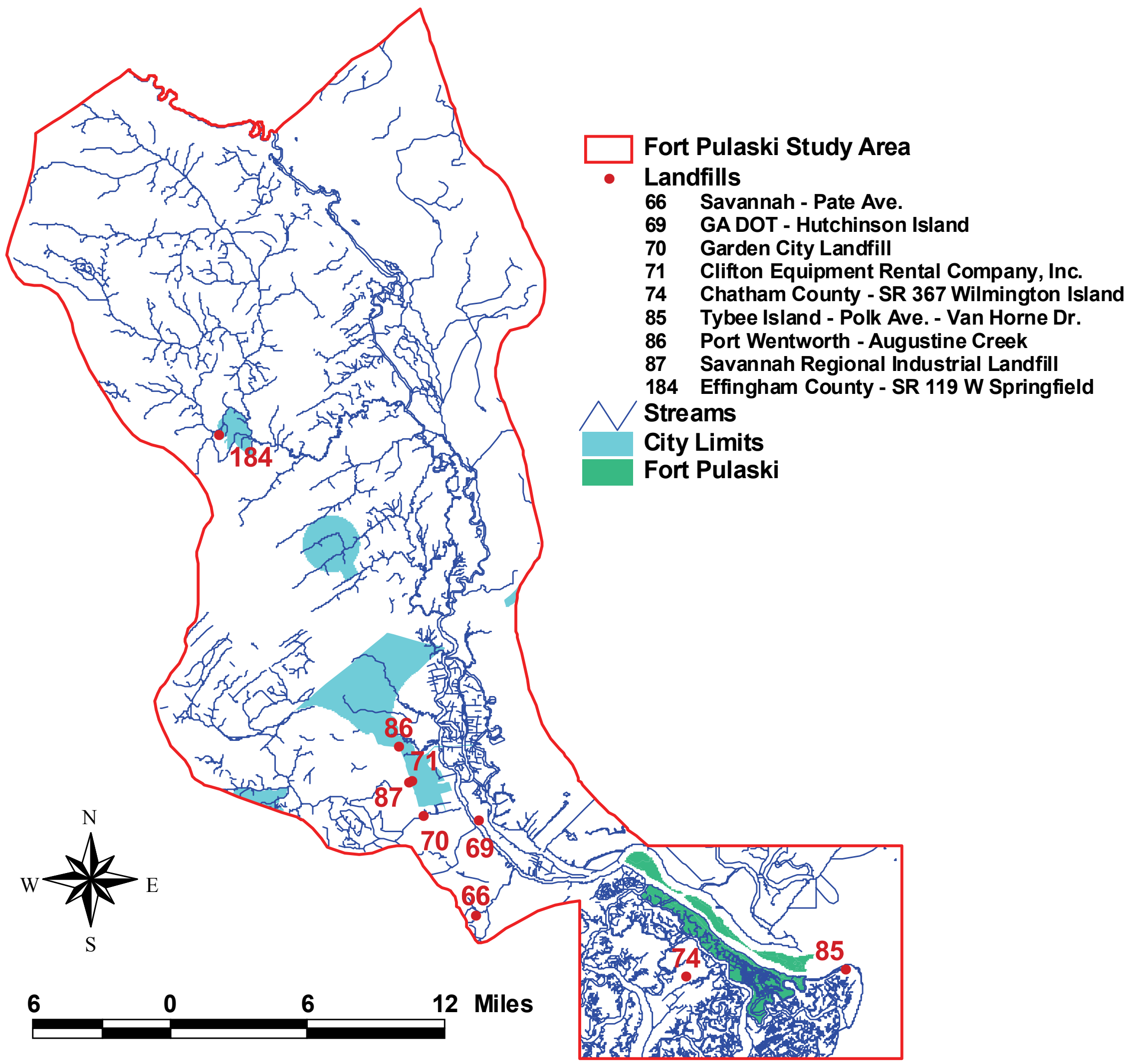
10611	CSXT Depriest Signal Shop	Chatham	II	Lead	Lead
10641	Kerr McGee Pigments, Inc.	Chatham	II	Vinyl Chloride	
10696	Hercules, Inc.	Chatham	II	Acrolein	Cyanides
10698	Norfolk Southern - Natrochem, Inc., Site	Chatham	II	Benzo(a)pyrene	Benzo(a)pyrene
10764	Martha's Dry Cleaner	Chatham	II	Tetrachloroethene	Tetrachloroethane
10339	CSX Transportation - Stevens Oil	Chatham	III	Lead	
10018	Atlantic Wood Industries	Chatham	IV	Benzo(a)pyrene	
10045	Colonial Terminals, Plant #1	Chatham	IV	Vinyl Chloride	
10105	Hunter Army Airfield	Chatham	IV	Tetrachloroethene	Lead
10114	Union Camp Corp - Former Amoco Property	Chatham	IV	Mercury	
10128	Atlanta Gas Light Company - Savannah MGP Site	Chatham	IV	Benzo(a)pyrene	Benzo(a)pyrene
10162	Ashland Chemical Company	Chatham	IV	Vinyl Chloride	
10241	Union Camp Corp - Allen Blvd Landfill	Chatham	IV	Lead	
10649	Chatham County Landfill	Chatham	IV	Cadmium	
10713	Effingham County - SR 17 MSWLF	Effingham	IV	Benzene	
10003	CSX Transportation - Savannah (Tremont Road)	Chatham	V	Lead	Lead
10101	CSX Transportation - Powell Duffryn	Chatham	V	Lead	Lead
10406	McKenzie Tank Lines, Inc.	Chatham	V	Vinyl Chloride	

Table 20. Superfund sites located within the 3-county region.

(Based on information from CERCLIS database (U.S. EPA 2004b))

Site Name	Address/Description	City	County	Year Added	EPA ID
BERNUTH LEMBCKE CO INC	N END OF E LATHROPE AVE	SAVANNAH	CHATHAM	1981	GAD980556864
BIG THREE INDUSTRIES	2601 EAST PRESIDENT STREET	SAVANNAH	CHATHAM	1994	GAD981275928
CERTAIN-TEED CORPORATION	FOUNDATION DRIVE	SAVANNAH	CHATHAM	1994	GAD003292935
E M CHEMICALS INC	O'LEARY RD GA 21 & I-95	SAVANNAH	CHATHAM	1980	GAD095797817
GULFSTREAM AMERICAN CORP	TRAVIS FIELD	SAVANNAH	CHATHAM	1980	GAD061022216
JORDAN SIGN COMPANY INC	PRESIDENT & RUDOLPH ST	SAVANNAH	CHATHAM	1979	GAD003293057
KEMIRA ACID SPILL	Removal Only Site (No Site Assessment Work Needed)	SAVANNAH	CHATHAM	1998	GASFN0406941
LATEX CONSTRUCTION CO	3126 RIVER RD	THUNDERBOLT	CHATHAM	1986	GAD980803696
MCKENZIE TANK LINES, INC	111 GRANGE ROAD	SAVANNAH	CHATHAM	1997	GAD981244767
OATLAND ISLAND EDUCATION CENTER	711 SANDTOWN ROAD	SAVANNAH	CHATHAM	2000	GAN000407185
OWENS CORNING FIBERGLAS PLANT	1 FOUNDATION DRIVE	SAVANNAH	CHATHAM	2003	GAD984316869
POWELL DUFFRYN FIRE	2 WAHLSTROM ROAD	SAVANNAH	CHATHAM	1995	GAD984291377
ROMINE EQUIPMENT RENTAL	HWY 21	GARDEN CITY	CHATHAM	1987	GAD981931116
SAFETY-KLEEN CORP 3-179-01	AUGUSTA RD (GA HWY 21)	GARDEN CITY	CHATHAM	1980	GAD000776781
SEA STAR TRUCK RELEASE	Removal Only Site (No Site Assessment Work Needed)	SAVANNAH	CHATHAM	2000	GASFN0407132
SWIFT AGRI-CHEM CORP/COLONIAL OIL INDS	1260 LATHROP AVE	SAVANNAH	CHATHAM	1979	GAD006926430
TRUMAN PARKWAY, PHASE II	PRESIDENT STREET	SAVANNAH	CHATHAM	1997	GA0001897669
UNION CAMP CORP	ALLEN BLVD NEXT TO SEPCO SUBST	SAVANNAH	CHATHAM	1981	GAD980559215
USCG AIR STATION SAVANNAH*	HUNTER ARMY AIR FIELD	SAVANNAH	CHATHAM	1980	GA4690315904
ZY - TRAVIS FIELD/SAVANNAH INT AIRPORT	---	SAVANNAH	CHATHAM	1993	GAD984307918

Figure 14. Landfills located within the Fort Pulaski study area (Georgia - EPD 2000).



Port of Savannah- A study by the National Resources Defense Council showed that ports can contribute to poor air and water quality as a consequence of the diesel engines of the associated ships, trucks, trains, and cargo-handling equipment, which emit particulate matter (dust and soot), volatile organic compounds[65], NO_x, ozone, SO_x, CO, heavy metals, dioxins, and pesticides (from produce). In addition, emptying of bilge water, leaching of toxic antifouling additives from paints[66], stormwater runoff, oil spills, and dredging contribute to poor water quality (Bailey

[65] These include benzene, 1,3-butadiene, formaldehyde, and toluene.
[66] Additives such as Tributylin (TBT) are added to the paint in order to prevent barnacle and marine fouling on the hull of the ship. These additives are slowly being phased out.

et al. 2004). The Port of Savannah is covered under a NPDES discharge permit, and both terminals are covered under separate NPDES stormwater permits. However, the Port is not listed as a GA-HSI or a Superfund site, nor are any chemical emissions reported to the TRI database.

B.3.b. Nonpoint Sources:

There are no real sources of non-point pollutants at Fort Pulaski itself, which is largely comprised of salt marshes (*see* **Table 3**). However, non-point sources from the larger region likely affect the area via stormwater runoff and atmospheric deposition. Non-point pollutants are very difficult to assess, but as part of the 2001 Savannah River Basin Management Plan the Georgia EPD identified non-point pollution, particularly "urban runoff", as having the most significant effects on water quality in the basin since industrial point sources are strictly regulated and sewage treatment has improved (Georgia - EPD 2001). EPD described "urban runoff" as a combination of industrial stormwater runoff, unauthorized discharges, accidental spills, and washoff from residential areas promoted by the abundance of impervious surfaces. Typically, urban runoff contains many of the same pollutants found in point source discharges (i.e. suspended solids, synthetic organic chemicals, oil and grease, nutrients, lead and other metals, and bacteria), and reaches surface waters intermittently with rain events. The ongoing population growth and accompanying development in the Savannah area (*see* Section **A.1.c.**) is likely to increase the amount of impervious surface, which will in turn result in increased runoff. Below we briefly review the available information for different non-point pollutants in the area.

B.3.b.i. Nutrients

A nationwide study found that non-point sources accounted for 93% of the nitrogen loading to major watersheds (Puckett 1994). The largest sources of nitrogen were fertilizer and animal feeding operations; fertilizer usage increased 20-fold between 1945 and1985 (Puckett 1994). Although little specific information exists on relative contributions of nutrients from non-point sources to the Savannah River, Asbury and Oaksford (1997) found that fertilizer and/or animal wastes were the largest contributors of both nitrogen and phosphorus to 7 of the rivers in the South Atlantic Bight (accounting for nearly two-thirds, and in some cases, 90%). Atmospheric deposition typically ranked 3rd among nitrogen sources and contributed one quarter of the total nitrogen to rivers. As in the nationwide study, the contributions of nitrogen and phosphorous from point sources such as wastewater treatment plants were usually comparatively smaller (< 7%).

Several of the streams located in the upstream portion of the watershed were listed on the 303 (d) list, with nonpoint source loading from agricultural lands identified as the major potential cause. However, concentrations are generally diminished in downstream areas. The Soil Conservation Service conducted a survey of estimated loads from agricultural lands by county in 1993 (as reported in (Georgia - EPD 2001). Estimated concentrations of nitrogen and phosphorous in runoff from agricultural lands were much higher in upstream counties (i.e. Banks, Franklin, Habersham, Hall, Madison, and Stephens, >0.3 ppm N, >0.04 ppm P) than downstream in Chatham and Effingham Counties (0.02 and 0.04 ppm N, 0.007 and 0.01 ppm P, respectively). This is consistent with Asbury and Oaksford's conclusion very little of the upstream agricultural sources of pollution are transported downstream (Asbury and Oaksford 1997).

Atmospheric deposition of nitrogen can come from combustion of fossil fuels (i.e. automobiles, electric utilities, industry). The National Atmospheric Deposition Program maintains a site on Skidaway Island near Fort Pulaski (GA-98) that has been operational since 2002. They collect data on a suite of constituents, including calcium, magnesium, potassium, sodium, inorganic nitrogen, chloride, sulfate, and hydrogen. Atmospheric deposition of ammonia during 2002-2004 at station GA 98 was 3.34 kg/ha, which was greater than the national average (2.24 kg/ha), whereas nitrate deposition (7.49 kg/ha) was lower than the national average (8.18 kg/ha) (National Atmospheric Deposition Program 2004). During the most recent report year (2004), atmospheric deposition of both ammonium and nitrate (2.76 and 8.93 kg/ha, respectively) were greater than the national averages (2.19 and 7.89 kg/ha).

B.3.b.ii. Organic Matter

Organic matter likely enters the watershed via overland runoff. There has been no estimate done of organic matter sources to the region, but it may originate from animal operations and/or urban areas (i.e. domestic pet waste). Failing septic tanks can also be a potential source, particularly if they are located close to a water body. Septic tanks would be more important in rural areas, as the cities and towns generally have wastewater treatment plants. Organic matter can be a problem in at least two ways: 1) by increasing the Biological Oxygen Demand, and thus lowering the available oxygen for aquatic organisms, and 2) fecal-coliform bacteria may accompany organic matter, indicating a potential health risk.

B.3.b.iii. Contaminants

Contaminants that enter the water as non-point sources can originate as pesticides or herbicides used in field agriculture[67] as well as on golf courses and suburban lawns[68]. However, only a small percentage (~5.5%) of the land in the lower Savannah River watershed (380,984 ac.) is used as cropland. Pesticides, herbicides and fungicides are also used in silviculture[69] but these are likely less important in the study area because they are primarily used in commercial tree nurseries and there are none in the Savannah River Basin. Furthermore, the EPD watershed assessment (305b/303d lists) found no streams in the basin that were considered impacted by forestry activities (Georgia - EPD 2001). Thus, urban and residential lands are likely the greatest

[67] Common herbicides include 2,4-d, Prowl, Blazer/Basagran/Trifluralin/Treflan/Trilin, Aatrex/Atizine, Gramoxone, Classic, Lexone/Sencor, and Lasso (alachlor) from the Georgia Herbicide Use Survey compiled by Monks and Brown 1991, as summarized by (Georgia - EPD 2001). Common pesticides include chlorothalonil, aldicarb, chlorpyifos, methomyl, thiodicarb, carbaryl, acephate, fonofos, methyl parathion, terbufos, disulfoton, phorate, triphenyltin hydroxide (TPTH), and synthetic pyrethroids/pyrethrins (Georgia - EPD 2001).

[68] Common herbicides include dicamba, 2,4-D, mecoprop (MCPP), 2,4-DP, MCPA, phenoxy-acid herbicides, glyphosphate, methyl sulfometuron, benefin (benfluralin), bensulide,acifluorfen, , 2,4-DP, Atrazine (until 1993), glyphosphate, methyl sulfometuron, MSMA, 2,4-D, 2,4-DP, dicamba, and chlorsulforon.). Pesticides include chlorpyrifos, diazinon, malathion, acephate, carbaryl, lindane, dimethoate, and dhlorothalonil (Georgia - EPD 2001).

[69] Common herbicides include glyphosate (Accord), sulfometuron methyl (Oust), hexazinone (Velpar), imazapyr (Arsenal), and metsulfuron methyl (Escort) Dicamba, 2,4-D, 2,4,-DP (Banvel), triclopyr (Garlon), and picloram (Tordon). Insecticides include chlorpyrifos, diazinon, malathion, acephate, carbaryl, lindane, dimethoate, chlorothalonil, dichloropropene, and mancozeb.

non-point sources of herbicides and pesticides in Savannah, as is the case in other highly populated Metropolitan Statistical Areas (Georgia - EPD 2001).

The atmosphere can also be an important route for the delivery of contaminants: the U.S. EPA identifies nitrogen compounds, mercury, other metals, pesticides, and combustion emissions as the five types of pollutants most likely to degrade water quality through atmospheric deposition (U.S. EPA 2004a). Data on toxic fugitive air emissions is reported in the EPA TRI Explorer database, although there is no information given on how much of each chemical actually precipitates out of the atmosphere (and returns to surface waters). Chemicals released within the Fort Pulaski study area at quantities greater than 10,000 lbs per year include methanol, toluene, biphenyl, styrene, and acetaldehyde; those released at quantities greater than 1,000 lbs per year include epichlorohydrin, titanium tetrachloride, sulfuric acid (1994 and after, acid aerosols only), ammonia, trichloroethylene, chloroform, methylethylketone, formaldehyde, xylene (mixed isomers), and phenol (U.S. EPA 2002).

C. Other Water Resource Issues of Concern

In 2004, Park Service personnel at Fort Pulaski took part in the NPS Southeast Coast Network's park-wide process to identify "vital signs"[70] by ranking issues related to environmental setting, park resources, and agents of change on a scale of 0 to 5 (where "0" is not applicable to the park and "5" is legally or contractually required) (DeVivo et al. 2005). Summarizing the natural resource issues related to this water assessment report," 72 issues at Fort Pulaski scored a "3" or "4" (none were given a score of "5") (DeVivo et al. 2005). Although many of these issues were already addressed in Part B, above, other issues of concern can be broadly grouped into 4 major categories: 1) water withdrawals (i.e. groundwater quality/quantity), 2) species of concern (including both threatened/endangered and invasive/exotic species), 3) anthropogenic alterations (i.e. effects of channel dredging/ deepening, roads/highways), and 4) shoreline and coastal erosion. These topics are discussed below.

C.1. Water Withdrawals

Information on water withdrawals comes from Fanning (2003) and Bristol and Boozer (2003), who provide water use estimates for the years 2000 and 2001, respectively. Total water usage within the 3-county Fort Pulaski study area was approximately 409 million gallons per day (mgd), slightly more than half of which was withdrawn in Chatham County (53%). Seventy percent of the total (287 mgd) was withdrawn from surface water and the remainder from groundwater sources (**Table 21**). Nearly all of the water withdrawn (94%) was used for thermo-electric, industry, and public supply. The majority of surface water was used for electricity (193 mgd) whereas most of the groundwater was used for either public supply (53 mgd) or industry (43 mgd). Industrial water use in the Georgia portion of the study area was primarily by paper (>50%) and chemical (45%) companies[71].

[70] Vital signs are measurable, predictable indicators of environmental health chosen based on management significance (NPS - Southeast Coast Network 2005).
[71] This accounts for the Georgia portion of the study area only because there was no breakdown of industrial users for South Carolina counties.

Virtually all of the groundwater in the 3 county-Fort Pulaski study area is supplied by the Upper Floridan Aquifer. In Georgia, it is the principal source of public supply water for all 6 coastal counties (including Chatham and Jasper Counties) and provides a substantial portion for 18 adjacent counties (Clarke et al. 1990). In areas where pumping is concentrated (in Brunswick GA, and in the Savannah GA/Hilton Head SC area), it has lowered the water level, resulting in saltwater intrusion into the aquifer .(Peck 1999; Krause and Clarke 2001) GA-EPD capped permitted withdrawals at 1997 rates in the Savannah and Brunswick areas as part of an interim management strategy. At the same time, the Coastal Georgia Sound Science Initiative was begun to support scientific and feasibility studies aimed at developing a final water-management strategy (expected to be completed in January 2006) (USGS 2000b). The broad objectives of the program are "to collect data necessary to characterize and monitor ground-water flow and saltwater contamination; evaluate possible alternative sources of water to the Upper Floridan aquifer; simulate ground-water flow and the movement of saltwater in response to a variety of water-management scenarios; and monitor changes in the hydrologic system". All program final reports are expected to be complete by spring 2005; many are available online on the Georgia USGS website[72]. Below we summarize results of several relevant studies already completed under the program.

Table 21. Surface water and Groundwater withdrawals in the 3-county Fort Pulaski region.

All data are in millions of gallons per day (mgd).
Sources: Fanning 2003 (USGS) and Bristol and Boozer 2003 (SC DHEC).

	Surface water			**Groundwater**			**Percent of Total**
	Chatham	**Effingham**	**Jasper**	**Chatham**	**Effingham**	**Jasper**	
Public Supply	0	31.1	0	33.5	1.9	17.7	20.6
Domestic	0	0	0	2.2	1.0	0	0.8
Irrigation	1.2	0.4	0	8.2	0.2	12.3	5.5
Industrial	43.3	17.3	0	27.1	2.1	13.7	25.3
Thermoelectric	98.2	95.2	0	0	0.06	0	47.3
Live-stock	0.02	0.03	0	0.01	0.01	0	0.02
Mining	0	0	0	0	0	0	0.00
Commercial	0	0	0	1.3	0	0	0.3
Aquaculture	0	0	0	0	0	0.2	0.05
Other	0	0	0	0	0	0.5	0.1
Total	142.8	144.0	0	72.2	5.3	44.5	100.0
Grand Total	**286.8 mgd**			**122.0 mgd**			

The interconnection of aquifers in Eastern Chatham County near Fort Pulaski and Tybee Island have been explored to examine the potential for saltwater contamination in the area, especially in light of the constant dredging and impending deepening project in the Savannah Harbor. Clarke et al. (1999) found both in Savannah and in Hilton Head (where saltwater enters the aquifer in Port Royal Sound), there was a decrease in hydraulic head with depth. These results indicate the

[72] Available at: http://ga2.er.usgs.gov/coastal/.

potential for downward leakage of water into the Upper Floridan from the surficial and upper Brunswick aquifers. It is possible that this type of leakage has previously occurred in the Fort Pulaski area response to pumping, as indicated by the low water levels observed in 1998. If leakage from the Upper Brunswick occurs, higher levels of sodium chloride and iron might be expected (Clarke et al. 1999).

Three groundwater flow models[73] have been developed for the coastal area of Georgia (Clarke and Krause 2001). Model simulations of increased pumpage in the Savannah-Hilton Head area indicated a probable increase in leakage and greater saltwater contamination. On the other hand, if pumpage were reduced by about 65 mgd in Chatham County, the hydraulic flow at Savannah would shift seaward toward Hilton Head again. If pumping in Chatham County were stopped completely, it is not clear how this would affect conditions.

C.2. Species of Concern

Information on species of concern comes from the GA and SC Department of Natural Resources Natural Heritage Programs (South Carolina - Wildlife and Freshwater Fisheries Division (SC-WFFD) 2003; Georgia - WRD 2005), US Fish and Wildlife Service – Georgia section (U.S. FWS 2004), and two reports on flora and fauna at Fort Pulaski (Govus 1998; Rabolli and Ellington 1998; South Carolina - Wildlife and Freshwater Fisheries Division (SC-WFFD) 2003; U.S. FWS 2004; Georgia - WRD 2005). Overall, there are 24 state and/or federally listed endangered or threatened animal and plant species confirmed to use upland and aquatic habitat in Chatham, Effingham, and/or Jasper Counties. These species, plus an additional 4 that are classified as rare (all birds), noted due to their use of Fort Pulaski, are included in (**Table 22).** Additional information on these species regarding listing status, habitat, use of Fort Pulaski, and threats are included in **Appendix I**.

Table 22. Protected species listed regionally, in Chatham, Effingham, and Jasper Counties.

Shading denotes those species that were observed in the Park by Rabolli and Ellington (1998). (Sources: Rabolli and Ellington 1998; South Carolina - Wildlife and Freshwater Fisheries Division (SC-WFFD) 2003; U.S. FWS 2004; Georgia - WRD 2005)

UPLAND ANIMALS –	
Birds:	
American Oystercatcher	*Haematopus palliatus*
Bachman's warbler	*Vermivora bachmanii*
Bald eagle	*Haliaeetus leucocephalus*
Gull-billed tern	*Sterna nilotica*
Least Tern	*Sterna antillarum*
Peregrine Falcon	*Falco peregrinus*
Piping plover	*Charadrius melodus*
Red-cockaded woodpecker	*Picoides borealis*
Swallow-tailed Kite	*Elanoides forficatus*
Wilson's Plover	*Charadrius wilsonia*

[73] A Regional Aquifer System Analysis, a Glynn County area model, and a Savannah area model.

Wood stork	*Mycteria Americana*
Reptiles:	
Eastern indigo snake	*Drymarchon couperi*
Gopher tortoise	*Gopherus polyphemus*
Spotted Turtle	*Clemmys guttata*
Amphibians:	
Flatwoods salamander	*Ambystoma cingulatum*
Dwarf Siren	*Pseudobranchus striatus*
Mammals:	
Rafinesque's Big-Eared Bat	*Corynorhinus rafinesquii*
PLANTS –	
Chaffseed	*Schwalbea Americana*
Dwarf witch-alder	*Fothergilla gardenii*
Narrowleaf obedient plant	*Physostegia leptophylla*
Pondberry	*Lindera melissifolia*
Pondspice	*Litsea aestivalis*
Tidal Marsh obedient plant	*Physostegia leptophylla*
AQUATIC ANIMALS –	
Mammals:	
Humpback whale	*Megaptera novaeangliae*
Right (Northern) whale	*Eubalaena glacialis*
West Indian manatee	*Trichechus manatus*
Fish:	
Shortnose sturgeon	*Acipenser brevirostrum*
Reptiles:	
Green sea turtle	*Chelonia mydas*
Hawksbill sea turtle	*Eretmochelys imbricata*
Kemp's ridley sea turtle	*Lepidochelys kempi*
Leatherback sea turtle	*Dermochelys coriacea*
Loggerhead sea turtle	*Caretta caretta*

C.2.a. Upland Habitat

C.2.a.i. Animals -

There are 17 state and/or federally listed endangered, threatened, or rare vertebrate species confirmed to use upland habitat in the 3 Counties (**Table 22**). In all, 9 of the 17 upland animals are likely to use habitat on Fort Pulaski, of which all but one (the gull-billed tern) were confirmed to be present by vertebrate surveys (Rabolli and Ellington 1998). Painted buntings

(*Passerina ciris*), which are not yet state-protected but appear to be in decline, are also common at Fort Pulaski (Rabolli and Ellington 1998).

C.2.a.ii. Plants -

There are 6 state or federally listed endangered or threatened plant species confirmed in the 3 Counties, none have been observed at Fort Pulaski (**Table 22**). However, Govus (1998) reported 2 species of "special concern" (Georgia Natural Heritage Program) on McQueen's Island: Florida privet (*Forestiera segregata*) and Swamp dock (*Rumex verticillatus*): Florida privet was found near shell deposits and swamp dock was found on low-lying portions of spoil deposits.

C.2.b. Aquatic Habitat

There are 9 state or federally listed endangered or threatened aquatic species confirmed in the 3 Counties, 2 of which have been observed at Fort Pulaski (**Table 22**). In addition, two species of anadromous fish are of concern within the lower Savannah River due to previous Harbor modifications and the impending deepening.

C.2.b.i. Striped Bass -

Striped bass (*Morone saxatilis*) have long represented an important recreational fish in the Savannah River (Reinert 2004). Spawning areas were historically found in the Back River where salinities were < 0.5, but since the construction of the tide gate in 1977 (see section **A.1.b.iii**.) spawning has taken place primarily in the Front River from RM 24-31 (86%) (Georgia Ports Authority 1998; Reinert 2004). To a lesser extent, spawning also occurs in the Little Back and Back River between RM 13-28 and throughout the Middle River, all where salinities are less than 1.0 (Georgia Ports Authority 1998 citing Reinert et al. 1996). The semibuoyant eggs are carried downstream by the current and hatch in about 44 hours, spend 18 days as larvae and 90 days as fingerling/fry. Throughout the growth period from eggs to young, optimal salinities are all less than 10. Almost all (99%) of the juveniles use waters < 0.5 as nursery habitat (primarily in the Back River, RM 14-28) (Georgia Ports Authority 1998 citing Wallin et al. 1995).

Striped bass populations declined markedly in the early 1980's: the catch-per-unit-effort of large adults (≥ 9.0 kg) declined by as much as 96% and egg production declined by as much as 97%. (Reinert et al. 2005). This change was primarily blamed on increased salinities in spawning areas and during egg transport[74] as a result of the tide gate (Reinert et al. 2005). However, the population has not fully recovered since the removal of the tide gate and the closure of New Cut (1991 and 1992, respectively), and striped bass have generally not yet returned to the Back River for spawning (Reinert 2004). If deepening increases salinities in their current spawning locations, it is uncertain whether they will move further upstream to spawn (discussed below).

C.2.b.ii Shortnose Sturgeon -

[74] Optimal salinities in the Savannah River for striped bass spawning have been found to be <1.5 ppt (spawning has been noted at RM 21.3-26.6 in the Front River and RM 17-28 in the Back River), and lethal salinities during egg transport have been reported at 9 ppt (Table 4-15 of Winger and Lasier 1994; Georgia Ports Authority 1998; Reinert et al. 1996).

There is one endangered fish species, the shortnose sturgeon (*Acipenser brevirostrum*), in the area. These fish have been classified as a federally endangered species since 1967. Currently, it is estimated that anywhere from 300-3,000 adult sturgeon exist in the Savannah River (Georgia Ports Authority 1998). Each year, adult sturgeon migrate upstream in mid-February to Savannah RM 112-119 and 172-174 to spawn (Georgia Ports Authority 1998 citing Hall et al. 1991). After spawning, the adults begin to move back downstream in March, arriving at the freshwater-saltwater interface near Kings Island Turning Basin (RM 19) around May. Both juveniles and adults seek out deep, cool holes of the turning basin for summer resting and feeding, and remain there throughout the fall and early winter. Little is known about larval habitat in the Savannah River (Georgia Ports Authority 1998). Concerns regarding how deepening the Harbor could potentially affect sturgeon are described below.

C.2.c. Pests, Invasive, and Introduced Species

A number of pests and invasive species are present on or near Fort Pulaski. Some species may have reached the area through natural expansion of their native range. However, Fort Pulaski's proximity to the Savannah Harbor, previous use as a depositing site for dredge-spoil and ballast heaps, and human utilization over time, have also resulted in the introduction of exotic species.

C.2.c.i. Upland Habitat -

Animals - One of the most conspicuous animals on Cockspur Island is white-tailed deer (*Odocoileus virginianus*), which is estimated to be at or near carrying capacity at about 63 deer mi^{-2} (Rabolli and Ellington 1998). Rabolli and Ellington (1998) recommended monitoring the deer population because they could have negative effects on native vegetation or cultural resources. Raccoons and rodents (black rats, house mice, squirrels, opossums) are the other major mammal species present in the park (Southeastern Wildlife Management 1981, Mills 1998 as cited in Rabolli and Ellington 1998). Although they have not affected native flora or fauna the rodents are potentially harmful to humans as disease vectors: raccoons on Fort Pulaski NM have been reported with rabies and rats and mice have been confirmed to carry hantavirus (transmissible to humans aerially or through direct contact with urine or feces) (Rabolli and Ellington 1998). The European starling (*Sturnus vulgaris*) is also present, and is of concern to park officials because it competes with native birds for nesting sites and food (Rabolli and Ellington 1998).

Plants - The greatest proportion of non-native plant species occurs in disturbed habitats: alongside navigation channels, on spoil areas, and on altered marshlands. Govus (1998) identified 68 plant species (23% of the total reported) as non-native. Many are well-established naturalized grasses found on the maintained grasslands, others are rare introductions that are poorly established (notably cat's ear (*Hypochoeris microcephala*) and puncture-weed (*Tribulus terestris*) that are new GA state records), and some (18) are invasive and potentially destructive to natural communities (these are listed in Table 3 of Govus 1998).

Three primary plant species appear to be widespread and current significant threats to the park's natural communities: Chinese privet (*Ligustrum sinense*), China berry (*Melia azedarach*), and

Chinese tallow (*Sapium sebiferum*). At Fort Pulaski, Chinese privet grows densely in the openings of older maritime forests, China-berry grows on spoil deposits and within the younger forest system (located inside the dike), and Chinese tallow grows in low-lying, saturated areas of the younger forest system (Govus 1998). Chinese tallow was introduced to the east coast in the late 1700s, primarily as an ornamental tree. It grows in a variety of habitats and climates (especially subtropical), and once established is very difficult to eradicate (USGS 2000a). In addition, the berries, sap, and fallen leaves contain toxins that are potentially harmful to humans and animals. A photopoint monitoring program was established to monitor vegetation changes over time (paying close attention to these 3 invasive species) as a result of Govus' vegetation survey (1998).

C.2.c.ii. Aquatic Habitat-

USGS (2004b) put together a searchable "Nonindigenous Aquatic Species Database" that details introduced species by watershed. It identified several species that have been introduced into the Savannah River watershed at the 6-digit HUC level (030601, which extends from the headwaters of the River in Tennessee all the way to the mouth in Savannah). In general, these introductions have been intentional stocking for sport-fishing or for baitfish and have been benign.

The green mussel (*Perna viridis*), was reported in the Savannah River in October 2003 (one was collected from the Savannah River at the U.S. Coast Guard Station at Fort Pulaski (Benson 2004; USGS 2004b). Originally native to the Indo-Pacific region of Asia the species was introduced in Tampa Bay FL and has migrated northward up the east-Florida and Georgia coastline. However, it is unlikely that these mussels can overwinter in Georgia and so the population may not be able to establish itself in the Savannah.

C.2.d. Commercial and Recreational fishing

White shrimp (*Penaeus setiferous*) and blue crabs (*Callinectes sapidus*) constitute the first and second most important commercial fishery species in Georgia[75], both of which are abundant in the Savannah River Estuary (EMAP program, U.S. EPA 1999). Commercial fishing does not take place within the Park itself but rather in the main channel of the river. Crab traps may be placed throughout the estuary to the saltwater demarcation line, located where Hwy 17 crosses the river (Georgia - CRD 2005a). Although shrimp are not as heavily fished within the estuary itself, they are caught in the Sounds along the entire coast of Georgia[76]. Recreational fishing occurs all along the river (including a public fishing pier on McQueen's Island, which provides access to Lazaretto Creek). Five recreationally-important fish most often caught in the estuary are southern kingfish (*Menticirrhus spp.*), spotted seatrout (*Cynoscion nebulosus*), red drum (*Sciaenops ocellata*), black sea bass (*Centropristis striatus*), and southern flounder (*Paralichthys lethostigma*) (Gillis and Millikin 1999).

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[75] Between 1989 and 2004, an average of 4.4 million lbs of shrimp and 5.7 million lbs of crabs are caught annually in Georgia, worth an average of $16.7 million and $2.8 million dollars, respectively (Georgia - CRD 2003; 2004; 2005b). These 2 species account for 90% of the total value of commercial landings in Georgia (Georgia - CRD 2005b).

[76] More than 80% of white shrimp caught commercially in Georgia in 2002 were in nearshore waters, <3 miles out (NMFS *pers. comm.*).

Between 1994 and 2003, commercial crab landings for the State decreased from 8.9 to 1.9 million pounds (Georgia - CRD 2005b). However, landings have recently increased, to 3.0 million pounds in 2004. Fish harvest statistics are not available for specific regions of the coast. Commercial catch data are not released because the State is required to protect confidentiality. Recreational finfish catch data are derived primarily from a creel survey (the Marine Recreational Fisheries Statistics Survey) performed by GA DNR in conjunction with NOAA fisheries. Here too, sub-state information is not available since sample size would have to be increased considerably to provide sub-state data with an acceptable statistical confidence.

C.3. Anthropogenic Alterations

C.3.a. Harbor Expansion Project

The Port of Savannah houses two major terminals, the Garden City and Ocean Terminals, both of which are owned and operated by the Georgia Ports Authority (Georgia Ports Authority 2005). Garden City is the primary terminal, located at approximately river mile 18, and, at 1,208 acres (485.6 ha), is the largest of its kind on the U.S. East and Gulf Coasts. It is equipped to handle all types of cargo. Just slightly upstream of the Garden City Terminal (at approx. river mile 19) is the Kings Island Turning Basin (1,500 x 1,600 ft), which allows large vessels to turn around. The Ocean Terminal is located approximately between river miles 14-15 and covers a much smaller area at 208 acres (84.2 ha) and a smaller turning basin at Marsh Island (900 x 1,000 ft) (approx. between river miles 16-17). This terminal is specialized in the handling of heavier cargo. Both terminals are serviced by two major rail providers for cargo shipment, CSX Transportation and Norfolk Southern Railroad.

The Savannah River Harbor area leading up to the Kings Island Turning Basin has been dredged several times and is currently at a depth of 42 ft. and a width of 500 ft (Georgia Ports Authority 2005). As described above (*see* section **A.1.b.iii.**), Georgia Ports Authority has proposed to deepen the 36-mile portion of the Savannah River from Fort Pulaski (at RM 0) to above the Kings Island Turning Basin from its current 42-foot depth to a maximum of 50 feet. Project alternatives considered in the 1998 EIS were no deepening, and deepening by 2, 4, 6, and 8 feet (Georgia Ports Authority 1998). Plans to deepen this area to 48 feet (MLW) are expected to be completed by 2010, pending a second EIS (Federal Register 2002).

The environmental concerns associated with the proposed deepening include the effects on sediment transport, water clarity, salinity and dissolved oxygen, and how these in turn will potentially affect wetlands and fish populations.

C.3.a.i. Effects on Sediment Transport -

Longshore currents move water from breaking waves parallel to the shoreline. The currents also transport sediments, generally causing erosion on the northern ends of Georgia's barrier islands and accretion on the southern ends. The direction in which the waves break and are moved along the shore depends on the bathymetry (and wind direction), with waves bending as they are slowed by shallow areas. Deepening will affect the nearshore bathymetry, as the Entrance Channel will become much deeper than the Tybee Island shoreline. This is likely to cause the waves to refract and become focused on the Tybee Island shoreline, which may exacerbate coastal erosion. An associated concern is the possibility that the proposed deepening might deposit sediment at the Entrance channel of the Harbor and thus reduce sediment transport to Tybee Island. To address these concerns, one of the modifications being considered is to build a feeder berm (3,000 x 1,000 ft) 5,000 ft. from the northern shore of Tybee Island. The berm would slow wave-induced erosion and provide a source of sediments. However, the hydrodynamic model predicted that waves would be refracted around the berm, break along the Tybee's shoreline, and exacerbate the erosion problem (Georgia Ports Authority 1998).

The changes in bathymetry anticipated in response to Harbor expansion project are also expected to alter ebb tidal currents, resulting in an increase in ebb flow in the North Channel and a concurrent decrease in the South Channel (Georgia Ports Authority 1998). This type of effect has already been noted in response to previous dredging, and likely affects the movement of sediment in the area.

C.3.a.ii. Effects on Water Clarity -

Background turbidity levels in the Savannah River were measured by investigators from the Skidaway Institute of Oceanography in 1993 (reported in Georgia Ports Authority 1998). Their findings indicated that peak turbidity levels (total suspended solids) were > 400 mg/L near Fort Pulaski at river mile 0, > 500 mg/L from approx. river miles 9-14, > 300 from approx. river miles 14-22, and > 200 mg/L from approx. river miles 22-32 (reported in Georgia Ports Authority 1998). During previous dredging events (1989-1991 and 1993-1994), the U.S. Army Corps of Engineers reported that 95% of the observations were below 410 mg/L, indicating that past dredging did not cause a significant problem (Georgia Ports Authority 1998). The majority of high readings came from bottom water, including the highest measurement recorded, 1,066 mg/L. None of the surface water measurements within 3 feet from the surface were above 100 mg/L.

Worst case scenarios (based on the highest percentage of fine sediments in the channel) projected for the proposed deepening indicate sediment plumes will likely be in excess of 1,000 mg/L and extend outward from the entrance channel as far as 1,000 feet from the discharge point (Georgia Ports Authority 1998). Although there are currently no federal[77] or state standards for total suspended solids, levels > 1,000 mg/L have been shown to have adverse effects on aquatic organisms, especially filter feeders and the juveniles, eggs, and larvae of fish species (LaSalle et al. 1991 as reported in Georgia Ports Authority 1998).

Another concern related to resuspension and dredging is the potential effect of releasing hazardous/toxic materials from the sediments back into the water. As described in Section B.1.b., sediment in parts of the Savannah River have heavy metals and organic contaminants (i.e. PCBs). However, sediment toxicity tests conducted in the area have been negative.

C.3.a.iii. Effects on Salinity -

[77] There are federal turbidity standrds, set at 50 NTUs, a different unit of measurement than total suspended solids.

One of the concerns associated with the proposed deepening is increased upstream intrusion of salt water, which could have an adverse affect on the habitat of estuarine organisms. In particular, there is concern that upstream encroachment of saline water could reduce populations of some fish species (like striped bass and shortnose sturgeon) and reduce the amount of freshwater wetlands. In the 1998 EIS (Georgia Ports Authority 1998), upstream shifts in the predicted high tide surface water salinities along the 0.5 ppt-contour line were chosen to evaluate the effects of deepening on tidal freshwater wetlands because high tide is when they are most likely to be flooded. Upstream shifts in the predicted bottom water salinities along 0.5, 1.0, 2.0, and 5.0 ppt-contour lines were chosen to evaluate effects on fish, as these are the maximum salinities they are likely to encounter. All predictions were made under 3 flow scenarios: spawning season flow (11,000 cfs at the USGS gage at Clyo), low growing season (summer) average flow (8,200 cfs), and critical low flow conditions (lowest mean annual flow recorded at Clyo; 5,500 cfs). *All predictions indicate that deepening will increase upstream salinities in the Front, Middle, Back, and Little Back Rivers, regardless of the flow condition.* The 0.5 ppt surface water contour is predicted to move a minimum of 1 and 0.5 miles upstream from its current location in the Front and Middle Rivers, respectively[78]. The 0.5 ppt bottom water contour is predicted to move a minimum of 2.3 and 0.8 miles upstream from its current location in the Front and Middle Rivers, respectively[79]. Shifts for the 1.0, 2.0, and 5.0 ppt contour lines follow a similar pattern. Although all of these effects are upstream of Fort Pulaski (the model predicts that the deepening will have the greatest affect on salinities in river reaches above RM 18), they would likely affect fauna shared by the two locations, especially with regard to waterfowl and anadromous fish populations.

An "avoidance option" developed as a potential way to mitigate salinity impacts caused by the proposed deepening was also evaluated. Under this option, the Middle River would be closed off from the Front River and New Cut would be reopened to establish better water circulation and reduce salinity intrusion in the closed off areas, identified as critical habitat for the freshwater wetlands and striped bass. With the opening of New Cut, the 0.5 ppt-surface salinity contour line moves downstream from its current location under all 3 flow scenarios in the Middle and Back Rivers. In the Front River, the contour moves upstream under the high (11,000 cfs) flow scenario[80], but further downstream under the 2 lower flow scenarios than deepening alone.

C.3.a.iv. Effects on Dissolved Oxygen -

Potential changes in DO concentrations were predicted in the 1998 EIS for three different flow conditions under the maximum (50 ft depth) Harbor deepening scenario (Georgia Ports Authority

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[78] Under the 11,000, 8,500, and 5,300 cfs flow scenarios in the Front River, the 0.5 ppt contour line is expected to move from RM 20.3 to RM 22.5, from RM 23 to RM 24, and from RM 25 to RM 26, respectively. Under the same flow scenarios in the Middle River, the 0.5 ppt contour line is expected to move from RM 21.5 to 23, from RM 23 to 24, and from RM 24.5 to RM25, respectively.

[79] Under the 11,000, 8,500, and 5,300 cfs flow scenarios in the Front River, the 0.5 ppt contour line is expected to move from RM 20.7 to RM 23, from RM 21.5 to RM 24, and from RM 22.7 to RM 25, respectively. Under the same flow scenarios in the Middle River, the 0.5 ppt contour line is expected to move from RM 21.5 to 22.3, from RM 21.7 to 23.2, and from RM 24 to RM 25.3, respectively.

[80] Although the median 0.5 ppt contour line moves downriver of the current location, the 90^{th} percentile 0.5 ppt contour line moves further upstream.

1998). DO in the Front River was predicted to decrease from current conditions by a maximum of 0.9, 0.5, and 0.1 mg L^{-1} [81] 50% of the time, in the 9,500, 8,200, and 4,000 cfs flow scenarios, respectively. This is of concern, since DO levels in some areas are already below GA-WQ standards. Moreover, the affected area includes Kings Island Turning Basin, which has implications for the recovery of shortnose sturgeon (See below). In contrast, predicted effects to the Middle, Little, and Little Back River varied from no to a slight change (~0.2 mg L^{-1} maximum increase or decrease) without any increase in exceedances. Although stations surrounding Fort Pulaski were not included in the model, no adverse changes in DO are expected based on results predicted for the most downstream station (GPA-04, RM 10) located at Fort Jackson, which actually improved with the proposed deepening (Georgia Ports Authority 1998).

C.3.a.v. Effects on Wetlands -

Potential freshwater wetland losses associated with upstream changes in salinity were estimated to be 722 acres under the 8,200 cfs flow scenario (based on the 0.5-ppt contour line). Potential loss of freshwater wetlands using the "avoidance option" (described above) was estimated at 361 acres under the 8,200 cfs flow scenario, which is less than half that estimated without it.

In addition to the potential conversion of tidal freshwater wetland, an estimated 40.21 acres of wetlands will be lost due to direct impacts of the proposed deepening project. Harbor modifications such as construction of a debris disposal ramp (accounting for ~0.05 ac. of wetland loss, Onslow Island), the closure of Middle River (~1-5 ac.), and the reopening of New Cut (~20 ac.) will result in wetlands being dredged and/or filled. In addition, 3 of 12 areas where the river will be widened to reduce bending will result in the direct loss of previously unimpacted wetlands (~5.21 ac., *see* Figure 4-15 of Georgia Ports Authority 1998). These areas are located upstream of Fort Pulaski, along Hutchinson Island.

Another, more subtle effect on wetlands will result from the fact that the deepening will affect inundation times. The hydrodynamic model predicts that with deepening, the water surface at low tide will be significantly higher (nearly 0.03 m) from Fort Pulaski to the I-95 Bridge. (No change in water level during high tide is predicted.) Increased low tide water levels could potentially affect wetlands since they will stay inundated for longer. Higher water levels (along with higher salinities) following the installation of the tide gate could have been partially responsible for the death of trees in freshwater wetlands near Ursla Island (located above RM 23 in the Front River, Georgia Ports Authority 1998).

C.3.a.vi. Effects on Fish -

Shortnose Sturgeon - Deepening of the Harbor may affect recovery of the shortnose sturgeon population directly by increasing salinity and decreasing dissolved oxygen and/or indirectly by affecting their benthic food source. Benthic losses at dredging sites are not expected to exceed regular routine maintenance operations in the Savannah River, and thus may not affect the sturgeon food supply any differently than usual dredging activity. It was even suggested in the *1998 EIS* that removal of a thicker layer may affect benthic communities less than maintenance

[81] Each of these maximum DO decreases occurred at RM 20.5. For the 90th percentile, maximum DO decreases occur further downstream, at RM 16.6 (0.9, 1.0, 0.5 mg L^{-1}).

operations, which disturb more surface sediments where food resources are located. Greater benthic losses are expected at the offshore disposal site (the Savannah ODMDS), where sturgeon are not located (Georgia Ports Authority 1998).

Sturgeon in the Savannah River have been located in a range of salinities, from 0 to 22 ppt. However laboratory studies show that significant mortality (all ages) occurs when they are exposed to salinities ≥ 9 for long periods of time, and salinities > 5 can be lethal to juveniles (Georgia Ports Authority 1998). The threshold for dissolved oxygen has been estimated at about 3.5 mg L^{-1}; below this level significant juvenile and young adult mortality has been documented. It is unclear how temperature, salinity, and dissolved oxygen concentrations interact to affect sturgeon viability, but it has been noted that salinity and dissolved oxygen tolerances are decreased at temperatures above 82ºF, which is commonly exceeded during July and August in the Savannah River (Georgia Ports Authority 1998).

In order to address the question of how combined changes in salinity and dissolved oxygen might affect shortnose sturgeon, the hydrodynamic model was run to evaluate how changes in depth (up to 50 ft) would affect habitat conditions under different flow scenarios. Criteria used to evaluate suitable habitat were as follows: dissolved oxygen >3.5 mg L^{-1}, salinity range 0-8, and location range RM 17.5-26.6. Under existing conditions (at 8,200 cfs), salinity in the turning basin is ≤ 12.5 ppt 90% of the time and the dissolved oxygen criterion (i.e. >3.5 mg L^{-1}) is met 63% of the time. Upstream stations (>RM 20.5) meet salinity and dissolved oxygen criteria 100% of the time (Georgia Ports Authority 1998). Following deepening, the model predicts that salinity at the turning basin will be ≤ 16.5 ppt 90% of the time[82], which is 4 ppt higher than existing conditions and well above the estimated juvenile and young fish threshold of 9 ppt. In addition, dissolved oxygen concentrations are predicted to decrease by ≤ 0.9-1.0 mg L^{-1} 90% of the time in KITB following deepening, meaning that it will only meet suggested criteria of 3.5 mg L^{-1} 50% of the time (Georgia Ports Authority 1998). Stations just upstream may also experience an increase in salinity and a decrease in oxygen (at RM 21.7). Not enough is known about the environmental tolerances of shortnose sturgeon in the southeast to determine how these alterations might translate into a change in population density.

Striped Bass **–** The hydrodynamic model found that at a flow of 8,200 cfs, the salinity in portions of the Back River exceed spawning tolerances of striped bass (i.e. >>1.5 ppt) and the lower portion of the Front River, where >85% of spawning is said to occur, will approach maximum optimal spawning salinity (i.e. >1.0 ppt). Under critically low-flow conditions (4,000-5,000 cfs), 100% egg mortality of striped bass would be expected to occur in all spawning areas.

Reinert (2004) used life history and Savannah River Estuary salinity data to model effects on striped bass recruitment potential with a shift in salinity predicted with the Harbor deepening. He found that a 1.67 km (~1 mi) salinity shift upstream would result in a 6% decrease in the current recruitment potential, a 3.33 km (~2.1 mi) shift would result in ≥ 20% decrease, and an 8.33 km (~5.2 mi.) shift would result in a 25% decrease. According to Reinert (2004), a 20% decrease in recruitment potential could be detrimental to the recovery of striped bass due to fewer sexually mature adults and fewer eggs. Furthermore, because little is currently known

[82] Predicted salinities are ≤ 22.6 ppt at RM 16.6, ≤ 16.5 ppt at KITB, ≤ 7.1 ppt at RM 21.7, and ≤ 0.6 ppt at RM 24.4, 90% of the time.

about the striped bass population that exists now (i.e. total population, age distribution, number of sexually mature adults), it is recommended that little (i.e. ~1 mi. shift, max.) to no upstream shift would be best to ensure future sustainability of the population. Deepening the Harbor to the maximum depth (50 ft) would result in a salinity shift around 2.3 mi. in the Front River and 0.8 mi. in the Back River could be expected (under all flows, see section *C.3.a.iii.*) (Georgia Ports Authority 1998). Although salinity shifts were not predicted for other depths, it is likely that any deepening will result in a salinity shift and have some effect on the recovery of striped bass.

C.3.b. Other Anthropogenic Alterations

As described in section **A.1c.**, Georgia's population is growing rapidly and the coast is no exception. Effingham County is especially of concern as its population has increased dramatically in the last 10 years, and the Savannah River basin itself must be able to support a projected 400,000 (+60%) more people over the next 50 years. In addition to deepening the Savannah Harbor, several major land use changes have been proposed for the area. Hwy 80, which connects Savannah to the Tybee Island resort area, is projected for widening to support increased commuter and tourist traffic. In Jasper County, development of a new port is being considered, which could potentially alter its current rural status and small population growth rate. Population and land use changes may have implications for boating/shipping traffic and marine debris.

C.3.b.i. Widening of Hwy 80 -

The Georgia Department of Transportation has proposed to widen (from 2-3 to 4 lanes) and elevate the 5.77-mile long portion of Hwy 80 that runs through McQueen's Island from the Bull River Bridge to the Lazaretto Creek Bridge (Georgia DOT 2005). The project start-date has been pushed back several times, and is currently scheduled for sometime before 2009. Widening the highway might potentially affect the adjacent salt marsh by altering the natural hydrology and/or increasing runoff of nutrients and hydrocarbons (by increasing the amount of impervious surface) (Holland et al. 2004; DeVivo et al. 2005). In addition, the park has expressed concern about the effects that widening might have on animal migrations, especially diamondback terrapins(DeVivo et al. 2005) .

C.3.b.ii. Proposed Container Port (Jasper County) -

A private company that runs cargo terminals worldwide, (Stevedoring Services of America, based out of Seattle, WA) recently proposed to finance and run a new container port in the Savannah River at Hardeeville, SC (Jasper Co)[83] (*see* **Appendix J**). If built, the port would be 10 miles closer to the ocean than the Port of Savannah's Garden City terminal, and thus would be more convenient and more cost-effective (in terms of the amount of fuel spent) for shipping companies (Chapman 2004). Although the controversial proposal has been challenged in court, Jasper County is continuing to move forward with the project (Kreuzwieser 2004). Water quality and physical effects associated with port development (dredging, channel maintenance, deepening, etc) were discussed in section *C.3.a.*

C.3.b.iii. Increased Boat Traffic -

Container traffic within Savannah Harbor increased by 20% during 1991-1995 and recent trends suggest traffic is still increasing (Georgia Ports Authority 2002b). A study conducted in Florida and South Carolina found that even smaller recreational boats negatively affected the shoreline by disturbing oyster reefs (dispersal of shells, shell damage of newer recruits), although this effect was mitigated when boats maximized their distance from the shoreline (Walters et al. 2004). Although little recreational boating activity occurs within the shipping channel due to vessel traffic (Georgia Ports Authority 1998), the boat wakes generated from larger vessels would likely be greater and cause greater damage to the shoreline. If the Harbor is deepened, one might expect even greater vessel traffic, with even larger ships.

C.3.b.iv. Marine Debris -

Marine debris has the potential to cause injury to marine organisms, poses a human health hazard, and is aesthetically displeasing (The Ocean Conservancy 2004). At least one study examined the accumulation of marine debris washed up (plastic, Styrofoam, glass, rubber, metal, rope, paper, medical waste) in the Fort Pulaski study area[84] (Gilligan et al. 1992). The study consisted of a total of 4 sites in Chatham County, 2 were located on Fort Pulaski NM (one on Cockspur along the North Channel and one on McQueen's Island at the junction of Lazaretto Creek and the South Channel). Results indicated that the site located on Cockspur Island accumulated the most marine debris (119 g/km); glass made up the largest portion by weight. Over all sites, plastics, styrofoam, and metal (aluminum cans, in particular) composed the largest percentage of items collected; no medical wastes were found. The rate of marine debris washed up in Chatham County was estimated at 102 kg/km/yr[85], which ranked it 10th of 22 coastal states

[83] Stevedoring Services of America has offered to spend as much as $750 million on the building the port, port facilities, roads, and warehouses.
[84] This study was initiated by the 1988 *Beachsweep* results, which found Georgia to have the most serious marine debris problem in the nation. However, these collections had taken place on previously uncleaned beaches and debris had been weighed while still containing sand and water, thus overestimating the amount of debris on Georgia's beaches.
[85] Extrapolating this rate to total shoreline between high and low tide (about 400 km), an estimated 40.8 tons of marine debris washes up on the Chatham County shoreline annually.

in comparison to 1989 Beach Sweep results (Gilligan et al. 1992). Currently, Tybee Island (Chatham County's major tourist beach) participates in the annual Beach Sweep (data on items collected are reported in the National Marine Monitoring Data[86] and International Coastal Cleanup programs, both of which are headed up by The Ocean Conservancy).

C.4. Coastal Erosion and Shoreline Change

C.4.a. Historic Change

Recent studies conducted by students at Georgia Southern and Savannah State University using GIS aerial imagery have indicated that Fort Pulaski's shoreline is changing (Alexander et al. 2004). From 1982 to 2000 (28 years) the armored portion (oyster bar) of Cockspur Island along the North Channel has accreted at a rate of 0.5 m/yr, while the unarmored portions have eroded at 0.1 m/yr. In addition, the oyster bar along the North Channel has grown a total of 288 meters (a rate of 10-28 m/yr) westward over the last 28 years, and has migrated onshore at a rate of 4.4 m/yr. It is unclear whether past Harbor expansion projects or natural processes have caused this shoreline change, thus Alexander et al. (2004) have proposed to evaluate shoreline change over a longer period of time (1850-2004). They will also evaluate potential effects on natural and cultural resources of the park. For example, historic changes in the oyster bar probably affected water flow patterns and may well have altered inundation patterns in the tidal marsh areas located directly behind the bar, thereby affecting both water quality and habitat. It is also unclear how future Harbor expansion activities will interact with these processes.

C.4.b. Future Change

Water level is measured by NOAA's National Ocean Services (NOS) at Fort Pulaski. Trends there suggest that sea level is currently rising at a rate of 13 inches (~0.33 m) per century, but it is expected to rise by 25 in. (~0.6 m) over the next century (year 2100) (U.S. EPA 1997). These changes in sea level could disrupt ecological services (nutrient recycling, sedimentation, primary/secondary productivity, etc) provided by wetlands due to changes in hydrology and physical structure, biogeochemistry, vegetation, and animal populations (Michener et al. 1997). In addition, Georgia is expected to experience a predicted increase in temperatures by as much as 4 F (~2 C; fall) and in precipitation by as much as 40% (summer/fall) (U.S. EPA 1997). This has large implications for Georgia's vast salt marsh and barrier island system since it could lead to loss of wetlands and beach erosion.

[86] Data is available online at www.oceanconservancy.org/, follow link *Issues*, then *Marine Debris*. It was unavailable during the time this report was being written.

D. Summary and Recommendations

D.1. Condition overview

Table 23. Potential for impairment of Fort Pulaski water resources.

Indicator	Savannah River Estuary	FOPU Estuary frontage	FOPU Tidal creeks	FOPU Fresh water	Ground water
Water Quality					
Nutrients	ND	EP	EP	PP	OK
Fecal bacteria	EP	OK	OK	ND	ND
Dissolved oxygen	EP	PP	PP	PP	NA
Metals	EP	EP	EP	ND	OK
Toxic contaminants	PP	EP	EP	NA	OK
Salinity effects	EP	OK	OK	NA	EP
Population Effects					
Fish/shellfish harvest	PP	PP	OK	NA	NA
Invasive species	PP	PP	ND	ND	NA
Habitat disruption	EP	EP	OK	OK	NA

Definitions: OK – low or no problem, NA – not applicable, ND – insufficient data to make judgment, PP – potential problem, EP – existing problem

The table above summarizes our best professional judgment regarding the potential for impairment of the water resources in and around Fort Pulaski National Monument as evidenced by the various listed indicators. Below we briefly describe the rationale for making these assignments:

<u>Savannah River Estuary</u> –The data summarized in this report identified several problems in the Savannah River Estuary, many of which are due to the extensive modifications of the Harbor coupled with the industries located in the area. We have listed dissolved oxygen as a problem based on observations in the Harbor. Salinity effects and habitat disruption have both occurred in the past due to Harbor modifications, and there is concern that these factors (as well as dissolved oxygen) will be further affected if the Harbor is again deepened. Metals were listed as a problem due to observations of elevated concentrations of arsenic, copper, chromium and cadmium in Harbor sediments. Although observations of organic contaminants were low in the studies done for the EIS, we have listed toxic compounds as a potential problem due to the proximity of both dredge spoils and Superfund sites, both of which have associated contaminants. In addition, there are reports of elevated concentrations of mercury and PCBs in fish tissue in samples collected from the lower Savannah River basin. Fecal coliform was identified as a problem in the upstream portion of the estuary due to observations in the Horizon report (64% of samples exceeded the bathing water criteria of 200 CFU/ml in upstream areas). More recent sampling by USGS also yielded increased concentrations in upstream areas of the

estuary. Although there are no specific reports of introduced species in the estuary, ballast water from ships is a common source of invasive species and so we have listed this as a potential problem.

FOPU Estuary Frontage – The area of the channel that directly borders FOPU is dredged regularly and will be directly affected if the Harbor is again deepened. Although salinity in this area is not expected to change, habitat destruction was listed as a potential problem due to the erosional effects of boat traffic and dredging in the area. Neither the EMAP nor the NCA analyses from sites near Fort Pulaski yielded any metal concentrations that exceeded standards, but we have listed this as a problem based on elevated concentrations of arsenic in both sediment and animal tissue (shrimp and oysters). Similarly, observations of increased concentrations of organic contaminants have also been reported: Loganathan et al. (2001) measured increased concentrations of DDT in sediment and PCBs in fish tissue. These contaminants were low in sediment sampled by the EMAP/NCA stations, but they did report slightly elevated PAH concentrations in shrimp tissue. There is also a dredge spoil site directly across from the Park, which represents a potential source of contaminants. Although tidal mixing helps to maintain reasonably high dissolved oxygen concentrations in the vicinity of Fort Pulaski, it is identified as a potential problem because of evidence for coast-wide decreases in dissolved oxygen that is likely caused by increased nutrient loading to the area. NCA and USGS nutrient analyses yielded numerous observations classified as fair or poor, particularly in terms of phosphate, so this was classified as a moderate problem. These observations were extremely limited, but they suggest a potential problem. Fecal coliform observations in the channel adjacent to Fort Pulaski, although infrequently sampled, tend to be lower than those further upstream and are not considered a problem. Fish and invasive species are identified as potential problems for the same reasons described above for the estuary in general.

FOPU Tidal Creeks - Tidal creeks were included in the NCA studies described above and so were classified similarly in terms of nutrients. Fecal coliform bacterial concentrations in Oyster Creek are generally low, and shellfishing is permitted in the area. Tidal creeks were classified similarly to estuary frontage in terms of dissolved oxygen, metals, and contaminants, for similar reasons. However, Richardson and Sajwan (2001, 2002) reported elevated concentrations of arsenic in both sediment and oyster tissues sampled directly in the Park.

FOPU Freshwater – The freshwater resources at FOPU are limited to the moat that surrounds the fort itself and two small mosquito ponds. There is very limited data on these small areas, but we have listed nutrients as a potential problem based on observations of algal blooms in the moat. Likewise, dissolved oxygen is identified as a potential problem because fish kills have been observed periodically.

Groundwater – Groundwater quality is monitored as part of the Georgia Groundwater Monitoring Network. In the two wells closest to the study area (Tybee and Thunderbolt), there are no reports of elevated levels of metals or volatile organic compounds, and nitrate and nitrite were also below detection limits (Donahue 2004). Saltwater intrusion into the Floridan aquifer represents a serious problem in the Savannah area, and for this reason salinity is identified as a high problem. The 6-year Sound Science Initiative being conducted by the Georgia Environmental Protection Division is almost complete, but it is unclear at this time whether additional groundwater withdrawals will be permitted in the region and how this will affect Fort Pulaski. In addition, there is also a concern that future dredging from the Savannah Harbor Expansion Project could breach the aquifer.

D.2. Recommendations

In writing this report we have encountered numerous data gaps as well as identified situations where additional and/or continuing observations would be useful to have to better evaluate the water resources of Fort Pulaski. These are summarized in **Table 24** and then expanded upon in some detail below. We recognize that many of these are beyond the jurisdiction of the National Park Service, but they are included below in order to provide a complete record of the types of information that would be helpful for future evaluations.

Table 24. Recommendations.

1. Work towards improved regional cooperation
2. Initiate regular water quality monitoring at FOPU
3. Collect additional water quality information
4. Perform additional plant and animal surveys
5. Identify sentinel organisms
6. Set up targeted monitoring for Harbor expansion and other modifications
7. Assess water movement, in terms of both upstream influence and downstream drainage
8. Improve access to state and federal water quality data and improved metadata

1. Work towards improved regional cooperation

One of the challenges of managing an area like the Savannah River comes from the fact that it cuts across jurisdictional areas. At times, the information we gathered reflected a lack of coordination between sampling programs in Georgia and South Carolina and could not be directly compared. At other times, neither State was monitoring the area. For example, there are no regular water quality stations from either State in the main channel adjacent to FOPU and only limited sampling by Georgia in the tidal creeks (the area averages 2-4 stations per year as part of the NCA program). Regional cooperation to choose stations and use consistent protocols would be beneficial to both states and would provide a better picture of the water quality/health of the Lower Savannah River. In this regard, it would also be useful to work with other programs (i.e. sampling for the Georgia Ports Authority) to avoid overlap and/or fill in station or data gaps and use consistent analytical methods.

Given that upstream decisions and continued alterations in the watershed are likely to have a direct effect on the water resources of Fort Pulaski, there is also a need to take a watershed-scale approach to management. Towards this end, the Park Service should strongly consider providing additional representation at regional-scale projects related to the Savannah River. For example, the Georgia Ports Authority, the Army Corps of Engineers and The Nature Conservancy, US Fish and Wildlife Service and other groups are all active in the area[87].

2. Initiate regular water quality monitoring at FOPU

It would be useful to have water quality data that directly applies to the Park. Ideally, stations would span water resources to include tidal creeks as well as the major channels adjacent to FOPU (both the South and North Channels) and be sampled on a year-round basis. For this report, we had to pull information from various programs, none of which were complete and/or provided adequate temporal or spatial coverage. The NCA program provides fairly complete information about its sites, but it only samples stations once (during the summer), and only 2-4 different stations each year were located in the study area. The GA-CRD shellfish stations are sampled monthly for both fecal coliform and nutrients, but only 4 of their stations are located in the Park, and all are within one tidal creek. Rather than set up an independent monitoring program, the Park should explore the potential of partnering with CRD or the South Carolina Dept. of Health and Environmental Control to add additional regular sampling stations at Fort Pulaski to their existing monitoring programs. That way, the data would be consistently sampled and processed with information collected in the rest of the region. This type of data would be useful for NPS to have in order to be able to link water quality directly back to Park resources.

3. Collect additional water quality information

There are several pieces of water quality information not being collected under existing program, which should also be considered.

<u>Dissolved oxygen</u> - The low dissolved oxygen concentrations observed upstream of Fort Pulaski are potentially the largest water quality problem identified in this report (*see* **section B.1.b**). Although dissolved oxygen concentrations are not as low near the Park, it is important to monitor, particularly given reports that DO is decreasing in Georgia's coastal water (Verity et al., submitted). These measurements are particularly critical during summer when concentrations generally reach their minima. It would be very useful to do some diel measurements of oxygen as well, and to take measurements in both surface and bottom water. If there were an indication of a real problem, it would be important to tie this information to observations of the distribution of organisms: are nekton leaving the area? are low oxygen concentrations affecting benthic organisms?

<u>Nutrients</u> – Current measurements of nutrients are mostly confined to dissolved inorganic nitrogen and phosphorus, which represent a small portion of the total. It would therefore be useful to have measures of total nitrogen and phosphorus (or at least total dissolved N and P) in order to have a better measure of total nutrient concentrations. If possible, it might also be useful

[87] In addition to the activities of stakeholder groups associated with the Savannah Harbor Expansion Project, the Army Corps of Engineers is currently doing a comprehensive study of the Savannah River Basin to evaluate the operation of the Dam in Augusta. As part of this, they are working with The Nature Conservancy to develop ecosystem flow requirements for the River and have begun releasing experimental pulses of water in the spring (www.freshwaters.org).

to add dissolved organic nitrogen (DON) to these observations. DON generally comprises 80% or more of total dissolved nitrogen, and Verity found that DON concentrations have been increasing at a faster rate than inorganic nitrogen in the Skidaway River (Verity 2002a; b).

Fecal coliform- Fecal coliform bacteria are not routinely sampled in the channel adjacent to Fort Pulaski, and within the tidal creeks of the Park itself they are only sampled in one channel (Oyster Creek). The observations compiled for this report do not indicate a problem and so this is probably a low priority, but it might be useful to collect additional samples in and around the Park to provide a complete picture of water quality.

Chlorophyll – Chlorophyll was measured as part of several programs, including NCA, but it is not part of the routine nutrient monitoring conducted by GA-CRD. We suggest adding this to any FOPU monitoring as this is a response variable that gives information on the effects of increasing nutrients. Moreover, many States have chlorophyll a standards.

Suspended Sediment – One of the concerns associated with the Port Deepening is the potential increase in the concentration of suspended sediment in the area. Monitoring water clarity as total suspended sediment would be most useful because organic matter tends to color the river water dark (which would interfere with a Secchi disk or nephelometer reading). In addition to the potential problems associated with high suspended sediment concentrations (reducing light; interfering with filter feeders), many metals and organic contaminants are also particle-associated.

Metals and pollutants –The limited observations of contaminant concentrations that we located for this report present an equivocal picture, and point towards a need for additional sampling at Fort Pulaski. Richardson and Sajwan (2001, 2002) reported elevated contaminants (PAHs, arsenic) in sediment and oysters at the Park; Loganathan (2001) reported elevated concentrations of DDT in sediment and PCBs in fish tissue; and numerous metals (chromium, copper, arsenic, cadmium, nickel, mercury, zinc, manganese, and molybdenum) have been detected in sediments associated with dredge disposal sites in close proximity to the area (Winger et al. 2000). In contrast, metals and PAHs measured in the vicinity of the Park for the EIS were either not considered high enough to cause adverse benthic effects or had low bioaccumulation potential, and neither the EMAP or NCA observations pointed to any problems. Both organisms and sediment should be tested for the compounds that have been reported. Sediment toxicity tests would also be helpful. It might also be useful to test for emerging pollutants such as pharmaceuticals and hormones.

Radionuclides – Radionuclides (Cobalt-60, Strontium-90, Cesium-137, Plutonium-238, and Plutonium-239) were found at elevated levels in sediment and Iodine-129 and tritium were found at elevated levels in surface water near the Savannah River Site. Although this is upstream of Fort Pulaski, it would be useful for testing to be done at the Park periodically, especially since tritium will be produced again in 2006 at the Savannah River Site.

4. Perform additional plant and animal surveys

Although species lists are available for much of Fort Pulaski, the marine areas associated with the Park have not been well-covered by past inventories. In addition, the emphasis of previous faunal surveys was placed on vertebrates. It would therefore be useful to survey intertidal areas in terms of their flora and fauna (both vertebrate and invertebrate). Inventories of marine habitats might also involve systematic sampling for invasive species, such as the green mussel and the green porcelain crab, both of which are likely in the area. It would also be appropriate to do some baseline sampling of Fort Pulaski's marshes and to maintain a continued awareness of their status in light of the recent marsh dieback that has affected coastal Georgia. In terms of other areas of the Park, it would be useful to characterize both the flora and fauna associated with the shell mounds and spoil sites, as these areas are associated with plant species of concern (Florida privet (*Forestiera segregata*) and swamp dock (*Rumex verticillatus*)) and the endangered Least Tern (*Sterna antillarum*). In addition, the two small freshwater ponds are not characterized, although they are man-made and probably a lower priority.

Another aspect of this recommendation would be to keep track of recreational shellfishing activity in Oyster Creek. This would allow the Park to develop baseline information regarding resource use. Specific information on the condition of fisheries and fish resources in the area would also be useful, although this type of data is difficult to get.

5. Identify sentinel organisms

It is often difficult to connect water quality observations with resource effects. One possibility is to select sentinel organisms in different habitat types that could act as indicators of degrading water quality. For example, studies in tidal creeks in South Carolina have shown that the abundance of penaid shrimp in tidal creeks decreases as the amount of impervious surface in the surrounding watershed increases (Sanger and Holland 2002).

6. Set up targeted monitoring for Harbor deepening and other modifications

Deepening of the Harbor is expected to affect many different aspects of the Savannah River. Of particular importance for the Fort Pulaski area is the possibility that dredging will affect water flow in the area near the Park with consequent effects in terms of shoreline erosion and sedimentation. It would be extremely valuable for the Park to collect baseline data on water flow and drainage patterns, shoreline configuration, and the utilization of the area by fish and other fauna prior to additional dredging. Although water quality effects (i.e. salinity, dissolved oxygen) are less likely to be apparent adjacent to the Park as in upstream areas, it would still be useful to establish several water quality stations in the channel adjacent to the Park. In addition to measuring nutrients and other standard water quality parameters, measurements of total suspended sediment (described in Recommendation #3, above) would be useful. Stations should be established in both the North Channel, where the deepening will occur, as well as the South Channel, since an expected reduction in ebb tidal flow likely affect the movement of sediment in the area (Georgia Ports Authority 1998). If possible, sampling at these stations should occur in both surface and bottom water.

A similar approach could be used for additional changes (i.e. the proposed port facility in Jasper County; widening of Hwy 80). In all of these cases, it would be useful for wetland habitat and fauna to be regularly monitored. For example, widening Hwy 80 could potentially disrupt animal migrations (such as turtles) at the Park (DeVivo et al. 2005).

7. Assess water movement, in terms of both upstream influence and downstream drainage

For this report, we assumed that pollutant sources located in the watershed of the Lower Savannah River had the potential to influence Fort Pulaski. However, portions of McQueen's Island fall into the watershed of the Ogeechee River. Although we also included the relevant HUC in our analysis, we excluded pollutant sources in the Ogeechee that were located downstream of the Park, as we assumed that they were unlikely to affect the area. However, it would be useful to have a better understanding of flow patterns in both watersheds. As part of this, information on the inflow of saltwater from the ocean would also be required, as well as the potential hydrologic connections between the Savannah and Ogeechee Rivers via marshes and tidal creeks. Without this type of information it is difficult to evaluate whether different far-field sources of pollutants actually reach the Park area. This is particularly important when assessing the potential influence of industrial pollutant sources and/or continued development in the region.

Along these same lines, it is important to understand how long water spends in the area, as this is a measure of the vulnerability of the area to pollutant exposure. There is no easy way to do this without additional hydrologic information regarding water flow in the area (i.e. through dye studies). However, it would be possible to perform targeted studies to estimate turnover times in specific areas of concern.

8. Improve access to state and federal water quality data and improved metadata

The process of compiling data for this report was often difficult, either because the information was not readily available or because there was not enough documentation provided. Both federal and state information on pollutants and impairments have inaccuracies and omissions with regard to location, making it difficult to construct a complete picture of either point source discharges or impaired waters. Below we provide specific suggestions for improving the different data sources we utilized. It would also be useful to have the various programs cross-referenced, as there is overlap in the types of information covered by each one.

<u>StoRet</u> - To the extent possible, all water quality data should be submitted to EPA StoRet. At present NCA is the only program currently submitting coastal Georgia data, and this information is not yet accessible in the database. The latest data currently available on-line for the study area is from December 1999.

<u>National Pollutant Discharge Elimination System (NPDES)</u> - It was not possible to determine the locations of all of the NPDES discharge point sources because some permits listed in the database have no location information associated with them and some contain errors about the county/watershed in which they are located. For example, Wilshire/Windsor WPCP, one of the

largest dischargers in the Savannah River, was incorrectly identified as discharging into the Vernon River and was not listed under Chatham County. In addition, several large permitees do not have discharge rates listed within the database (i.e. Savannah Electric Co. in Effingham, 108 mgd). Lastly, few of the permittees were classified as "major" or "minor", which would be useful, especially in terms of industrial dischargers (since this classification is based on the nature of the chemicals discharged).

Impaired waters - The 303(d) and 305(b) lists of impaired streams required under the Clean Water Act would be more useful if the database were modified. At present, the data maps to an entire water body because the different stream segments have not been separated out. For example, "Savannah Harbor" is listed as an impaired water body, but impairments were observed in the section from "SR 25 (Old US Hwy 17) to Elba Island Cut" and it is really only this section that should be flagged. A similar problem exists in the Georgia River Basin Management Plans, where it is not always clear how many stream segments were evaluated when classifying the area. The extent (and identification) of evaluated segments should accompany the list of segments not fully supporting designated uses. In addition, all of the violations within a given stream segment are listed as a single attribute (in this case, "FC, DO"), making it difficult to query the database to find all of the segments with violations based on a particular violation (i.e. “FC” is currently different from “FC, DO”). There are also no units associated with the "extent" attribute and this could be included in the name (e.g.: “Extent_miles”).

U.S. EPA Envirofacts - Location information is not consistent throughout the Envirofacts database: sometimes the location refers to the parent company (rather than the point source) and sometimes it is missing. HUCs are not consistently listed and spatial information is sometimes lacking entirely. It would be more useful if the information were searchable by county names. Relevant municipalities should also be listed.

Superfund and Hazardous Sites - It would be useful to provide contaminant information on superfund sites listed under the Comprehensive Environmental Response, Compensation, and Liability Act database (i.e. why sites are placed on the list). At present, information is only available for sites that are also on the National Priority List. Although contaminants are identified in the Hazardous Site Inventory, there is no information regarding their quantities.

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APPENDICES

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Appendix A – Calculation of land cover in the Fort Pulaski study area.

Although a number of recent projects have studied land cover in the Georgia-South Carolina area, none of the data sets cover the entire Fort Pulaski study area. We therefore used three separate data sets for this project: 1) the 1998 Georgia GAP Analysis land cover set, which covered the northern-most Georgia portion of the study area, 2) the1997 Georgia C-CAP, which covered most Georgia portions of the study area, and 3) the 1995 South Carolina C-CAP land cover set, which covered the South Carolina portion of the study area (NOAA - CSC 1997; 2001) (**Figure A-1**)

In order to obtain one continuous data set which was as consistent as possible, these three data sets were stitched together. For maximum consistency, the Georgia C-CAP data were used where available because it covered most of the project area. Where it was not available in the northern portion of the study area, South Carolina C-CAP data was used (although note that it is 2 y earlier than the Georgia C-CAP data). In the small northern portion of the study area, which is located within the state of Georgia, the Georgia GAP data was used (again, note that it is 1 y later than the Georgia C-CAP data set). The land classification categories for the Georgia GAP project are different than those used for C-CAP, so a crosswalk was performed in order to match up land cover categories in the two data sets. The Georgia GAP data was then reclassified to match the C-CAP categories (**Table A-1**).

Figure A-1. Area of coverage by 3 different land cover data sets.

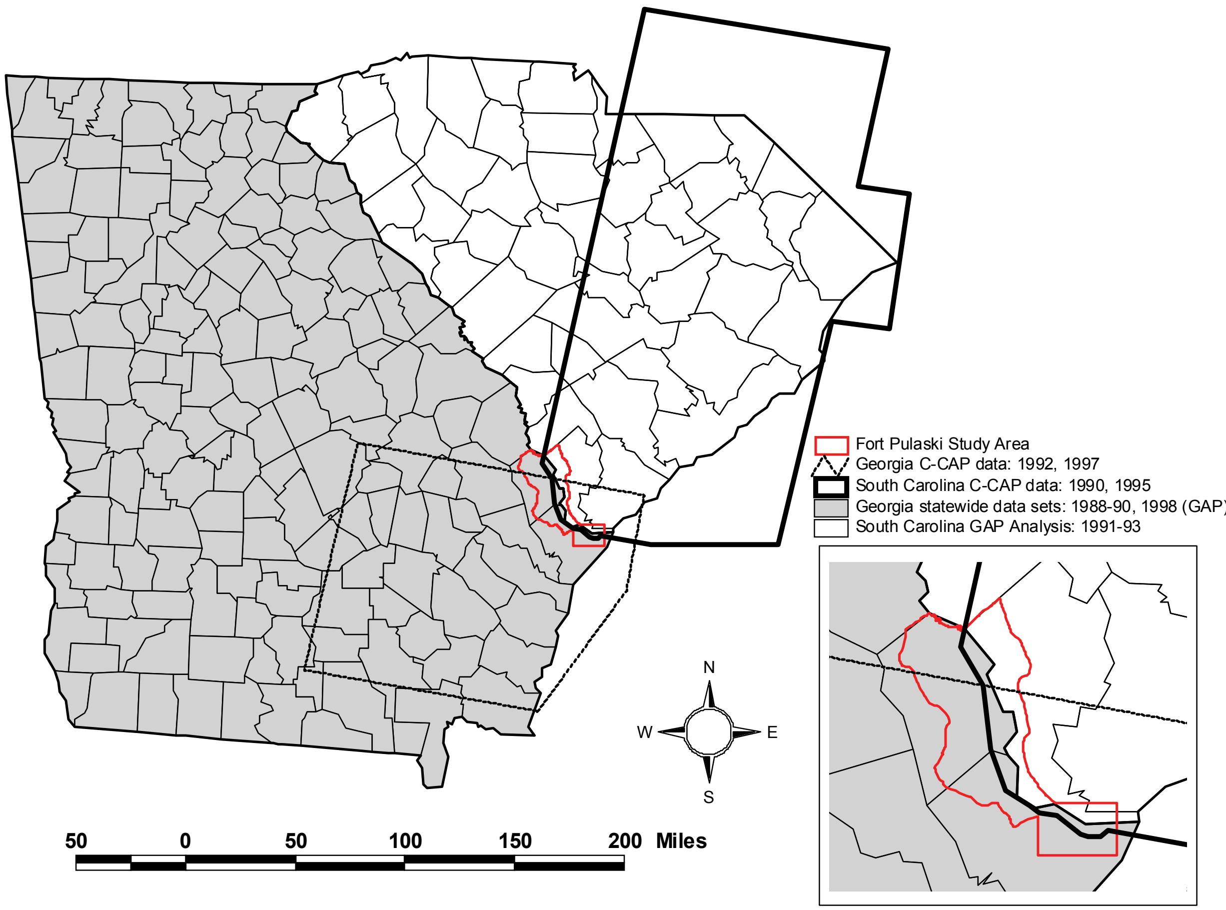


Table A-1. Crosswalk used to reclassify 1998 Georgia GAP data to match South Carolina (1995) and Georgia (1997) C-CAP data.

GEORGIA GAP VALUE	LAND_COVER	CCAP VALUE	LAND_COVER
0	No Data	0	Background
9	Coastal Dune	16	Unconsolidated Shore
11	Open Water	18	Water
18	Transportation	2	High Intensity Developed
20	Utility Swaths	2	High Intensity Developed
22	Low Intensity Urban-Nonforested	3	Low Intensity Developed
24	High Intensity Urban	2	High Intensity Developed
31	Clearcut-Sparse Vegetation	17	Bare Land
33	Quarries, Strip Mines	17	Bare Land
72	Parks, Recreation	5	Grassland
73	Golf Course	5	Grassland
80	Pasture, Hay	4	Cultivated Land
83	Row Crop	4	Cultivated Land
201	Forested Urban-Deciduous	3	Low Intensity Developed
202	Forested Urban-Evergreen	3	Low Intensity Developed
203	Forested Urban-Mixed	3	Low Intensity Developed
412	Hardwood Forest	6	Deciduous Forest
413	Xeric Hardwood	6	Deciduous Forest
420	Live Oak	6	Deciduous Forest
432	Xeric Mixed Pine-Hardwood	8	Mixed Forest
434	Mixed Pine-Hardwood	8	Mixed Forest
441	Loblolly-Slash Pine	7	Evergreen Forest
512	Sandhill	17	Bare Land
513	Coastal Scrub	9	Scrub/Shrub
620	Longleaf Pine	7	Evergreen Forest
890	Cypress-Gum Swamp	10	Palustrine Forested Wetland
900	Bottomland Hardwood	10	Palustrine Forested Wetland
920	Saltmarsh	15	Estuarine Emergent Wetland
930	Freshwater Marsh	12	Palustrine Emergent Wetland
980	Shrub Wetland	11	Palustrine Scrub/Shrub Wetland
990	Evergreen Forested Wetland	10	Palustrine Forested Wetland

Appendix B - Inventories of nektonic and benthic organisms.

Table B-1 - Inventory of nektonic organisms collected by the EPA Environmental Monitoring and Assessment Program.

Organisms were caught in 4.9-m otter trawls with 2.5 cm mesh wings. All stations were located in the lower Savannah River Estuary. The Tybee Roads station (CP95161) was sampled on August 30th 1995, and the South Channel (CP95162) and Bull River (CP95163) stations were sampled on August 29th, 1995. Data source: Hyland et al. 1998.

Station Name	Latin Name	Common Name	**Abundance**
CP95161	*Arius felis*	hardhead catfish	9
	Brevoortia tyrannus	atlantic menhaden	1
	Callinectes sapidus	blue crab	3
	Callinectes similis	crab	20
	Cynoscion regalis	weakfish	2
	Etropus crossotus	fringed flounder	5
	Lagodon rhomboides	pinfish	1
	Larimus fasciatus	banded drum	4
	Leiostomus xanthurus	spot	1
	Ophichthus gomesi	shrimp eel	1
	Paralichthys lethostigma	southern flounder	2
	Penaeus aztecus	brown shrimp	1
	Penaeus setiferus	white shrimp	80
	Prionotus tribulus	bighead searobin	1
	Stellifer lanceolatus	star drum	41
	Symphurus plagiusa	blackcheek tonguefish	8
	Trinectes maculatus	hogchoker	7
CP95162	*Arius felis*	hardhead catfish	1
	Callinectes sapidus	blue crab	2
	Penaeus setiferus	white shrimp	64
	Trinectes maculatus	hogchoker	1
CP95163	*Arius felis*	hardhead catfish	2
	Bagre marinus	gafftopsail catfish	1
	Callinectes sapidus	blue crab	1
	Callinectes similis	crab	5
	Chaetodipterus faber	atlantic spadefish	2
	Cynoscion regalis	weakfish	5
	Etropus crossotus	fringed flounder	2
	Leiostomus xanthurus	spot	1
	Menticirrhus americanus	southern kingfish	2
	Paralichthys lethostigma	southern flounder	1
	Penaeus setiferus	white shrimp	61
	Stellifer lanceolatus	star drum	29
	Symphurus plagiusa	blackcheek tonguefish	6
	Trinectes maculatus	hogchoker	5
Grand Total			**378**

Table B-2 -Inventory of benthic organisms collected by the EPA Environmental Monitoring and Assessment Program.

Organisms were caught using a 0.04 m^2 Young grab sampler. Abundance is mean abundance per 440 cm^2. All stations were located in the lower Savannah River Estuary. The Tybee Roads station (CP95161) was sampled on August 30th 1995, and the South Channel (CP95162) and Bull River (CP95163) stations were sampled on August 29th, 1995. Data source: Hyland et al. 1998.

Latin Name	Total Abundance	Latin Name	Total Abundance
Oligochaeta	602	*Glycera americana*	3
Streblospio benedicti	321	*Glycinde solitaria*	3
Parapionosyllis longicirrata	126	*Odontosyllis sp*	3
Nematoda	71	*Sclerodactyla briareus*	3
Batea catharinensis	70	*Tharyx sp*	3
Caulleriella sp	35	*Bryozoa*	2
Actiniaria	34	*Cirrophorus sp*	2
Cyathura burbancki	32	*Corbula barrattiana*	2
Streptosyllis sp	28	*Corbula contracta*	2
Mediomastus sp	26	*Hemipholis elongata*	2
Nemertea	24	*Maera caroliniana*	2
Scoletoma tenuis	22	*Mediomastus californiensis*	2
Tellina sp	19	*Nephtys bucera*	2
Carinomidae	12	*Nephtys picta*	2
Cirratulidae	12	*Ostracoda*	2
Neanthes succinea	11	*Sabellaria vulgaris*	2
Polydora sp	11	*Alpheus normanni*	1
Monticellina dorsobranchialis	9	*Ameroculodes sp*	1
Heteromastus filiformis	8	*Ampelisca vadorum*	1
Scoloplos rubra	8	*Arabella iricolor*	1
Prionospio sp	7	*Aricidea wassi*	1
Tellina agilis	7	*Autolytus cornutus*	1
Paraprionospio pinnata	6	*Bivalvia*	1
Prionospio perkinsi	6	*Callianassidae*	1
Sphenia antillensis	6	*Decapoda/caridea*	1
Unid. ophiuroidea	6	*Gorgonacea*	1
Mediomastus ambiseta	5	*Hexapanopeus angustifrons*	1
Podarkeopsis	5	*Mooreonuphis pallidula*	1
Spheαrosyllis sp	5	*Pinnixa sp*	1
Microphthalmus	4	*Spionidae*	1
Syllides sp	4	*Synalpheus sp*	1
Aphelochaeta sp	3	*Tagelus divisus*	1
Chiridotea almyra	3	*Xanthidae*	1
Exogone dispar	3		

Surface water quality standards for dissolved oxygen; fecal coliform concentration, pH, and temperature are listed in **Table A-1**, below. These apply to all Georgia waters, although the standard for fecal coliform is different from coastal as compared to fresh water.

Table C-1. GA surface water quality standards.

	Bacteria (fecal coliform)		**Dissolved Oxygen**[1]		**pH**	**Temperature**[1]	
Use Classification	30-day geometric mean (CFU/100 ml)	maximum (CFU/100 ml)	daily average (mg/l)	minimum (mg/l)	std. units	max. rise (°F)	max. (°F)
Drinking Water (requiring treatment)	≤1,000 (Nov-April) ≤200 (May-Oct)	≤4,000 (Nov-April)	≥5.0	≥4.0	≥6.0, ≤8.5	≤5	≤90
Recreation	≤200 (fresh) ≤100 (coastal)	--	≥5.0	≥4.0	≥6.0, ≤8.5	≤5	≤90
Fishing[2]			≥5.0	≥4.0	≥6.0, ≤8.5	≤5	≤90
Wild River	No alteration of natural water quality						
Scenic River	No alteration of natural water quality						

In trout streams, different standards apply: dissolved oxygen (average 6.0 mg/l, minimum 5.0 mg/l), temperature (no alteration in primary trout streams, 2ºF change allowed in secondary trout streams).

[2] For coastal fishing areas, different dissolved oxygen standards apply (site specific).

Standards for toxic substances in coastal waters are summarized below. This covers chemical constituents which are considered to be other toxic pollutants of concern in the State of Georgia and those listed by the U.S. Environmental Protection Agency as toxic priority pollutants (excerpted from Georgia Rules and Regulation for Water Quality Control, Ch 391-3-6.03 *Water Use Classifications and Water Quality Standards*). **Table C-2** lists criteria not to be exceeded under 7-day, 10-year minimum flow or higher stream flow conditions except within established mixing zones, and **Table C-3** lists criteria not to be exceeded under annual average or higher stream flow conditions[88]. The law also specifies that asbestos criteria will be developed on an as-needed basis through toxic pollutant monitoring efforts at new or existing discharges that are suspected to be a source of the pollutant at levels sufficient to interfere with designated uses, and that applicable State and Federal requirements and regulations for the discharge of radioactive substances shall be met at all times.

[88] In addition, there is an upper concentration of 0.0012 ng/l 2,3,7,8-tetrachlorodibenzo-p-dioxin (TCDD) that is not to be exceeded under long-term average stream flow conditions.

Table C-2. GA criteria for toxic substances not to be exceeded under a 7-day, 10-year minimum flow or higher stream flow condition.

Constituent	Coastal and Marine Standard (µg/l)	Standard differs from that for Freshwater
Arsenic	36	X
Cadmium	9.3	X
Chlordane*	0.004	X
Chromium VI	50	X
Total Chromium (at hardness >200mg/l)	370	
Copper	2.9	X
Cyanide*	1.0	X
Dieldrin	0.0019	
2,4-Dichlorophenoxyacetic acid (2,4-D)	70	
4,4 -DDT*	0.001	
a-Endosulfan*	0.0087	X
Endrin*	0.002	
Heptachlor*	0.0036	X
Lead*	5.6	X
Lindane (hexachlorocyclohexane [g-BHC-gamma])	0.8	
Mercury*	0.025	X
Methoxychlor*	0.03	
Nickel, C	8.3	X
Pentachlorophenol*	7.9	X
PCB-1016	0.014	
PCB-1221	0.014	
PCB-1232	0.014	
PCB-1242	0.014	
PCB-1248	0.014	
PCB-1254	0.014	
PCB-1260	0.014	
Phenol	300	
Selenium	71	X
Silver	**	
Toxaphene	0.0002	
2,4,5-Trichlorophenoxy propionic acid (TP Silvex)	50	
Zinc	86	X

* Instream criterion is lower than the EPD laboratory detection limits.
** Numeric limit not specified (contaminant is covered in more detail in the Rules).

Table C-3. GA criteria for toxic substances not to be exceeded under annual average or higher stream flow conditions.

Constituent	Standard (µg/l)
Acenaphthene	**
Acenaphthylene	**
Acrolein	780
Acrylonitrile	0.665
Aldrin	0.000136
Anthracene	110000
Antimony	4308
Arsenic	0.14
Benzidine	0.000535
Benzo(a)Anthracene	0.0311
Benzo(a)Pyrene	0.0311
3,4-Benzofluoranthene	0.0311
Benzene	71.28
Benzo(ghi)Perylene	**
Benzo(k)Fluoranthene	0.0311
Beryllium	**
a-BHC-Alpha	0.0131
b-BHC-Beta	0.046
Bis(2-Chloroethyl)Ether	1.42
Bis(2-Chloroisopropyl)Ether	170000
Bis(2-Ethylhexyl)Phthalate	5.92
Bromoform (Tribromomethane)	360
Carbon Tetrachloride	4.42
Chlorobenzene	21000
Chlorodibromomethane	34
2-Chloroethylvinyl Ether	**
Chlordane	0.000588
Chloroform (Trichloromethane)	470.8
2-Chlorophenol	**
Chrysene	0.0311
Dibenzo(a,h)Anthracene	0.0311
Dichlorobromomethane	22
1,2-Dichloroethane	98.6
1,1-Dichloroethylene	3.2
1,3-Dichloropropylene (Cis)	1700
1,3-Dichloropropylene (Trans)	1700
2,4-Dichlorophenol	790
1,2-Dichlorobenzene	17000
1,3-Dichlorobenzene	2600
1,4-Dichlorobenzene	2600
3,3'-Dichlorobenzidine	0.077
4,4'-DDT	0.00059

4,4'-DDD	0.00084
4,4'-DDE	0.00059
Dieldrin	0.000144
Diethyl Phthalate	120000
Dimethyl Phthalate	2900000
2,4-Dimethylphenol	**
2,4-Dinitrophenol	14264
Di-n-Butyl Phthalate	12100
2,4-Dinitrotoluene	9.1
1,2-Diphenylhydrazine	0.54
Endrin Aldehyde	0.81
Endosulfan Sulfate	2.0
Ethylbenzene	28718
Fluoranthene	370
Fluorene	14000
Heptachlor	0.000214
Heptachlor Epoxide	0.00011
Hexachlorobenzene	0.00077
Hexachlorobutadiene	49.7
Hexachlorocyclopentadiene	17000
Hexachloroethane	8.85
Indeno(1,2,3-cd)Pyrene	0.0311
Isophorone	600
Lindane [Hexachlorocyclohexane g-BHC-Gamma)]	0.0625
Methyl Bromide (Bromomethane)	4000
Methyl Chloride (Chloromethane)	**
Methylene Chloride	†
2-Methyl-4,6-Dinitrophenol	765
3-Methyl-4-Chlorophenol	**
Nitrobenzene	1900
N-Nitrosodimethylamine	8.12
N-Nitrosodi-n-Propylamine	**
N-Nitrosodiphenylamine	16.2
PCB-1016	0.00045
PCB-1221	0.00045
PCB-1232	0.00045
PCB-1242	0.00045
PCB-1248	0.00045
PCB-1254	0.00045
PCB-1260	0.00045
Phenanthrene	**
Phenol	4,600,000
Pyrene	11,000
1,1,2,2-Tetrachloroethane	10.8
Tetrachloroethylene	8.85
Thallium	48 (6.3) ‡
Toluene	200000
1,2-Trans-Dichloroethylene	**
1,1,2-Trichloroethane	41.99

Trichloroethylene	80.7
2,4,6-Trichlorophenol	6.5
1,2,4-Trichlorobenzene	**
Vinyl Chloride	525

** Numeric limit not specified (toxin is covered in more detail in the Rules).

† EPD has proposed to the Board of Natural Resources changing numeric limits for methylene chloride from unspecified to 1600 µg/l consistent with EPA's National Toxics Rule.

‡ EPD has proposed to the Board of Natural Resources changing numeric limits for thallium from 48 to 6.3 µg/l consistent with EPA's National Toxics Rule.

Appendix D – Contaminants detected in shrimp tissue.

Table D-1: Contaminants detected in shrimp tissue collected from the GA-CRD NCA and EPA EMAP programs.

Data sources: NCA program data from Georgia DNR-CRD and EMAP data from Hyland et al. 1998. Shading indicates elevated concentrations, based on EPA Risk Guidelines. NCA stations GA00-0030 were sampled in summer 2000 and the EMAP station CP95162 (South Channel) on August 29th, 1995.

Category	Chemical	NCA (ppm)	EMAP (ppm)
METAL	ALUMINUM	161	
	ARSENIC (inorganic portion)	0.04	0.26
	CADMIUM	0.03	0.11
	CHROMIUM	0.21	
	COPPER	24.1	28.0
	IRON	67.4	
	LEAD	0.09	0.21
	MANGANESE		2.90
	MERCURY	0.01	0.07
	NICKEL	0.23	0.17
	SELENIUM	0.50	1.80
	SILVER	0.09	
	TIN	0.52	
	ZINC	14.6	
PAH	1-METHYLNAPHTHALENE	0.00078	
	2-METHYLNAPHTHALENE	0.00140	
	C3-NAPHTHALENES		0.04830
	ACENAPHTHENE	0.00050	
	BENZO(A)ANTHRACENE	0.00051	
	BENZO(B)FLUORANTHENE	0.00020	
	FLUORANTHENE	0.00100	0.00660
	FLUORENE	0.00047	0.01070
	NAPHTHALENE	0.00240	0.02560
	PYRENE	0.00097	0.00990
	TOTAL PAHs (without Pyrelene)		0.15360
PCB	2,2',4,5,5'-PENTACHLOROBIPHENYL	0.00032	0.00096
	2,3,3',4,4'-PENTACHLOROBIPHENYL	0.00006	
	2,3',4,4',5-PENTACHLOROBIPHENYL	0.00026	
	2,2',3,4,4',5'-HEXACHLOROBIPHENYL	0.00039	0.00164
	2,2',4,4',5,5'-HEXACHLOROBIPHENYL	0.00059	0.00186
	2,2',3,3',4,4',5-HEPTACHLOROBIPHENYL	0.00007	0.00546
	2,2',3,4,4',5,5'-HEPTACHLOROBIPHENYL	0.00024	0.00264
	2,2',3,4',5,5',6-HEPTACHLOROBIPHENYL	0.00025	
	2,2',3,3',4,4',5,5',6-NONACHLOROBIPHENYL	0.00004	
	2,2',5,5'-TETRACHLOROBIPHENYL	0.00013	

Category	Chemical	NCA (ppm)	EMAP (ppm)
	2,3',4,4'-TETRACHLOROBIPHENYL	0.00008	
	2,4'-DICHLOROBIPHENYL		0.00158
	TOTAL PCBs		0.03934
PESTICIDE	DIELDRIN	0.00017	
	HEPTACHLOR-EPOXIDE	0.00004	
	HEXACHLOROBENZENE	0.00004	
	MIREX	0.00046	0.00266
	O,P'DDD	0.00006	
	P,P'DDE	0.00044	
	TRANS-NONACHLOR	0.00013	0.00058
	TOTAL CHLORDANE		0.00082
	TOTAL DDE		0.00147
	TOTAL DDT		0.00147
	TRIBUTYLTIN		0.04685

Sediment contamination due to trace metals and organic compounds can be evaluated using an effects-based method developed by Long et al. (1995), which estimates the percent incidence at which adverse biological effects occur to aquatic organisms[89] at specific contaminant concentrations. For each chemical, the distribution of effects[90] were ranked in order of chemical concentration, with the lower 10th percentile referred to as the effects range-low (ERL) and the 50th percentile (median) referred to as the effects range-median (ERM). From these 2 guideline values, 3 concentration ranges were delineated for each chemical, which corresponded to the likelihood of adverse effects: 1) <ERL, rare, 2) ERL-ERM, occasional, and 3) >ERM, frequently. Sediment ERL and ERM values are presented for each chemical, along with Long et al.'s (1995) applied results, testing these guidelines against the BEDS dataset to calculate percentages of previously observed adverse effects in the 3 categories.

[89] Adverse biological effects included: "1) measures of altered benthic communities (depresses species richness or total abundance), significantly or relatively elevated sediment toxicity, or histopathological disorders in demersal fish observed in field studies; 2) EC50 or LC50 concentrations determined in laboratory bioassays of sediments spiked with single compounds or elements; and 3) toxicity predicted by equilibrium-partitioning models", which were all treated equally (Long et al. 1995).

[90] Based on sediment toxicity results compiled from numerous publications into a single database BEDS (biological effects database for sediments).

Table E-1. ERL and ERM sediment guidelines and % incidence of adverse effects.

Trace metals (ppm, dry wt) and organic compounds (ppb, dry wt) and the percent incidence of biological effects calculated from the BEDS database.

	Guidelines		Percent Incidence of Adverse Effects		
Trace Metals	**ERL**	**ERM**	**<ERL**	**ERL-ERM**	**>ERM**
Arsenic	8.2	70	5.0	11.1	63.0
Cadmium	1.2	9.6	6.6	36.6	65.7
Chromium	81	370	2.9	21.1	95.0
Copper	34	270	9.4	29.1	83.7
Lead	46.7	218	8.0	35.8	90.2
Mercury	0.15	0.71	8.3	23.5	42.3
Nickel	20.9	51.6	1.9	16.7	16.9
Silver	1	3.7	2.6	32.3	92.8
Zinc	150	410	6.1	47.0	69.8
Organic Compunds					
Acenaphthene	16	500	20.0	32.4	84.2
Acenaphthylene	44	640	14.3	17.9	100.0
Anthracene	85.3	1100	25.0	44.2	85.2
Fluorene	19	540	27.3	36.5	86.7
2-Methyl naphthalene	70	670	12.5	73.3	100.0
Naphthalene	160	2100	16.0	41.0	88.9
Phenanthrene	240	1500	18.5	46.2	90.3
Low-molecular weight PAH	552	3160	13.0	48.1	100.0
Benz(a)anthracene	261	1600	21.1	43.8	92.6
Benzo(a)pyrene	430	1600	10.3	63.0	80.0
	Guidelines		**Percent Incidence of Adverse Effects**		
Organic Compounds	**ERL**	**ERM**	**<ERL**	**ERL-ERM**	**>ERM**
Chrysene	384	2800	19.0	45.0	88.5
Dibenzo(a,h)anthracene	63.4	260	11.5	54.5	66.7
Fluoranthene	600	5100	20.6	63.6	92.3
Pyrene	665	2600	17.2	53.1	87.5
High-molecular weight PAH	1700	9600	10.5	40.0	81.2
Total PAH	4022	44792	14.3	36.1	85.0
p,p'-DDE	2.2	27	5.0	50.0	50.0
Total DDT	1.58	46.1	20.0	75.0	53.6
Total PCB	22.7	180	18.5	40.8	51.0

Adapted from Long et al. 1995.

Appendix F – Sediment contaminants

Table F-1: Contaminants detected in sediments collected from GA-CRD NCA and EPA EMAP programs.

Data sources: NCA program data from Georgia DNR-CRD and EMAP data from Hyland et al. 1998. Cells with "<" indicate that the concentration was below the lab detection limit; blank cells indicate that the chemical was not tested. NCA stations GA00-0030, GA00-31, and GA01-0009 were sampled in summer 2000 and EMAP stations CP95161 (Tybee Roads), CP95162 (South Channel), CP95263 (Bull River) were sampled in August, 1995.

		NCA Stations (2000, 2001)*			EMAP Stations (1995)		
Category	**Chemical**	**GA00-0030**	**GA00-0031**	**GA01-0009****	**CP95161**	**CP95162**	**CP95163**
METAL (ppm)	ALUMINUM	34300	18600	1627	15553	16799	17254
	ANTIMONY	0.30	0.20	<	<	<	<
	ARSENIC	7.00	2.00	2.50	2.93	4.27	4.43
	CADMIUM	0.95	0.15	<	0.10	0.04	0.16
	CHROMIUM	64.00	19.00	<	13.31	13.36	52.33
	COPPER	10.00	7.00	<	1.25	0.93	1.65
	IRON	18900	11800	5634	6726	8939	14700
	LEAD	9.90	9.40	3.11	6.35	8.58	8.87
	MANGANESE	234	384	234	185	371	401
	MERCURY	<	<	<	0.01	0.01	0.02
	NICKEL	15.00	3.00	1.59	2.00	2.60	3.00
	SELENIUM	0.40	<	<	<	<	<
	SILICON				471395	483569	446429
	SILVER	0.20	0.10	0.06	<	<	0.02
	TIN	1.20	1.00	6.37	0.38	0.58	0.90
	ZINC	45.00	26.00	12.25	19.03	24.81	28.57
PAH (ppb)	1-METHYLPHENANTHRENE	<	<		0.30	<	<
	(I)1,2,3-C,D-PYRENE	1.20	9.90		<	0.30	0.60
	ACENAPHTHYLENE	<	1.60		<	<	<
	ANTHRACENE	1.30	1.80				
	BENZO(A)ANTHRACENE	2.00	22.00		0.20	0.30	0.50
	BENZO(A)PYRENE	1.60	15.00		<	<	0.60
	BENZO(B)FLUORANTHENE	2.50	30.00		<	<	<
	BENZO(G,H,I)PERYLENE	1.30	10.00		<	<	<
	BENZO(K)FLUORANTHENE	1.00	11.00		<	<	<
	CHRYSENE	1.40	36.00		<	0.80	0.70
	DIBENZO(A,H)ANTHRACENE	<	1.60				
	FLUORANTHENE	5.00	28.00		<	2.50	1.30
	PYRENE	6.30	35.00		<	2.00	1.30
	BENZO(E)PYRENE				<	<	0.60
	BIPHENYL	<	<		0.40	0.50	0.30
	C1-PHENANTHRENES				0.50	0.50	0.50

	C2-DIBENZOTHIOPHENES	<	<		0.60	0.30	0.40
	C2-PHENANTHRENES				1.80	0.90	1.00
	C3-DIBENZOTHIOPHENES	<	<		0.80	1.00	0.70
	C3-FLUORENES	<	<		1.70	1.50	1.30
	C3-NAPHTHALENES	<	<		1.60	2.00	1.80
	C3-PHENANTHRENES				3.30	0.80	0.90
	C4-NAPHTHALENES	<	<		1.00	1.00	<
	C4-PHENANTHRENES				6.40	<	<
	NAPHTHALENE	<	<		2.90	<	<
	PERYLENE				1.10	1.20	1.70
	PHENANTHRENE				<	1.20	<
	TOTAL PAHS (WITHOUT PERYLENE)				28.90	25.40	22.70
PCB (ppb)	2,2',4,5,5'-PENTACHLOROBIPHENYL	<	0.35	<	<	<	<
	2,2',3,4,4',5,5'-HEPTACHLOROBIPHENYL	<	<	<	<	0.05	0.10
	PCB CONGENER 138/160	<	<	<	<	0.13	<
	PCB CONGENER 170/190	<	<	<	<	<	0.28
	TOTAL PCBS				2.65	2.97	3.25
PESTICIDE (ppb)	ALDRIN	<	<	<	<	<	0.89
	ALPHA-BHC			<	<	<	1.86
	BETA-BHC			<	<	<	0.19
	2,4'-DDE	<	<	<	0.08	<	<
	4,4'-DDE	<	<	<	<	<	0.09
	TOTAL DDTS				0.18	0.08	0.12
	DELTA-BHC			<	<	<	0.14
	DIELDRIN	<	<	<	<	<	0.15
	ENDRIN	<	<	<	0.19	<	0.11
	HEPTACHLOR	<	<	<	<	<	1.58
	HEPTACHLOR EPOXIDE	<	<	<	<	<	0.28
	LINDANE	<	<		<	<	1.27
	TOTAL CHLORDANE				0.08	0.13	0.08
	TOTAL HCH (BHC)				0.07	0.06	3.47
ALKANE (ppb)	N-DOCOSANE				3.00	4.00	1.00
	N-DODECANE				3.00	4.00	30.00
	N-DOTRIACONTANE				<	5.00	9.00
	N-EICOSANE				1.00	4.00	1.00
	N-HENEICOSANE				8.00	7.00	7.00
	N-HENTRIACONTANE				27.00	19.00	56.00
	N-HEPTACOSANE				13.00	13.00	17.00
	N-HEPTADECANE				5.00	2.00	4.00
	N-HEXACOSANE				<	7.00	<
	N-HEXADECANE				2.00	2.00	4.00
	N-NONACOSANE				37.00	23.00	61.00
	N-NONADECANE				2.00	1.00	3.00
	N-OCTADECANE				2.00	2.00	1.00
	N-PENTACOSANE				10.00	10.00	6.00

	N-PENTADECANE	6.00	2.00	69.00
	N-TETRADECANE	2.00	2.00	11.00
	N-TETRATRIACONTANE	<	<	4.00
	N-TRIACONTANE	10.00	<	18.00
	N-TRICOSANE	5.00	6.00	4.00
	N-TRIDECANE	1.00	<	1.00
	N-TRITRIACONTANE	16.00	7.00	<
	TOTAL ALKANES	177.00	142.00	322.00
ISOPRENOID (ppb)	PHYTANE	1.00	1.00	1.00
	PRISTANE	2.00	1.00	1.00

*The NCA program did not test sediments for alkanes or isoprenoids.
** PAHs, PCBs, Organochlorines (OCs) were tested for in sediments at station GA01-0009, but were not detected.

Appendix G – Point source dischargers located within the Fort Pulaski study area.

The NPDES (National Pollutant Discharge Elimination System) program was initiated in 1972 under the Clear Water Act as a way to regulate water pollution from point-sources. All industrial, municipal, and other facilities that discharge effluent directly to surface waters must obtain a NPDES permit. In addition, as of 2000, all industries that discharge stormwater associated with industrial activity, municipal separate storm sewer systems (MS4s with populations ≥100,000), and construction sites that disturb ≥ 1 acre of land, required coverage under NPDES stormwater permits. Industrial and municipal permittees are listed in Table G-1 and stormwater dischargers in Table G-2. Data Source: U.S. EPA 2004b.

Table G-1. Industrial and municipal permittees under the NPDES program.

Major municipal and industrial permittees are highlighted.

Operator or Facility Name (Alias)	County	Type	Permitted Flow (mgd)	NPDES Permit Number	ECHO Violation[a]	Toxic Release[b]	GA Hazardous Site[c]	Enforcement Orders[d]	Spills[e]	Leaking Tanks[f]	USGS HUC Code	Receiving Stream
AIR LIQUIDE AMERICA CORPORATION	CHATHAM	INDUSTRIAL GASES		GA0046230						1C	3060109	Savannah River
ATLANTIC WOOD INDUSTRIES INCORPORATED	CHATHAM	SEWERAGE SYSTEMS		GA0047783		●	●	1-AQA, 1-HWMA	1		3060109	Savannah River
BLOOMINGDALE (SWP)	CHATHAM	SEWERAGE SYSTEMS		GAS000207								
BUDGET INN SAVANNAH	CHATHAM	HOTELS AND MOTELS	0.023	GAG550002								Springfield Canal
CARIBBEAN VILLAGE SUB (LAS)	CHATHAM			GAU030610								
CHATHAM CO (PINE BARREN RD)	CHATHAM	SEWERAGE SYSTEMS	0.0600	GAU020285								Chatham Co. LAS
CHATHAM COUNTY (SWP)	CHATHAM	SEWERAGE SYSTEMS		GAS000206							3060109	Savannah River
CITGO ASPHALT REFINING COMPANY	CHATHAM	SEWERAGE SYSTEMS		GA0004332		●			1	2C	3060109	Savannah River
CITY OF SAVANNAH WATER POLLUTION CONTROL PLANT (SAVANNAH TRAVIS FIELD WPCP)	CHATHAM	SEWERAGE SYSTEMS	1.5000	GA0020427	●						3060109	Savannah River
COLONIAL TERMINALS 1	CHATHAM	SPECIAL WAREHOUSING AND STORAGE, NOT ELSEWHERE CLASSIFIED		GA0037923			●		1			Savannah River

CONSOLIDATED UTILITIES, INC.	CHATHAM	SEWERAGE SYSTEMS	0.2000	GA0034819							3060204	Hardin Canal
EMD CHEMICALS INCORPORATED (E.M. INDUSTRIES)	CHATHAM	INORGANIC PIGMENTS		GA0034355		•					3060109	Savannah River
ENGELHARD CORPORATION	CHATHAM	INDUSTRIAL INORGANIC CHEMICALS, NOT ELSEWHERE CLASSIFIED		GA0048330		•					3060109	Savannah River
FUJI VEGETABLE OIL INCORPORATED	CHATHAM			GA0038521		•		2-WQCA			3060109	Savannah River
GA PORTS AUTHORITY	CHATHAM	MARINE CARGO HANDLING		GA0047937						2C	3060109	Savannah River
GAF MATERIALS CORP	CHATHAM	ASPHALT FELTS AND COATINGS		GA0003841							3060109	Dundee Canal and Savannah River
GARDEN CITY (SWP)	CHATHAM	SEWERAGE SYSTEMS		GAS000208							3060109	Pipe Makers Canal
GARDEN CITY WATER POLLUTION CONTROL PLANT	CHATHAM	SEWERAGE SYSTEMS	2.0000	GA0031038	•						3060109	Savannah River
GEORGIA PACIFIC RESINS INCORPORATED	CHATHAM	SEWERAGE SYSTEMS		GA0047007		•				1C IF PORT WENT.	3060109	Savannah River
GULFSTREAM AEROSPACE CORPORATION	CHATHAM	AIRCRAFT		GA0003255		•				2C	3060109	Pipe Makers Canal
HARBOR TANK WASH	CHATHAM		0.0065	GAU050240								Trib in Garden City
HERCULES INCORPORATED	CHATHAM	CHEMICALS AND CHEMICAL PREPARATIONS, NOT ELSEWHERE CLASSIFIED		GA0026867			•	1-WQCA	11		3060109	Dundee Canal
HERTY FOUNDATION SAVANNAH	CHATHAM	COMMERCIAL PHYSICAL AND BIOLOGICAL RESEARCH		GA0002402							3060109	Dundee Canal
INTERMARINE USA	CHATHAM	NATIONAL SECURITY		GA0003671						1C	3060109	Savannah River
INTERNATIONAL PAPER COMPANY (UNION CAMP CORP)	CHATHAM	PAPER MILLS	42.3	GA0001988	•	•			3		3060109	Savannah River
JCB, INC	CHATHAM	SEWERAGE SYSTEMS	0.0336	GAU050228								Trib in Pooler
KERR-MCGEE PIGMENTS (KEMIRA)	CHATHAM	INORGANIC PIGMENTS	24.5	GA0003646	•	•	•	2-WQCA, 1-AQA, 1-HWMA			3060109	Savannah River
MILLER TRANSPORTERS INC	CHATHAM	SEWERAGE SYSTEMS	0.0100	GAU050134								Trib in Garden City, Millers Creek

NASSAU WOODS MHP	CHATHAM			GAG550031				1-SDWA				
OAKLEY TRANS.TANK WASH	CHATHAM	SEWERAGE SYSTEMS	0.0025	GAU050242								Trib in Garden City
OWENS-CORNING	CHATHAM	SEWERAGE SYSTEMS	0.0065	GAU050166		•					3060109	Savannah River
PCS NITROGEN FERTILIZER LIMITED PARTNERSHIP SAVANNAH PLANT	CHATHAM	NITROGENOUS FERTILIZERS	0.2	GA0002356							3060109	Savannah River
PINE FOREST S/D PORT WENTWORTH	CHATHAM	OPERATIVE BUILDERS	0.0400	GAG550135							3060109	Black Creek
POOLER (SWP)	CHATHAM	SEWERAGE SYSTEMS		GAS000209								
POOLER/BLOOMINGDALE REG WPCP	CHATHAM	SEWERAGE SYSTEMS	0.9800	GA0047066							3060109	Hardin Canal
PORT WENTWORTH (SWP)	CHATHAM	SEWERAGE SYSTEMS		GAS000210								
QUALA SYSTEMS INCORPORATED GARDEN CITY GEORGIA	CHATHAM	SEWERAGE SYSTEMS	0.0100	GAU050124								Trib in Garden City
SAVANNAH (SWP)	CHATHAM	SEWERAGE SYSTEMS	2.4500	GAS000205	•			1-SDWA	1	1C	3060204 3060109	Springfield, Savannah, Ogeechee Canals
SAVANNAH ELEC & PWR RIVERSIDE STM	CHATHAM	ELECTRIC SERVICES		GA0003751					2	1C	3060109	Savannah River
SAVANNAH ELECTRIC AND POWER PLANT KRAFT	CHATHAM	ELECTRIC SERVICES		GA0003816		•	•			2C	3060109	Savannah River
SAVANNAH PINES MHP	CHATHAM			GAG550127								
SAVANNAH SUGAR REFINERY	CHATHAM	CANE SUGAR REFINING		GA0003611					1	1C	3060109	Savannah River
SAVANNAH YACHT CLUB	CHATHAM	PHYSICAL FITNESS FACILITIES	0.0083	GA0033189							3060204	Wilmington River
SAVANNAH, PRESIDENT ST. REUSE (WPCP)	CHATHAM	SEWERAGE SYSTEMS	27.0000	GAU020198 GA0025348				1-AQA			3060109	Savannah River
SKIDAWAY ISLAND UTILITIES	CHATHAM	SEWERAGE SYSTEMS	1.2500	GAU030941						2C		Trib at Skidaway Island
SOUTHERN STATES PHOSPHATE & FERTILIZER COMPANY INCORPORATED	CHATHAM	PHOSPHATIC FERTILIZERS		GA0002437		•	•	1-HSRA			3060109	Kayton Canal to Savannah River
THUNDERBOLT (SWP)	CHATHAM	SEWERAGE SYSTEMS		GAS000211				2-SDWA				
TYBEE ISLAND (SWP)	CHATHAM	SEWERAGE SYSTEMS		GAS000212					1		3060109	Savannah River

TYBEE ISLAND WASTEWATER TREATMENT PLANT	CHATHAM	SEWERAGE SYSTEMS	1.1500	GA0020061							3060109	Savannah River
WESTWOOD HEIGHTS & MILLCREEK	CHATHAM	SEWERAGE SYSTEMS	0.1300	GAU020234								Trib in Rincon
WEYERHAEUSER COMPANY (STONE CONTAINER CORP)	CHATHAM	PULP MILLS	38.0	GA0002798	•	•				1C	3060109	Savannah River
WILSHIRE/WINDSOR WPCP	CHATHAM	SEWERAGE SYSTEMS	4.5	GA0020443							3060109	Savannah River
EFFINGHAM COUNTY POWER LLC	EFFINGHAM	ELECTRIC SERVICES		GAU010564								
GEORGIA PACIFIC CORP SAVANNAH RIVER MILL (FORT JAMES OPERATING CO/FORT HOWARD CORP)	EFFINGHAM	PAPER MILLS	13.9	GA0046973		•					3060109	Savannah River
RINCON , TOWN OF	EFFINGHAM	SEWERAGE SYSTEMS	0.5000	GA0046442				2-WQCA			3060109	Sweigoffer Creek
SAVANNAH ELECTRIC AND POWER COMPANY PLANT MCINTOSH	EFFINGHAM	ELECTRIC SERVICES	108.00	GA0003883		•					3060109	Savannah River
SOUTH EFFINGHAM ELEM	EFFINGHAM	SCHOOL SYSTEM	0.0150	GAG550101							3060109	Unamed Tributary to Black Creek
SPRINGFIELD WPCP	EFFINGHAM	SEWERAGE SYSTEMS	1.5000	GA0020770							3060109	Ebenezer Creek
ABLE CONTRACTING/ COOLER MINE	JASPER	MISCELLANEOUS NONMETALLIC MINERALS, EXCEPT FUELS		SCG730392			NA	NS	NS	NS		
ATLANTIC COAST BLDRS/RED DAM P	JASPER	MISCELLANEOUS NONMETALLIC MINERALS, EXCEPT FUELS		SCG730416			NA	NS	NS	NS		
B & T PROPERTIES	JASPER	GENERAL WAREHOUSING AND STORAGE		SCR003216			NA	NS	NS	NS		
BJW&SA/HARDEEVILLE-DELTA PLANT	JASPER	SEWERAGE SYSTEMS	0.0550	SC0048127	•		NA	NS	NS	NS	3060109	Savannah River @ Millstone
BUNTON CONST/BELLINGER HILL MN	JASPER	MISCELLANEOUS NONMETALLIC MINERALS, EXCEPT FUELS		SCG730396			NA	NS	NS	NS		
COOSAWHATCHIE LAND COMPANY LLC	JASPER	GASOLINE SERVICE STATIONS		SC0035394			NA	NS	NS	NS	3050208	Little Bees Trib, Coosawhatchie
CSR AMERICA	JASPER	CONSTRUCTION SAND AND GRAVEL		SCR003434			NA	NS	NS	NS		

DONNA LYNN BEACH	JASPER	CLAY, CERAMIC, AND REFRACTORY MINERALS, NOT ELSEWHERE CLASSIFIED		SCR003581	NA	NS	NS	NS		
HARDEEVILLE CHURCH ROAD PLANT	JASPER	SEWERAGE SYSTEMS	0.6000	SC0034584	NA	NS	NS	NS	306010 9	
HICKORY HILL LANDFILL	JASPER	REFUSE SYSTEMS		SCR000301	NA	NS	NS	NS		
JEJ CONST/SERGEANT JASPER PARK	JASPER	MISCELLANEOUS NONMETALLIC MINERALS, EXCEPT FUELS		SCG730399	NA	NS	NS	NS		
MALPHRUS CONSTRUCTION:PLANT #2	JASPER	CONSTRUCTION SAND AND GRAVEL		SCR003496	NA	NS	NS	NS		
MCGRAWS AUTO SALVAGE	JASPER	MOTOR VEHICLE PARTS, USED		SCR002364	NA	NS	NS	NS		
NATHAN WILSON/JASPER MINE	JASPER	MISCELLANEOUS NONMETALLIC MINERALS, EXCEPT FUELS		SCG730415	NA	NS	NS	NS		
OKEETEE CLUB/CROWFIELD RD MINE	JASPER	CONSTRUCTION SAND AND GRAVEL		SCG730325	NA	NS	NS	NS		
PALMETTO ELECTRIC COOP, INC.	JASPER	ELECTRIC SERVICES		SCR002931	NA	NS	NS	NS		
REA CONSTRUCTION COMPANY	JASPER	CONSTRUCTION SAND AND GRAVEL		SCR003108	NA	NS	NS	NS		
REA CONSTRUCTION FKA CLECKLEY	JASPER	ASPHALT PAVING MIXTURES AND BLOCKS		SCR002892	NA	NS	NS	NS		
RIDGELAND AIRPORT	JASPER	AIRPORTS, FLYING FIELDS, AND AIRPORT TERMINAL SERVICES		SCR000663	NA	NS	NS	NS		
RIDGELAND, TOWN OF WWTP	JASPER	SEWERAGE SYSTEMS		SC0047929	NA	NS	NS	NS	305020 8	Captain Bills Creek
RIVERS EDGE COMPANY	JASPER	CONSTRUCTION SAND AND GRAVEL		SCG730372	NA	NS	NS	NS		
S & W WOOD PRODUCTS, INC.	JASPER	WOOD PRESERVING		SCR000207	NA	NS	NS	NS		
SC DEPT. OF TRANSPORTATION	JASPER	TERMINAL AND JOINT TERMINAL MAINTENANCE FACILITIES FOR MOTOR FREIGHT TRANSPORTATION		SCR000265	NA	NS	NS	NS		
STUCKEY'S PECAN SHOPPE #83	JASPER	EATING PLACES		SC0034550	NA	NS	NS	NS	305020 8	Little Bees Trib to Coosawhatchie

UNICON CONCRETE, LLC	JASPER	READY-MIXED CONCRETE	SCR003289	NA	NS	NS	NS

[a] This plant is listed in the ECHO database as having had a violation in the last two years, but is not listed for a current significant violation (U.S. Environmental Protection Agency 2004)

[b] EPA, TRI (Toxic Release Inventory) Database, releases to surface water or air.

[c] GA EPD, HSI (Hazardous Site Inventory) List, releases to groundwater or soil.

[d] GA EPD, Enforcement order search page: WQCA (Water Quality Control Act), AQCA (Air Quality Control Act), SDWA(Safe Drinking Water Act), HSRA (Hazardous Site Response Act), HWMA (Hazardous Waste Management Act).

[e] Only spills that impacted waterways during 1/1999-9/2000 were included; a total of 102 spills impacted waterways during that time, most from unknown sources.

[f] GA EPD, Leaking underground storage tanks: S-Suspected C-Confirmed

NA: not applicable, could not locate SC DNR HSI list
NS: database not searched for this information

Table G-2. Industrial stormwater permittees

Data Source: Georgia - EPD 2004c.

ID	Facility	Facility Address	Zip Code	Receiving Stream
1268	ADDCO RECYCLING CORPORATION OF GEORGIA	P. O. BOX 1312	31402	SPRINGFIELD CANAL
1946	ADDLESTONE INTERNATIONAL CORPORATION	#1 HATCHCOVER ROAD	31402	SAVANNAH RIVER
1512	ADM - COCOA SAVANNAH, INC.	P. O. BOX 68	31402	PIPE MAKERS CANAL
3525	AMERICAN FREIGHTWAYS - SAVANNAH	130 TELFAIR ROAD	31402	SPRINGFIELD CANAL
2836	APAC GEORGIA, INC. SAVANNAH DIVISION PLANT	P. O. BOX 1224	31498	DUNDEE CANAL
2648	APAC GEORGIA, INC. - SRB, CONCRETE PAVING DIVISION		31408	BORROW PIT LAKE
541	ATLANTIC EQUIPMENT & GEAR REPAIR, INC.	P. O. BOX 3147	31401	SAVANNAH RIVER
214	ATLANTIC WOOD INDUSTRIES, INC.	P. O. BOX 1608	31407	SAVANNAH RIVER
3112	ATLAS WASTE & RECYCLING SYSTEMS, INC.	P. O. BOX 249	31404	BILBO BOX CANAL
152	BLUE CIRCLE MATERIALS - SAVANNAH	620 STILES AVENUE	31401	SAVANNAH RIVER
3411	BLUE CIRCLE MATERIALS - WHEATON STREET PLANT	761 WHEATON STREET	31401	SAVANNAH RIVER
121	BO-MARK TRANSPORT, INC.	P. O. BOX 652	31408	PIPE MAKERS CANAL
1951	BRASSELER USA I, LP	800 KING GEORGE BLVD.	31419	LITTLE OGEECHEE RIVER
14	BTI - SAVANNAH ASP	P. O. BOX 216	31402	SAVANNAH RIVER
1641	BUILDERS TRANSPORT, INC.	P. O. BOX 2726	31498	MAKERS CANAL
1942	CARIBBEAN LUMBER COMPANY, INC.	P. O. BOX 2687	31322	HARDIN CANAL
1542	CAROLINA FREIGHT CARRIERS CORPORATION - SAVANNAH	2821 TERMONT ROAD	31405	SAVANNAH RIVER
2456	CARROLL & CARROLL, INC.	FOUNDATION DRIVE	31418	PIPE MAKERS CANAL
3109	CARSON PRODUCTS COMPANY	P. O. BOX 22309	31405	SAVANNAH RIVER
2029	CHATHAM AREA TRANSIT AUTHORITY	900 EAST GWINNETT STREET	31401	SAVANNAH RIVER
2052	CHATHAM KEY	501 WEST BOUNDARY STREET	31402	SPRINGFIELD CANAL
1557	CHATHAM STEEL CORPORATION	P. O. BOX 2567	31401	SPRINGFIELD CANAL
1556	CHATHAM STEEL CORPORATION	HATCHCOVER ROAD	31401	SAVANNAH RIVER
1016	CITY OF SAVANNAH - GEORGETOWN	1400 EAST PRESIDENT STREET	31419	COUNTY CANAL
2745	CLIFTON EQUIPMENT RENTAL	18 GULFSTREAM ROAD	31418	PIPE MAKERS CANAL
1528	CLIFTON LANDFILL	P. O. BOX 7003	31418	PIPE MAKERS CANAL
2373	COASTAL CONCRETE - CHATHAM DIVISION	2839 U.S. HIGHWAY 80	31408	DUNDEE CANAL
126	COASTAL REFINING CORPORATION	2830 TREMONT ROAD	31405	SPRINGFIELD CANAL
2350	COASTAL TRANSPORT, INC.	322 GRANGE ROAD	31407	SAVANNAH RIVER
2862	COBURG DAIRY, INC.	1120 ARMSTEAD AVENUE	31408	SAVANNAH RIVER

1866	COCKE BROTHERS	P. O. DRAWER 7547	31408	SAVANNAH RIVER
605	COLONIAL TERMINALS, INC.	P. O. BOX 576	31402	SAVANNAH RIVER
168	CON-WAY SOUTHERN EXPRESS - NSA	4006 AUGUSTA ROAD	31408-2102	PIPE MAKERS CANAL
3530	CON-WAY SOUTHERN EXPRESS -NSA	1497 LISSNER AVENUE	31408	SAVANNAH RIVER
2523	CONCRETE EXPRESS, INC.	1502 LOUISVILLE ROAD	31401	OGEECHEE CANAL
2260	CSX TRANSPORATION, INC.	1401 STALEY AVENUE , NW	31405	LITTLE OGEECHEE RIVER
2344	DEAN FOREST ROAD MSWLF	1327 DEAN FOREST ROAD	31402	HARDIN CANAL
1487	DEPUE-WILBERT VAULT COMPANY, INC.	412 BONAVENTURE ROAD	31404	PLACENTA CANAL
2771	DERST BAKING COMPANY	P. O. BOX 22849	31403	SPRINGFIELD CANAL
371	DIXIE CRYSTALS BRANDS, INC.	P. O. BOX 9177	31412	SAVANNAH RIVER
3082	EM INDUSTRIES, INC.	P. O. BOX 1206	31402	SAVANNAH RIVER
2216	EMERALD PETROLEUM	P. O. BOX 2281	31408	SAVANNAH & OGEECHEE CANAL
2814	ENGELHARD CORPORATION - SAVANNAH OPERATION	1800 EAST PRESIDENT STREET	31404	SAVANNAH RIVER
3075	ESTES EXPRESS LINES	1123 LOUISVILLE RD	31401	SAVANNAH RIVER
2828	FANCY BLUFF	P. O. BOX 7192	31418	SOUTH BRUNSWICK RIVER
2915	FEDERAL EXPRESS SAVA	51 NICHOLSON DRIVE	31408	PIPE MAKERS CANAL
1669	FLEET TRANSPORT COMPANY, INC.	36 TELFAIR PLACE	31401	DUNDEE CANAL
149	FLORIDA MINING & MATERIALS	102 WAHLSTROM ROAD	31402	SAVANNAH RIVER
2521	FLORIDA ROCK & TANK LINES, INC.	P. O. BOX 7738	31418	SAVANNAH RIVER
2472	FOUNTAIN MARINA, INC.	2812 RIVER DRIVE	31404	WILMINGTON RIVER
520	FUJI VEGETABLE OIL	120 BRAMPTON ROAD	31408	SAVANNAH RIVER
2698	GAANG ORGANIZATIONAL MTN SHOP #3	1248 EISENHOWER DRIVE	31406	SAVANNAH RIVER
2898	GAF MATERIALS CORPORATION	P. O. BOX 7329	31418	DUNDEE CANAL
2790	GARY CONCRETE PRODUCTS, INC.	P. O. BOX 5007	31414	SAVANNAH RIVER
73	GARY CONCRETE PRODUCTS, INC.	P. O. BOX 5007	31404	SAVANNAH RIVER
1672	GENERAL CHEMICAL CORPORATION SAVANNAH WORKS	211 BRAMPTON ROAD	31402	SAVANNAH RIVER
979	GEORGIA - PACIFIC CORP. - SAVANNAH PLYWOOD	P. O. BOX 367	31498	PIPE MAKERS CANAL
1875	GEORGIA - PACIFIC GYPSUM CORPORATION	P. O. BOX 1526	31498-2401	SAVANNAH RIVER
256	GEORGIA - PACIFIC RESINS, INC.	P. O. BOX 4188	31407	SAVANNAH RIVER
1793	GEORGIA AIR NATIONAL GUARD	165 AIRLIFT WING/EM, 1401 ROBERT B. MILLER JR DR.	31408	PIPE MAKERS CANAL
2874	GEORGIA KAOLIN TERMINALS	P. O. BOX 576	31402	SAVANNAH RIVER
679	GEORGIA PORTS AUTHORITY - GARDEN CITY TERMINAL	P. O. BOX 2406	31408	SAVANNAH RIVER
680	GEORGIA PORTS AUTHORITY - OCEAN TERMINAL	P. O. BOX 2406	31402	SAVANNAH RIVER
2308	GEORGIA STEAMSHIP TERMINAL	CROSSGATE ROAD	31407	SAVANNAH RIVER
2822	GRAINDER LAKE	P. O. BOX 7192	31418	OGEECHEE CANAL

3493	GRAINGER AUTO PARTS AN LKQ COMPANY	P.O BOX 7334	31408	SAVANNAH OGEECHEE CANAL
2195	GREAT DANE TRAILERS, INC.	P. O. BOX 67	31402-0067	SAVANNAH RIVER
1497	GREYHOUND LINES, INC.	610 WEST OGLETHORPE AVENUE	31401	SPRINGFIELD CANAL
2772	GULFSTREAM AEROSPACE CORPORATION	P. O. BOX 2206 M/S D-02	31402	PIPE MAKERS CANAL
2718	HERCULES INCORPORATED	3000 LOUISVILLE ROAD	31401-1631	DUNDEE CANAL
1981	HOWARD SHEPPARD, INC.	P. O. BOX 7043	31418	PIPE MAKERS CANAL
2869	HUNT - WESSON, INC.	P. O. BOX 247	31402	SAVANNAH RIVER
1113	INDUSTRIAL METALWORKS, INC.	P. O. BOX 1488	31402	SPRINGFIELD CANAL
2149	INFINGER TRANSPORTATION COMPANY, INC.	32 TELFAIR PLACE	31402	SAVANNAH & OGEECHEE CANAL
55	INTERCAT - SAVANNAH, INC.	115 ELI WHITNEY BLVD.	31408	PIPE MAKERS CANAL
2854	INTERMARINE USA	P. O. BOX 3045	31402	SAVANNAH RIVER
2003	J & M TRANSPORT INC.	420 TELFAIR ROAD	31401	SAVANNAH & OGEECHEE CANAL
2572	JACK B. KELLEY, INC.	P. O. BOX 1766	31402-1766	WILMINGTON RIVER
3161	JARRELL'S RECYCLING, INC.	P. O. BOX 1585	31401	SPRINGFIELD CANAL
3510	JOE DOUGLAS -- PIT #2	373 CHEVIS ROAD	31419	LITTLE OGEECHEE RIVER
3074	KEMIRA PIGMENTS, INC.	P. O. BOX 368	31402	SAVANNAH RIVER
2835	KEMWATER NORTH AMERICA	EAST PRESIDENT STREET EXTENSION GATE #2	31402	WILMINGTON RIVER
740	KENAN TRANSPORT COMPANY	113 TELFAIR PLACE	31401	OGEECHEE CANAL
1160	KOCH MATERIALS COMPANY	P. O. BOX 7074	31408	SAVANNAH RIVER
744	KRAFT STEAM ELECTRIC GENERATING PLANT	600 EAST BAY STREET, P.O. BOX 4068	31407	SAVANNAH RIVER
254	L. B. FOSTER COMPANY	GEORGIA PORT AUTHORITY - GARDEN CTY TERMINAL	31408	SAVANNAH RIVER
3291	LUMMUS CORPORATION	1 LUMMUS DRIVE CROSSROADS BUSINESS CTR.	31422	ST. AUGUSTINE CREEK
2417	MABBETT TRANSPORT, INC.	31 MINUS AVENUE	31418	DUNDEE CANAL
1900	MARTIN MARIETTA AGGREGATES - SAVANNAH YARD	4140 OGEECHEE ROAD	31402	LITTLE OGEECHEE RIVER
1593	MCKENZIE TANK LINES, INC.	111 GRANE ROAD	31407	SAVANNAH RIVER
2605	MILLER TRANSPORTERS, INC.	6053 COMMERCE COURT	31408	MILLERS CREEK
2823	MORGAN LAKES	P. O. BOX 7192	31418	PIPE MAKERS CANAL
702	NATIONAL GYPSUM COMPANY	P. O. BOX 7016	31408-7016	SAVANNAH RIVER
1813	NATROCHEM, INC.	1 EXLEY AVENUE	31402	SAVANNAH RIVER
2868	NORFOLK SOUTHERN - PORT WENTWORTH DEPOT	U.S. HIGHWAY 17	31408	FRONT RIVER
2866	NORFOLK SOUTHERN - SAVANNAH (BAY STREET YARD)		31408	OGEECHEE CANAL
789	NORFOLK SOUTHERN - SAVANNAH (DILLARD YARD)	110 FRANKLIN ROAD, S.E.	31408	SAVANNAH & OGEECHEE CANAL
585	OCCIDENTAL CHEMICAL CORPORATION	P. O. BOX 1751	31408	SAVANNAH RIVER

1818	OVERNITE TRANSPORTATION COMPANY	1503 LISSNER AVENUE	31402	SAVANNAH RIVER
1494	OWENS - CORNING	1 FOUNDATION DRIVE	31408	SAVANNAH RIVER
810	PAKTANK CORPORATION SAVANNAH TERMINAL	P. O. BOX 7390	31408	SAVANNAH RIVER
1863	PALMER JOHNSON SAVANNAH, INC.	3124 RIVER DRIVE	31404	WILLIAMSON CREEK
360	POWELL DUFFRYN TERMINALS	2 WAHLSTROM ROAD	31404	SAVANNAH RIVER
1018	PRESIDENT STREET WATER QUALITY CONTROL PLANT	1400 EAST PRESIDENT STREET	31404	JONES CANAL
746	RIVERSIDE STEAM - ELECTRIC GENERATING PLANT	600 EAST BAY STREET, P.O. BOX 4068	31402	SAVANNAH RIVER
1288	ROADWAY EXPRESS, INC.	3501 EDWIN AVENUE	31405	SAVANNAH RIVER
3487	RPS, INC. - SAVANNAH	P. O. BOX 108	31408	PIPE MAKERS CANAL
382	RUAN LEASING COMPANY	ROUTE 5, BOX 5590A	31408	SAVANNAH RIVER
2993	RUAN LEASING COMPANY	5556 EXPORT BLVD.	31408	SAVANNAH RIVER
340	RYAN - WALSH, INC.	1600 ROGERS STREET	31407	SAVANNAH RIVER
1272	SAFETY - KLEEN CORPORATION	5217 AUGUSTA ROAD	31408	PIPE MAKERS CANAL
3025	SATILLA MINE	P. O. BOX 7192	31418	ALTAMAHA RIVER
223	SAVANNAH INTERNATIONAL AIRPORT	400 AIRWAYS AVENUE	31408	PIPE MAKERS CANAL
1048	SAVANNAH MANUFACTURING COMPANY	11 ARTLEY ROAD	31408	SAVANNAH RIVER
2627	SAVANNAH MARINE TERMINAL	110 FORBES ROAD	31404	SAVANNAH RIVER
3165	SAVANNAH PAINT MANUFACTURING COMPANY	100 OLD WEST LATHROP AVENUE	31415	SAVANNAH RIVER
3275	SAVANNAH REGIONAL INDUSTRIAL LANDFILL	P. O. BOX 7003	31418	ST. AUGUSTINE CREEK
2729	SAVANNAH STEEL & METAL COMPANY, INC.	P. O. BOX 1585	31401	SAVANNAH & OGEECHEE CANAL
2208	SAVANNAH STEEL & METAL COMPANY, INC.	501 WEST BOUNDARY STREET	31401	SPRINGFIELD CANAL
3146	SAVANNAH STEEL COMPANY	P. O. BOX 1988	3146	OGEECHEE CANAL
1206	SAVANNAH SUGAR REFINERY	P. O. BOX 710	31407	SAVANNAH RIVER
2151	SCHWERMAN TRUCKING COMPANY	205 LISSNER AVENUE	31408	SAVANNAH RIVER
209	SHEAROUSE LUMBER COMPANY	P. O. DRAWER C	31322	HARDIN CANAL
3376	SHERMAN CONCRETE PIPE	P. O. BOX 2528	31405	OGEECHEE CANAL
855	SHUMAN CONSTRUCTION COMPANY, INC.	4140 OGEECHEE ROAD	31405	LITTLE OGEECHEE RIVER
811	SOUTHEAST PAPER RECYCLING COMPANY	10 HOSS DRIVE	31408	SAVANNAH & OGEECHEE CANAL
1081	SOUTHEASTERN FREIGHT LINES, INC.	1717 OLD DEAN FOREST ROAD	31322	RASPBERRY CANAL
1710	SOUTHERN STATES PHOSPHATE & FERTILIZER COMPANY	1600 EAST PRESIDENT STREET	31404	SAVANNAH RIVER
1856	SPANISH MOSS PRINTING	501 EAST LIBERTY STREET	31401	SAVANNAH RIVER
2618	ST SERVICES - SAVANNAH TERMINAL	1 WOODCOCK ROAD	31404	SAVANNAH RIVER
2629	STEVEDORING SERVICES OF AMERICA	P. O. BOX 1767	31401	SAVANNAH RIVER
1421	STONE CONTAINER CORPORATION	P. O. BOX 548	31402	SAVANNAH RIVER
1172	SUPERIOR LANDFILL, PHASE 1, SITES 1 & 2	3001 LITTLE NECK ROAD	31419	LITTLE OGEECHEE RIVER

1168	THE CLOWHITE COMPANY	2500 WEST GWINNETT STREET	31401	SAVANNAH RIVER
1770	THE WESTBURY COMPANIES	120 GULFSTREAM ROAD	31407	PIPE MAKERS CANAL
2323	TIDEWATER BOATWORKS, INC.	P. O. BOX 5627	31404	WILMINGTON RIVER
1251	TOSCO SAVANNAH TERMINAL	110 FORBES ROAD	31404	SAVANNAH RIVER
2257	TOTAL DISTRIBUTION SERVICES, INC.	3000 TREMONT AVENUE	31405	SPRINGFIELD CANAL
1017	TRAVIS FIELD WATER QUALITY CONTROL PLANT	1400 EAST PRESIDENT STREET	31408	PIPE MAKERS CANAL
429	U.S. ARMY/HUNTER ARMY AIRFIELD	ENV. & NATURAL RES. DIV., 98 S. MIDDLEGROUND ROAD	31409-4629	FORREST RIVER
2411	U.S.P.S. VEHICLE MAINTENANCE FACILITY	2 NORTH FAHM STREET	31402-9721	SAVANNAH RIVER
157	UNION CAMP - CARTER-ADAMS LANDFILL	P. O. BOX 570	31419	LITTLE OGEECHEE RIVER
2751	UNION CAMP CORPORATION	P. O. BOX 570	31402	SAVANNAH RIVER
2447	UNITED PARCEL SERVICE, INC.	ROUTE 5 DEAN FOREST ROAD	31401	SALT CREEK
3278	UNITED PARCEL SERVICE, INC. SAVANNAH	3 PROSPERITY DRIVE	31401	SALT CREEK
1926	W. T. MAYFIELD SONS TRUCKING COMPANY, INC.	5514 SILK HOPE ROAD	31405	SALT CREEK
2872	WASTE MANAGEMENT OF SAVANNAH	P. O. BOX 1357	31408	SAVANNAH & OGEECHEE CANAL
832	WASTE MANAGEMENT OF SAVANNAH	2141 GAMBLE ROAD	31405	SPRINGFIELD CANAL
615	WATKINS MOTOR LINES, INC.	2400 TREMONT ROAD	31405	MUSGROVE CANAL
2773	WHITAKER POND	P. O. BOX 7192	31419	OGEECHEE CANAL
1015	WILSHIRE WATER QUALITY CONTROL PLANT	1400 EAST PRESIDENT STREET	31419	WILSHIRE CANAL

Appendix H – Class designations and definitions for GA Hazardous Site Inventory.

(Excerpted from Georgia - EPD 2004b, Hazardous Site Inventory (HIS) Instroduction)

Class I - "Sites that have resulted in known human exposure to regulated substances, that have sources of continuing releases, or that are causing serious environmental problems are designated on the HSI as Class I sites. These sites will be EPD's highest priority for corrective action. Persons responsible for these sites are required to perform corrective action and put a notice in the deed to their property. If a responsible party fails to perform corrective action as required, EPD may use the state hazardous waste trust fund to clean up the site and then recover the cost of the cleanup from the responsible party later. Class I sites retain that classification until they are cleaned up to meet applicable clean-up standards."

Class II - "For many sites listed on the HSI, further evaluation of the site must be done before EPD can decide whether corrective action is needed. These are known as Class II sites. Persons responsible for Class II sites are given an opportunity to voluntarily investigate and clean up their site and report their findings to EPD. The site is either removed from the HSI or reclassified as Class I or III, based on whether it meets the clean-up standards. While classified as Class II, sites are not designated as needing corrective action, so property owners do not immediately have to place notices on deeds and other property records. If a responsible party at a Class II site fails to do the required investigation, the site priority can be upgraded to Class I."

Class III - "Sites designated on the HSI as Class III sites are those that cannot meet residential clean-up standards but do meet alternative clean-up standards. These sites are designated as needing corrective action and the property owners are required to make the same deed notices as apply to Class I sites. These sites may require continued monitoring to make sure they continue to meet the appropriate standards. They will also require further corrective action before they can be used for residential purposes. Class III sites that meet the non-residential standards (Types 3 and 4) will be removed from the HSI once the property owner has filed a deed notice. Class III sites that can only meet the Type 5 standards remain on the HSI. Land use at sites that meet only the Type 5 standards is restricted, and the responsible party must provide long term monitoring and maintenance of the site."

Class IV - "These are sites where corrective action is already being conducted or has been completed under other federal or state authority. These sites are presumed to be in compliance with the Type 5 clean-up standards. They are designated as needing corrective action, remain on the HSI, and the property owner is required to file deed notices. This edition of the HSI has 179 Class IV sites. If it is ever determined that the corrective action at a Class IV site does not protect human health or the environment, then the site may be redesignated from Class IV to Class I. If it can be certified that the site meets one of the other clean-up standards (Types 1-4), it can be reclassified and may be removed from the HSI."

Class V - "These are sites that have a known release that requires corrective action and are not in compliance with any of the risk reduction standards of Rule 391-3-19-.07, but corrective action is being performed in compliance with a corrective action plan approved by the Director which will bring the site into compliance with the risk reduction standards."

Appendix I – Status, habitat, and threats of protected species found in Chatham, Effingham, and Jasper Counties.

(Sources: Rabolli and Ellington 1998; South Carolina - Wildlife and Freshwater Fisheries Division (SC-WFFD) 2003; U.S. FWS 2004; Georgia - WRD 2005)

Below is a compliation of threatened and protected species found in the study site, along with potential habitat threats.

The following abbreviations are used to indicate the legal status of federally-protected plants and animals or those proposed for federal protection by the US Fish and Wildlife Service:

E - Listed as endangered. The most critically imperiled species. A species that may become extinct or disappear from a significant part of its range if not immediately protected.

T - Listed as threatened. The next most critical level of threatened species. A species that may become endangered if not protected.

The following abbreviations are used at the state level by the Georgia and South Carolina Departments of Natural Resources to indicate the status of state-protected plants and animals or those proposed for state-protection in Georgia and South Carolina:

E - Listed as endangered. A species which is in danger of extinction throughout all or part of its range

T - Listed as threatened. A species which is likely to become an endangered species in the foreseeable future throughout all or parts of its range.

R - Listed as rare. A species which may not be endangered or threatened but which should be protected because of its scarcity.

U - Listed as unusual (and thus deserving of special consideration). Plants subject to commercial exploitation would have this status.

NL – Not Listed
ND – Not Determined

UPLAND ANIMALS

Birds

American Oystercatcher (*Haematopus palliates*) Federal: NL, GA: R SC: NL

Habitat - Sandy beaches; tidal flats; salt marshes

Use of FOPU - nesting habitat/ winter-mid-April

Threats - ND

Bachman's warbler (*Vermivora bachmanii)* Federal: E; GA: E; SC: NL

Habitat - Probably extinct; last seen in Georgia in 1976.

Use of FOPU - marshes and open water (fish are prey)/ uncommon winter visitor.

Threats - ND

Bald eagle (*Haliaeetus leucocephalus)* Federal: T; GA: E; SC: E

Habitat - Inland waterways and estuarine areas in Georgia.

Threats - Major factor in initial decline was lowered reproductive success following use of DDT. Current threats include habitat destruction, disturbance at the nest, illegal shooting, electrocution, impact injuries, and lead poisoning

Gull-billed tern (*Sterna nilotica*) Federal: NL, GA: T, SC: NL

Habitat - Nests in colonies on sandy sites; forages over salt marsh, dunes and other grassy areas for insects, spiders, and other invertebrates.

Use of FOPU - nesting habitat (obs. on Oysterbed Island across the North Channel)/ summer.

Threats – ND

Least Tern (*Sterna antillarum*) Federal: E, GA: R, SC: T

Habitat – Sandy beaches; sandbars.

Use of FOPU: spoil sites may provide important breeding grounds/ summer

Threats – ND

Peregrine Falcon (*Falco peregrinus*) Federal: E, GA: E, SC: NL

Habitat - Rocky cliffs & ledges; seacoasts

Use of FOPU: migratory habitat are wetlands and seacoast/ uncommon winter.

Threats - ND

Piping plover (*Charadrius melodus*) Federal: T, GA: T, SC: T

Habitat - Winter on Georgia's coast; prefer areas with expansive sand or mudflats (foraging) in close proximity to a sand beach (roosting).

Use of FOPU: shores and spoil areas/ winter

Threats - Habitat alteration and destruction and human disturbance in nesting colonies. Recreational and commercial development have contributed greatly to loss of breeding habitat.

Red-cockaded woodpecker (*Picoides borealis*) Federal: E, GA:E, SC: E

Habitat - Nest in mature pine with low understory vegetation (<1.5m); forage in pine and pine hardwood stands > 30 years of age, preferably > 10" dbh.

Threats - Reduction of older age pine stands and encroachment of hardwood midstory in older age pine stands due to fire suppression.

Swallow-tailed Kite (*Elanoides forficatus*) Federal: NL, GA: R, SC: NL

Habitat – River swamps; marshes (primarily Effingham County)

Use of FOPU - some foraging habitat (more typical of river bottoms of coastal plains)/ rare summer visitor)

Threats - ND

Wilson's Plover (*Charadrius wilsonia*) Federal: NL, GA: R, SC: NL

Habitat - Sandy beaches; tidal flats

Use of FOPU - shores and spoil areas/ summer

Threats - ND

Wood stork (*Mycteria Americana*) Federal: E, GA: E, SC: E

Habitat - Primarily feed in fresh and brackish wetlands and nest in cypress or other wooded swamps.
Use of FOPU: marshes/ summer
Threats - Decline due primarily to loss of suitable feeding habitat, particularly in south Florida. Other factors include loss of nesting habitat, prolonged drought/flooding, raccoon predation on nests, and human disturbance of rookeries.

Reptiles

Eastern indigo snake (*Drymarchon couperi*) Federal: T, GA: T, SC: T
Habitat - During winter, den in xeric sandridge habitat preferred by gopher tortoises; during warm months, forage in creek bottoms, upland forests, and agricultural fields.
Threats - Habitat loss due to uses such as farming, construction, forestry, and pasture and to overcollecting for the pet trade.

Gopher tortoise (*Gopherus polyphemus*) Federal: NL, GA: T, SC: E
Habitat - Well-drained, sandy soils in forest and grassy areas; associated with pine overstory, open understory with grass and forb groundcover, and sunny areas for nesting (Sandhills; dry hammocks; longleaf pine-turkey oak woods; old fields).
Threats - Habitat loss and conversion to closed canopy forests. Other threats include mortality on highways and the collection of tortoises for pets.

Spotted Turtle (*Clemmys guttata*) Federal: NL, GA: U, SC: T
Habitat – Heavily vegetated swamps, marshes, bogs, and small ponds; nest and possibly hibernate in surrounding uplands.
Threats – ND

Amphibians

Flatwoods salamander (*Ambystoma cingulatum*) Federal: T, GA: T, SC: E
Habitat - Pine flatwoods; moist savannas; isolated cypress/gum ponds. Adults and subadults are fossorial (i.e. having a burrowing life-style; lives underground); found in open mesic pine/wiregrass flatwoods dominated by longleaf or slash pine and maintained by frequent fire. During breeding period, which coincides with heavy rains from Oct.-Dec., move to isolated, shallow, small, depressions (forested with emergent vegetation) that dry completely on a cyclic basis. Last breeding record for Effingham County was in 1962-1963.
Threats – ND

Dwarf Siren (*Pseudobranchus striatus*) Federal: NL, GA: NL, SC: T
Habitat – Swamps; marshes; limesink ponds; cypress ponds.
Threats - ND

Mammals

Rafinesque's Big-Eared Bat (*Corynorhinus rafinesquii*) Federal: NL, GA: R, SC: E
Habitat – Pine forests; hardwood forests; caves; abandoned buildings (primarily Jasper County).
Threats - NL

PLANTS

Chaffseed (*Schwalbea Americana*) Federal: E, GA: E, SC: E
Habitat – ND
Threat - ND

Climbing buckthorn (*Sageretia minutiflora*) Federal: NL, GA: T, SC: NL
Habitat - Calcareous rocky bluffs, forested shell middens on barrier islands, and evergreen hammocks along streambanks and coastal marshes.
Threats - ND

Dwarf witch-alder (*Fothergilla gardenii*) Federal: NL, GA: T, SC: NL
Habitat - Low, flat, swampy areas, especially shrub-dominated margins of upland swamps (pocosins), Carolina bays, pitcherplant bogs, wet savannahs, and Atlantic white-cedar swamps.
Threats - ND

Pondberry (*Lindera melissifolia*) Federal: E, GA: E, SC: E
Habitat - Shallow depression ponds of sandhills, margins of cypress ponds, and in seasonally wet low areas among bottomland hardwoods Threats - Drainage ditching and subsequent conversion of habitat to other uses; domestic hogs, cattle grazing, and timber harvesting; and apparent lack of seedling production

Pondspice (*Litsea aestivalis*) Federal: NL, GA: T, SC: SC
Habitat - Margins of swamps, cypress ponds, and sandhill depression ponds and in hardwood swamps.
Threats - ND

Tidal Marsh obedient plant (*Physostegia leptophylla*) Federal: NL, GA: T, SC: NL
Habitat - Wet muck or peat in shallow water of river swamp openings and in the margins of both fresh and brackish (tidal) marshes
Threats - ND

AQATIC SPECIES

Mammals

Humpback whale (Megaptera novaeangliae) Federal: E, GA: E, SC: E
Habitat - Coastal waters during migration.
Threats - Entanglement in commercial fishing gear and collisions/disturbance associated with boats and barges.

Right (Northern) whale (*Eubalaena glacialis*) Federal: E, GA: E, SC: E
Habitat - Mate and calve in shallow coastal waters.
Threats - Initial decreases probably due to overharvesting. Slow population growth after exploitation halted may be due to collisions/disturbance associated with boats and barges, inbreeding, inherently low reproductive rates, or a reduction in population below a critical size for successful reproduction.

West Indian manatee (*Trichechus manatus*) Federal: E, GA: E, SC: E
Habitat - Coastal waters, estuaries, and warm water outfalls.
Use of FOPU: creeks and rivers/ uncommon summer visitor
Threats - Initial decreases probably due to overharvesting for meat, oil and leather. Current mortality due to collisions with boats and barges and from canal lock operations. Declines also related to coastal development and loss of suitable habitat, particularly destruction of seagrass beds.

Fish

Shortnose sturgeon (*Acipenser brevirostrum*) Federal: E, GA: E, SC: E
Habitat - Atlantic seaboard rivers.
Threats - See Fisheries Section.

Reptiles

Green sea turtle (*Chelonia mydas*) Federal: E, T, GA: T, SC: T
Habitat - Rarely nests in Georgia; migrates through Georgia's coastal waters.
Threats - Exploitation for food, high levels of predation, loss of nesting habitat due to human encroachment, hatchling disorientation due to artificial lights on beaches, and drownings when trapped in fishing and shrimping nets.

Hawksbill sea turtle (*Eretmochelys imbricata*) Federal: E GA: E, SC: NL

Habitat - Migrates through Georgia's coastal waters (Open ocean; sounds; coastal rivers; beaches).

Threats - Primary causes of population decline are development and modification of nesting beaches and exploitation for the shell. Secondary causes include egg consumption, use of the skin for leather, and heavy predation of eggs and hatchlings.

Kemp's ridley sea turtle (*Lepidochelys kempi*) Federal: E, GA: E, SC: E

Habitat - Migrates through Georgia's coastal waters (Open ocean; sounds; coastal rivers; beaches).

Threats - Overharvesting of eggs and adults for food and skins and drowning when caught in shrimp nets.

Leatherback sea turtle (*Dermochelys coriacea*) Federal: E, GA: E, SC: E

Habitat - Rarely nests in Georgia; migrates through Georgia's coastal waters (Open ocean; sounds; coastal beaches).

Threats - Human exploitation, beach development, high predation on hatchlings, and drowning when caught in nets of commercial shrimp and fish trawls and longline and driftnet fisheries.

Loggerhead sea turtle (*Caretta caretta*) Federal: T, GA: T, SC: T

Habitat - Nests on Georgia's barrier island beaches; forages in warm ocean waters and river mouth channels.

Use of FOPU: creeks and rivers/ any season

Threats - Loss of nesting beaches due to human encroachment, high natural predation, drownings when turtles trapped in fishing and shrimping trawls, and marine pollution.

Appendix J – Newspaper coverage of proposed port in Jasper County, SC.

Article (text and front page picture) from the Atlanta Journal Constitution, December 8th, 2004. (Source: http://www.ajc.com)

Port hopes run into blockade

Jasper County dreams of easier life, but Savannah, Charleston fight upstart

Dan Chapman - Staff
Wednesday, December 8, 2004

Hardeeville, S.C. --- The river, just beyond Gascoigne Bluff and the palmetto-pocked field of oak trees and weathered tombstones, courses through the lives of the Rev. Renty Elvis Kitty Jr. and his parishioners at Pilgrim Baptist Church.

It carried ancestors to the slave markets of Savannah. It sent slave-harvested rice and cotton to New York and London.

Today, many in the Rev. Kitty's flock work at the port, the sugar refinery or the tourist shops that line the Savannah River's namesake town. The preacher, though, harbors a dream of riverine riches that will keep his people from having to cross over into Georgia in search of better lives.

Folks in Jasper County, one of the poorest corners of South Carolina, desperately want to build a port from scratch on marshland below Pilgrim Baptist. A private company is offering to finance and run a $350 million container terminal.

"It's like the gospel song says, 'Payday Is Coming After a While,' " Kitty said. "With that port coming in, there'd be a great payday for parishioners and their families."

Outsiders don't universally support the so-called South Atlantic International Terminal, which would be conveniently located 10 miles closer to the ocean than the Port of Savannah's container terminal.

The people who run Savannah's port have essentially joined their rivals, 80 miles to the north in Charleston, to keep Jasper County from potentially siphoning off lucrative container traffic. They have stymied Jasper's grandiose plans once and will try to do so again.

They have powerful allies: Georgia Gov. Sonny Perdue and South Carolina Gov. Mark Sanford, to name two. And they hold a trump card: Georgia owns the Jasper County property being considered for the port.

Jim Lientz, chief operating officer for the state of Georgia and a Port Authority board member, said that if Jasper again tries to condemn the property, "we have to react."

"It takes a long time to build a port, to get all the permits, to develop the infrastructure. It's also quite expensive," Lientz said. "So I would say that there won't be any vessel docking at any potential port for a long time."

Ports protect turf

Gary Morelli hopes to prove Lientz wrong. Morelli works for Stevedoring Services of America, a Seattle-based conglomerate that runs cargo terminals worldwide and wants to develop the Jasper port.," Savannah and Charleston "will do whatever they need to protect their turf," Morelli said as container-laden trucks and trains crisscrossed the terminal outside his Savannah office. "But we believe there's enough future growth in the area to keep everyone happy."

Global container traffic has exploded, due largely to China's manufacturing juggernaut. East Coast ports, Savannah in particular, have notched record levels of trade as the world's shippers use larger vessels to reach more distant harbors via the Panama Canal.

No East Coast port has grown faster than Savannah's since 1998. Port officials predict 150 percent growth by 2018. Container Berth 8, a $110 million expansion set to open in 2006, will swell the port's container capacity by 20 percent.

"There's an awful lot of growth that's going to occur in the Southeastern corridor the next 10, 20 years," Lientz said. "That's why we're expanding at the Garden City [Terminal], and Charleston is working to expand at the Navy base."

South Carolina plans a $500 million port expansion, adding three berths and 250 acres of container space at the old Charleston Naval Base.

South Carolina and Georgia officials insist their ports will be able to handle the growth in traffic. Morelli isn't convinced, and chides the states' leaders for thwarting a much-needed boost for the region's economy.

"South Carolina and Georgia have budgetary constraints, so it's hard for them to commit $350 [million] to $400 million," Morelli said. "What we bring to the table is the ability to finance the operation and do it with no bureaucratic red tape."

SSA approached Jasper County officials in 2000 with plans to build a 1,776-acre terminal on land used by the Army Corps of Engineers to deposit muck dredged from the river.

The privately held company, with 4,600 employees at 150 ports worldwide, said it could spend as much as $750 million on wharves, cranes, warehouses and roads. The prospect of an immediate 400 jobs is enough to make locals dream.

"People that live here are just plain poor," said Charlie Monzel, a construction worker preparing to bait with corn a hog-hunting field near Daufuskie Island.

Forty percent of residents leave Jasper for work each day. Per capita income is $17,356, ranking Jasper County 43rd out of 46 South Carolina counties.

Bea Jones sees the new port as a godsend. "I have three children, and only one lives in Jasper County," said Jones, who is a member of the Hardeeville City Council. "We want children to stay in the area and raise families. If you send your kids to college, they don't come home."

Georgia fights project

For 15 years local officials have dreamed of a container port along the Savannah River. SSA offered in December 2000 to buy the property for $8.5 million, give it to Jasper County and then lease it back. The Georgia Department of Transportation, which owns the land, refused to sell.

The county condemned the property a month later. Georgia sued. A South Carolina circuit court judge ruled in favor of Jasper County. Georgia appealed to the South Carolina Supreme Court and prevailed in

September 2003. Judges ruled that condemning property for a private company was not in the public interest.

Unbowed, Jasper created a county port authority. County officials are expected to again file for condemnation, an act that will most likely restart the judicial merry-go-round.

"We have always been somewhat surprised that if a company comes up with $350 million to invest, rather than fight against it, the two governors would fight to have it locate in their state," said Morelli.

Ports, though, aren't auto plants --- economic development plums that states fight over. The Georgia Ports Authority is a quasi-public entity, and the state's taxpayers help foot the bill for expensive expansions. Competition potentially dilutes the value of the facility.

"I don't believe you can have a completely private enterprise over there that wouldn't potentially harm the taxpayers of Georgia," said state Senate President Pro Tem Eric Johnson (R-Savannah). "Being closer downriver is a more attractive docking facility for shippers, where time is money."

Judy Jennings, a port watchdog, said SSA would undercut port authority shipping contracts at every turn.

"Competition quickly siphons off business from nearby ports. SSA could give a slightly better deal by offering loss-leader prices and global deals [to shippers]," Jennings said. "I'm the local vocal granny screaming louder than anybody. It's a bad idea. It's nuts."

Morelli said start-up costs are too steep to let SSA offer below-rate deals to shippers just to lock in business. An SSA-commissioned study shows that while container traffic would initially dip at the ports of Savannah and Charleston, the downturn is "likely to be modest." Eventually the new port would "generate excess demand" for all ports, the study concluded.

Georgia and South Carolina officials probably won't take that chance. Together they're exploring how their ports can continue to prosper while planning for the day when space runs out. None of their scenarios for the future involves SSA gaining sole control of a Jasper port.

Looking for a sign

Kitty, like the Hardeeville councilwoman, the wild hog hunter and just about everybody else in this Lowcountry backwater, doesn't care who owns the port, as long as it's built.

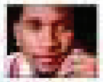
The preacher, whose white cinder-block church is enveloped by 200-year-old oaks, their limbs festooned with Spanish moss, is a patient man. All he wants is a sign.

"Most people, they want to deal with tangible things," he said. "If they could see some dirt moving, some trucks driving, or something in the news that says a groundbreaking is set to begin, they'd be more apt to speak about it."

PORT OF CHARLESTON, S.C. Chart tracks Port of Charleston, S.C. 10-year container volume (in thousands) since 1995. 2004: 1,724,586.

PORT OF SAVANNAH: Chart tracks Port of Savannah 10-year container volume (in thousands) since 1995. 2004: 1,572,734.

Source: S.C. State Ports Authority, GPA Marketing/ KATIE RIDLEY / Staff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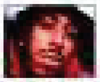
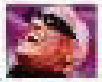
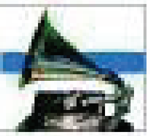

Ludacris


Kanye West


Ray Charles

The Grammy Award nominations



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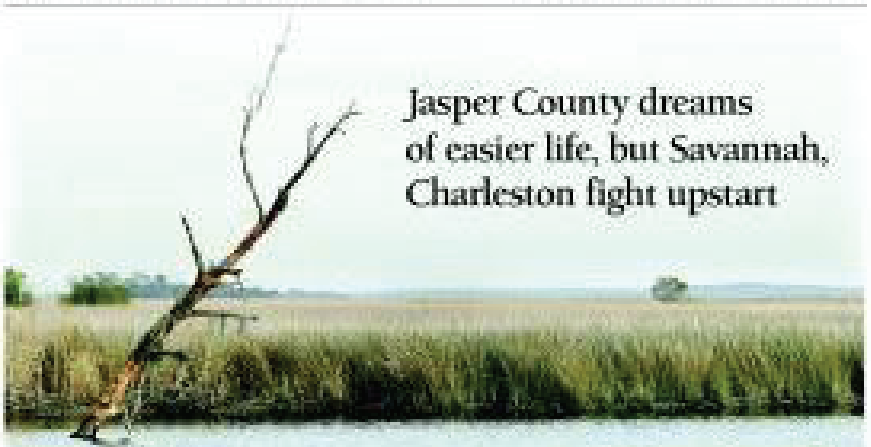
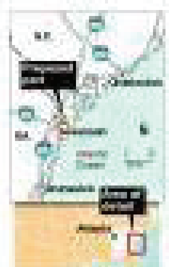


Jasper County dreams of easier life, but Savannah, Charleston fight upstart

Port hopes run into blockade



Agency lightens stream protections

Decision about 'wet-weather' ditches worries environmentalists

India's Coke, Pepsi may bear warning

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Appendix K – Annotated Bibliography

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Keywords: Sediment, contaminants, Savannah River, heavy metals, PAH, pesticides, TBT; PCB
Summary (Abstract): Pollution histories of the Savannah estuary for trace metals, polycyclic aromatic hydrocarbons (PAH), polychlorinated biphenyls (PCB), pesticides, and butyltins were constructed using six sediment cores collected from various sites inthe estuary. Silver, cadmium and zinc increased steadily over time, suggesting nonpoint sources associated with human population growth, while chromium showed a maximum in progressively more recent sediments going downstream, indicating a 1950s-era source up-estuary and subsequent movement of contaminated sediments downstream. Mercury was enriched in only two cores, and in those, maxima occurred in sediments of different age, indicating spatial and temporal variability in mercury contamination. Lead showed inconsistent distribution patterns among the cores that were attributed to local sources and downstream sediment transport. PAH concentrations were maximal in sediments from the 1950s and early 1960s in some cores, while PCB concentrations peaked in 1967. Pesticide and butyltin concentrations were very low. These data may be useful for evaluating potential pollutant recontamination in the event that a proposed flow regime is expected to result in significant sediment resuspension and transport. Several sediment cores surrounded Fort Pulaski: Cores A, B, C, F, and G at Cockspur Island and cores E, LC92-1, and LC92-2 at McQueen's Island.

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Summary: This report was written to supply the Georgia Ports Authority with water quality data for the Tier II EIS for the Savannah Harbor Deepening Project. Four of the Georgia Ports Authority (GPA) stations were established in waters directly surrounding FOPU, GPA-23, -24, -03 (located in tributaries of and within South Channel, next to McQueens Island), and GPA-26 (Front River). Maps of stations and transects are included in the document.

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Keywords: Isotope dilution, icp-ms, technetium-99, iodine-129, tritium, environmental
Abstract: Surface water samples were collected from streams on and around the Savannah River Site (SRS) to assess current H-3, Tc-99, and I-129 concentrations in the water. The SRS is a nuclear facility operated by Westinghouse Savannah River Company for the U.S. Department of Energy. Water quality parameters were measured at the time of collection using field portable instrumentation. The tritium activity was determined by liquid scintillation spectrometry. The isotopes, Tc-99 and I-129, were determined by isotope dilution/inductively coupled plasma-mass spectrometry (D.M. Reals, Determination of technetium-99 in aqueous samples by isotope dilution inductively coupled plasma-mass

spectrometry. Presented at the 3rd International Conference on Nuclear and Radiochemistry, Vienna, September 1992, unpublished data; D.M. Peals, P. Chastagner and P.K. Turner, Analysis of iodine-129 in aqueous samples by inductively coupled plasma-mass spectrometry. Presented at the 38th Annual Conference on Bioassay, Analytical and Environmental Radiochemistry, Santa Fe, NM, November 1992). Elevated activities of H-3, Tc-99, and I-129 were found in some surface streams of the SRS, principally due to migration of ground water from beneath old seepage basins, however the levels in the waters leaving the SRS are well below any regulatory guidelines.

Beaton, G., P. Sykes and J. Parrish (2003). Annotated Checklist of Georgia Birds (ACOGB). Georgia Ornithological Society.
URL: http://www.gos.org
Keywords: Georgia, birds
Summary: (from website) "Provides comprehensive detail of range, status, and dates of occurrence for 446 species of which 407 are now accepted on Regular Species List."

Benson, A. (2004). Perna viridis. Nonindigenous Aquatic Species Database, Gainesville, FL.
URL: http://canal.er.usgs.gov/SpFactSheet.asp?speciesID=110
Keywords: Green mussel; native range, life history, habitat, nonindigenous occurrences, means of introductions, impacts, control and management
Summary: USGS fact sheet about green mussels. Introduction to the US occurred via ballast water. Tampa, FL is the first location to report their occurrence in 1999. They have potential impacts on power plants as a fouling organism, and to mussels, oysters, or other species through competition, displacement, and/or the introduction of diseases and pests.

Bristol, P.L. and A.C. Boozer (2003). South Carolina Water Use Report. 2001 Summary., South Carolina Department of Health and Environmental Control (SC-DHEC).
URL: http://www.scdhec.gov/eqc/water/pubs/wtruse2001.pdf
Keywords: Jasper County, SC, water withdrawal/use
Summary: There were no reported uses of surface water in Jasper County. Groundwater was used primarily for irrigation (373.2 mil gal/day) and public supply (538.22 mil gal/day). Other significant uses of groundwater were 16 mil gal/day for facility-reported, non-specific uses and 7.0 mil gal/day for aquaculture.

Brush, Janell, Tom Reinert and Amanda Wrona (2004). Savannah River Estuary and Tidal Freshwater Wetlands. Workshop to Develop 905 (b) Reconnaissance Report for SRE, Savannah, GA, Unpublished manuscript, The Nature Conservancy, Georiga Chapter and U.S. Fish and Wildlife Service.
Keywords: Savannah River Estuary, salt marsh, freshwater tidal marsh, fish, birds, harbor deepening and modifications
Summary: This report provided background information on the Savannah River Estuary for those participating in the workshop to develop the 905 (b) Reconnaissance Report, including habitat types, flora and fauna, and various river modifications that have been implemented over the years. It discusses impacts to flora (including marsh habitats) and fauna (especially fish species) as attibuted to the tide gate and harbor modifications.

Chapman, Dan (2004). Port hopes run into blockade: Jasper County dreams of easier life, but Savannah, Charleston fight upstart. Atlanta Journal Constitution. Hardeeville, SC.
URL: www.ajc.com

Clarke, J.S., C.H. Smith and J. B. McConnell (1999). Aquifer Interconnection in Eastern Chatham County, Georgia, as Indicated by Hydraulic and Water-Chemistry Data. Proceedings of the 1999 Georgia Water Resources Conference, held March 30-31, 1999, at the University of Georgia, Athens, GA.

Clarke, J.S., C.M. Hacke and M.F. Peck (1990). Geology and ground-water resources of the coastal area of Georgia, USGS, Water Resources Division, Bulletin 113.
Keywords: Ground-water pumpage, surficial aquifer, Floridan aquifer, Brunswick aquifer, Savannah, chloride, water quality
Summary: This report describes water use (pumpage), geologic units, and hydraulic properties (including water levels) of 5 ground-water sources for coastal Georgia counties: the surficial aquifer, upper and lower Brunswick aquifers, and upper and lower Floridan aquifers. Throughout coastal Georgia including the Savannah area, the upper Floridan is the principal artesian aquifer, supplying the majority of drinking and industrial water, the surficial aquifer is used primarily for domestic lawn irrigation and for drinking water in rural areas, and the upper and lower Brunswick aquifers (some use occurs where there are multi-acquifer wells, that also tap the upper Floridan below, the lower aquifer is not present in Chatham County) and lower Floridan aquifers (few wells tap it because it is deeply buried, >570 ft, and contains saline water) are rarely used. Savannah is a major pumping center of the upper Floridan aquifer (73 Mgal/d in 1986), using equal amounts for drinking water and for industry, which has caused major declines in the water levels to >20 ft. below sea level and has created cones of depression due to lower transmissivity than other Georgia coastal areas. The Floridan aquifer is semiconfined between dense layers of limestone or dolomite, layered with vuggy, fossiliferous zones that are permeable and allow water ciculation. The depth to the top of the aquifer at Fort Pulaski is 110 ft and is ca. 250-260 ft. thick (the shallowest/thinnest along the Georgia coast).

Clarke, J.S. and R.E. Krause (2001). Use of Ground-Water Flow Models for Simulation of Water-Managment Scenarios for Coastal Georgia and Adjacent Parts of South Carolina. Proceedings of the 2001 Georgia Water Resources Conference, held March 26-27, 2001, at the University of Georgia, Athens, GA.
URL: http://ga.water.usgs.gov/publications/gwrc2001clarke.html

Coastal Georgia Regional Development Center (2004). History. Retrieved 2004.
URL: http://coastalgeorgiardc.org/
Keywords: Coastal Georgia, middens, history, natural environment, climate, economy, land use planning
Summary: Contains historical (colonization, Indians, middens, etc) and current (land use, etc) information about coastal Georgia.

Collins, M.R., A.R. Rourk, C.K. Way and W.C. Post. (2002). Temporal and Spatial Distribution of Estuarine-Dependent Species in the Savannah River Estuary, South Carolina Department of Natural Resources. Prepared for Georgia Ports Authority, Savannah, GA.
Keywords: Crustaceans, finfish, abundance, species richness, water quality, Savannah River, Atlantic and Shortnose Sturgeon
Abstract: During the dates from September 2000-September 2002, trawls and gillnets were used to collect finfish and crustaceans twice monthly from 8 sites located in the Back, Front, Middle, and South Channel of the Savannah River. Finfish and crustacean abundance and species richness were quantified for each site monthly, and lengths were measured. A total of 88 species of finfish and crustaceans, including the threatened Atlantic Sturgeon and endangered Shortnose Sturgeon, were collected. The site furthest downstream, where the Back, Front, and Middle Rivers converge in the South Channel (site SR01) was found to be the most diverse (and the closest to Fort Pulaski NM). This study showed that the Savannah River is ecologically important to many commercially and recreationally important species, however the "[] scarcity of certain valuable species", such as red drum, striped bass, and spotted seatrout, compared to other estuaries in the region may indicate compromised habitat function due to river divergence and dredge and fill activities.

Dame, R.F. (1979). "The Abundance, Diversity and Biomass of Macrobenthos on North Inlet, South Carolina, Intertidal Oyster Reefs." Proceedings of the National Shellfisheries Association 69.
Keywords: South Carolina, oysters, macrobenthos
Summary (from Abstract): "The seasonal abundance of macrobenthos varied from 2467-4077 m^{-2} with a maximum in early summer. Species number varied from 15-24 per sample with a total of thirty-seven species found. Nineteen species in North Inlet were common to Georgia and North Carolina oyster reefs."

Deutsch, C.J., J.P. Reid, R.K. Bonde, D.E. Easton, H.I. Kochman and T.J. O'Shea (2003). Seasonal movements, migratory behavior, and site fidelity of West Indian manatees along the Atlantic Coast of the United States.
Keywords: Savannah River, West Indian manatees (Trichechus manatus), endangered species, migration, coastal development, watercraft, radio-tag
Abstract: The West Indian manatees utilize coastal, estuarine, and riverine systems in Georgia during the warm summer months. They typically migrate seasonally between south Florida, Georgia, and southern South Carolina, but venture as far north as Rhode Island, during the summer; median migration distances were 280 km (one way). They are endangered throughout their span of Atlantic coastline due to collisions with watercraft, entanglement in fishing lines, and loss of habitat via water quality degradation as coastal populations increase and/or mechanical injury to seagrass beds due to propellers and trawls.

DeVivo, J.C., C.J. Wright, M.W. Byrne and S. McCort (2005). Vital signs monitoring in the Southeast Coast Inventory & Monitoring Network - Phase II (draft) Report, National Park Service, Southeast Coast Network, Atlanta, Georgia.
Keywords: SECN, NPS, Fort Pulaski, vital signs, monitoring questions, resource-based adaptive management

Summary: Summaries of Natural Resource Issues can be found in Appendix 5. Water bodies identified at parks including Fort Pulaski can be found in Appendix 8. Monitoring questions asked of Fort Pulaski can be found in Appendix 9. This program to identify vital signs will help to standardize monitoring formats and strategies throughout southeastern parks. Vital signs are used because they are measureable, predictable, and cost effective. Fort Pulaski identified groundwater issues, coastal/shoreline erosion issues, and anthropogenic stressers as high priority.

Donahue, J.C (2003). Ground-Water Quality in Georgia for 2002, Georgia Environmental Protection Division, Circular 12R.
Keywords: Georgia, ground water, surficial aquifer, Floridan aquifer
Summary: Summarizes the chemical quality of groundwater throughout Georgia; used by EPD to assess trends of groundwater resources. Includes a summary of each aquifer in Georgia, i.e. sediments they are comprised of, hydraulic head, depth, thickness, etc.

Donahue, John C. (2004). Ground-water quality in Georgia for 2003. Atlanta, GA, Georgia Department of Natural Resources, Environmental Protection Division, Georgia Geologic Survey: 85.
Keywords: Georgia, ground water
Summary: EPD personnel collected 124 water samples from 113 wells and nine springs on the Ground-Water Monitoring Network during calendar year 2002 for volatile organic and limited inorganic analysis. These wells and springs monitor the water quality of nine aquifer systems in Georgia. Comparisons of analyses of water samples collected during calendar year 2002 were made with analyses for the Ground-Water Monitoring Network dating back to 1984, permitting the recognition of temporal trends. Table 4-1 lists the contaminants and pollutants detected at stations of the Ground-Water Monitoring Network during 2002. Although isolated water quality problems existed at specific localities, the quality of water from most of the Ground-Water Monitoring Network stations remains excellent.

Eudaly, E.M. (1999). Reconnaissance Planning Aid Report on Savannah River Basin Study. Atlanta, GA, U.S. Fish and Wildlife Service, Southeast Region.
Keywords: Savannah National Wildlife Refuge, wetlands, water quality, dams, flow, Savannah River, Corps of Engineers
Summary: Discusses impacts of various Savannah River alterations (dams, deepening, dredging) on flora and fauna associated with the Savannah National Wildlife Refuge. Also, makes recommendations for mitigating and preventing further impacts to SNWR.

Fanning, J.L (2003). Water Use in Georgia by County for 2000 and Water-Use Trends for 1980-2000., USGS, Information Circular 106.
URL: http://ga.water.usgs.gov/pubs/other/ggs-ic106/pdf/ggs-ic106.pdf
Keywords: Chatham County, Effingham County, GA, Water withdrawal/use
Summary: Chatham County: The top 3 uses of surface water were thermoelectric power (98.24 mil gal/day), industry (43.30 mil gal/day), and irrigation (1.24 mil gal/day). Of industry, the major users are chemical and paper companies. All public supply comes from groundwater at 33.45 mil gal/day. Effingham County: The top 3 uses of surface water were thermoelectric power (95.20 mil gal/day), public supply (31.09 mil gal/day), and industry

(17.27 mil gal/day). Of industry, all surface water uses are attributed to paper companies. Only 5.29 mil gal/day of groundwater is used with the majority of use attributed to industry and public supply.

Federal Register (2000). Standards for Defining Metropolitan and Micropolitan Statistical Areas. Notice: Vol. 65, No. 249. Part IX, Office of Management and Budget.
Keywords: Metropolitan statistical area definition
Summary: (from Register) "Announces OMB's adoption of Standards for Defining Metropolitan Statistical Areas. These new standards replace and supersede the 1990 standards for defining Metropolitan Statistical Areas."

Federal Register (2002). Intent to Prepare a Draft Tier II Environmental Impact Statement (DEIS) for the Savannah Harbor Expansion Project, Savannah, GA (Volume 67, Number 14).
URL: http://www.epa.gov/fedrgstr/EPA-IMPACT/2002/January/Day-22/i1448.htm

Fledderman, P., D. Padgett, M. Steedley, T. Jannik and R. Turner (2004). Chapter 4, Environmental Surveillance. Savannah River Site Environmental Report for 2003. A.R. Mamatey (ed). Prepared for the U.S. Department of Energy.

GAEMN (2005). Georgia Automated Environmental Monitoring Network, Griffin Campus, University of Georgia. Retrieved 2004.
URL: http://www.georgiaweather.net/
Keywords: Georgia, weather, precipitation, Savannah
Summary: Provides weather and precipitation statistics for several stations throughout Georgia, including Savannah.

Georgia - CRD (2003). Georgia Shrimp Landings, 1972-2003., Department of Natural Resources.
URL: http://crd.dnr.state.ga.us/assets/documents/shrprice.pdf
Keywords: Shrimp, Georgia, landings (lbs), revenue
Summary: Summary of average pounds caught and revenue earned in Georgia for the years 1972-2003.

Georgia - CRD (2004). Georgia (Soft, Peeler, Hard) Blue Crab Landings, 1989-2003, Department of Natural Resources.
URL: http://crd.dnr.state.ga.us/assets/documents/crab89_03.pdf
Keywords: Blue crabs, Georgia, landings, revenue
Summary: Summary of average pounds caught and revenue earned for blue crab landings from 1989-2003.

Georgia - CRD (2005a). Coastal Resources Division Website. Brunswick, GA, Georgia Department of Natural Resources.
URL: http://crd.dnr.state.ga.us//
Summary: The website includes information on these areas: *Coastal Management Program* (about GCMP, Coastal Advisory Council, grant program, marsh dieback, marsh hammocks,

technical assistance, water quality), *Commercial Fishing* (announcements, blue crab, industry newsletters, landings and licensing statistics, meetings, regulations, studies), *Saltwater Recreational Fishing* (artificial reefs, boating information, fisheries management , fishing education and information, fishing licenses & regulations, freshwater fishing information, research projects), *Current Events* (blue crab fishery crisis, career opportunities, coastal resources events, press releases, public hearings/meetings), *Education and Outreach* (beaches, coastal critters, CoastFest, Earth Day nature trail & pavilion, Georgia Sound newsletter, publications & TV programs), *General Information* (citizen advisory groups/committees, coastal links, contact ss, CRD mailing list, directions to CRD, trouble shooting PDF files, web site policies), *Laws and Regulations* (beach driving rules, Coastal Marshlands Protection Act, federal consistency regulations, Shore Protection Act), and *Permits and Public Notices* (public notices, pending projects, beach driving, dock permits, federal donsistency, marsh permits, revocable licenses & nationwide permits, shore permits, when a permit is needed).

Georgia - CRD (2005b). Summary of Georgia historical landings by broad category, 1994-2005, Department of Natural Resources.
URL: http:/crd.dnr.state.ga.us.assets/documents/broadhis.pdf
Keywords: Georgia, coast, commercial fish landings
Summary: Summary of pounds and revenue by category of commercial fishery for 1994-2003.

Georgia - EPD (2000). Solid Waste Landfills within the State of Georgia Permitted through December 1999. Documentation Report 00-2. Geologic Survey Branch.

Georgia - EPD (2001). Savannah River Basin Management Plan. Atlanta, GA, Department of Natural Resources.
Keywords: Savannah River, water quality, aquifers, population, basin morphology, land cover, land use, NPDES, nonpoint source pollution
Summary: A comprehensive report describing the Savannah River Basin characteristics, water quality and quantity, point and non-point souces affecting water quality within the basin, and other concerns and future issues.

Georgia - EPD (2002a). Environmental Protection Division Website. Atlanta, GA, Georgia Department of Natural Resources.
URL: http://www.dnr.state.ga.us/dnr/environ/
Summary: *Geologic Resources*: Ground-Water Quality in Georgia Reports are available online for calendar years 1997 through 2002. Unfortunately, the earliest online reports are not "text-searchable" and some lack the figures and tables included in the printed documents. However, they still comprise a useful backdrop of ground-water quality trends in the state.*Hazardous Site Inventory*: This directory of sites includes; name, location, property owner, regulated substances released, threats to human health and environment posed by the release, status of cleanup activities, cleanup priority, and the GA EPD Director's "determination regarding corrective action". *Enforcement Order:* A search page allows one to access a list (for a particular authority, facility, location, or time period) of the proposed and executed EPD enforcement orders resulting from action under the Water Quality Control Act (including Surface Water Allocation); Air Quality Act; Comprehensive Solid Waste

Management Act; Erosion and Sedimentation Act; Safe Drinking Water Act; Surface Mining Act; or the Underground Storage Tank Act. *Regulated Community:* These pages include information on the Air Protection Branch, Geologic Survey Branch, Land Protection Branch, Water Protection Branch, and Water Resources Branch. The Land Protection Branch includes a list of leaking underground storage tanks - there are 79 in Camden County, GA (34 of them located at the Naval Submarine Base at Kings Bay.)

Georgia - EPD (2002b). Section D - Savannah River Site (SRS) and Vogtle Electric Generating Plant (VEGP). Georgia Environmental Radiation Surveillance Report 2000 – 2002.
Keywords: Savannah River Site, Vogtle Electric Plant, radiation, tritium, plutonium, cesium, groundwater, air
Summary: Georgia DNR's most extensive environmental radiation monitoring network is focused on an area in Georgia adjacent to and downstream of the U.S. Department of Energy's Savannah River Site in South Carolina and Georgia Power Company's Vogtle Electric Generating Plant (VEGP) in Georgia. A combined monitoring network between the 2 sites has been monitored since 1978.

Georgia - EPD (2004a). Fish tissue contamination database. Athens, GA, Department of Natural Resources.
Keywords: The annual Fish Consumption Guidelines are determined (wholly or in part) by the detection of contaminants in fish tissues, as tested by the Georgia DNR Environmental Protection Division.

Georgia - EPD (2004b). Georgia Environment webpage - Hazardous Site Inventory (Sites Listed by County), Department of Natural Resources.
URL: http://www.dnr.state.ga.us/dnr/environ/gaenviron_files/gaenviro.htm

Georgia - EPD (2004c). Georgia Regulated Community webpage - List of Industrial Stormwater permittees, Department of Natural Resources.
URL: http://www.dnr.state.ga.us/dnr/environ/regcomm_files/regcomm.htm

Georgia - WRD (2005). Nongame Plants and Animals website. Natural Heritage Program, Department of Natural Resources.
URL: http://georgiawildlife.dnr.state.ga.us
Keywords: Georgia, wildlife, natural areas, birds
Summary: Information regarding natural areas managed by GA-Wildlife Resources Division of DNR under the Nongame Wildlife and Natural Heritage Program. Information regarding birds found along Georgia's Colonial Coast Birding Trail. Also, contains information on threatened and endangered species under the Georgia Rare Species Information link.

Georgia DOT (2005). Georgia Department of Transportation Website.
URL: www.dot.state.ga.us/dot
Keywords: Chatham and Hwy 80
Summary: Provides information on current and proposed road construction.

Georgia Magazine (2005). Little Tybee, Williamson, and Cabbage Islands. Georgia Magazine. Retrieved 2005.
URL: http://georgiamagazine.com
Keywords: Little Tybee Island, conservation easement, The Nature Conservancy
Summary: Information regarding the history of ownership of Little Tybee conservation area, habitat types, size, managment, and visitation.

Georgia Museum of Natural History and Georgia Department of Natural Resources (2000). Georgia Wildlife Web.
URL: http://museum.nhm.uga.edu/GAWildlife/gaww.html
Keywords: Georgia, wildlife, taxonomy
Summary: The purpose of this web site is to provide information concerning the common species of mammals, birds, reptiles, and amphibians found in the State of Georgia. Each species has a home page which contains a description of the animal; its taxonomic relationships; information about the animal's biology, natural history, distribution, and conservation status; and a review of similar animals which might be confused with it.

Georgia Ports Authority (1998). Environmental Impact Statement (EIS): Savannah Harbor Expansion Feasibility Study. Savannah, GA, Submitted by Georgia Ports Authority under NEPA.
URL: http://www.sysconn.com/harbor/Tier%20I/Tier%20I%20EIS.pdf
Keywords: Savannah Harbor, environmental impacts, channel deepening, water quality, biota, erosion
Summary: Outlines potential impacts of deepening the Savannah Harbor in 2-ft increments, from the present 42-ft depth to 44, 46, 48, and 50 feet deep. For each alternative, the channel will be widened at 12 bends and at KITB to allow easier ship navigation, and the Middle River will be closed to reestablish flow in New Cut. Under NEPA (National Environmental Policy Act), GPA was required to submit an EIS (Environmental Impact Statement), which outlines potential impacts to the environment. In this report, GPA assesses impacts to wetlands, endangered species, fisheries, benthic communities, birds, marine mammals, water quality, historic properties, and potable surface and ground water supplies under the maximum harbor-deepening alternative of 50 feet. Although potential biological changes around Fort Pulaski NM may occur due to altered water quality (especially DO and chloride levels), there is no indication that the monument itself will be impacted (although ship-wake generated erosion is currently a problem on the channel side).

Georgia Ports Authority (2002a). Savannah Harbor Expansion Feasibility Study: Potential Groundwater Impacts, Georgia Ports Authority.
Keywords: Floridan aquifer, Brunswick aquifer, surficial aquifer, Savannah harbor, dredge, salinity
Summary: This study was done to evaluate the impacts of deepening the Savannah harbor on groundwater resources, particularly the Floridan aquifer. Each aquifer is more shallow and thinner at Fort Pulaski and Tybee Island than they are at southwestern portions of Georgia, and thus the concerns were that deepening might breach the confining layers. The conclusion of the study was that although the quantity and quality of the Floridan aquifer are not likely to be impacted, the deepening may impact the Brunswick aquifer, as it will cut

through confining units of the Miocene unit B sediments. The Miocene unit B sediments and Oligocene sediments (they comprise the top of the Floridan aquifer) are closest to the current channel depth near Fort Pulaski, thus this is the biggest area of concern. Previous deepening has already cut through the surficial aquifer and through the Miocene unit A sediments.

Georgia Ports Authority (2002b). A Year of Positive Growth for Georgia's Ports. Georgia AnchorAge. 42.
URL: www.gaports.com/
Keywords: Georgia ports, economy, revenue, jobs
Summary: A magazine issued quarterly by the Georgia Ports Authority, describing the economy of port facilities in Georgia and other news.

Georgia Ports Authority (2004). "Deepwater Ports are one of Strongest Economic Engines". Georgia AnchorAge. 44.
URL: www.gaports.com/index2.html
Keywords: Georgia ports, economy, revenue, jobs
Summary: A magazine issued quarterly by the Georgia Ports Authority, describing the economy of port facilities in Georgia and other news.

Georgia Ports Authority (2005). Georgia Ports Authority website.
URL: http://www.gaports.com/index2.html

Georgia State Climatology Office (2005). Historical data and summaries. Georgia State Climatology website. Athens, GA, University of Georgia.
URL: http://climate.engr.uga.edu
Keywords: Georgia, Savannah, climate, weather, precipitation
Summary: This website provides historic/long-term weather data and current weather conditions for stations located throughout the state.

Gilligan, M.R., R.S. Pitts, J.P. Richardson and T.R. Kozel (1992). "Rates of accumulation of marine debris in Chatham County, Georgia". Marine Pollution Bulletin 24(9): 436-441.
Keywords: Pollution, Chatham County, Fort Pulaski, plastic, metal, glass
Abstract: Four sites of different types, barrier beach, salt marsh, upper tidal river, and lower Savannah River area, were chosen in Chatham County, Georgia to monitor washed-up, marine debris during 1989-1990. Collected debris was sorted by type (glass, metal, styrofoam, plastic), weighed, and measured. Plastics and styrofoam constituted the largest portion and weight of debris found, and no medical wastes were found at any site. From the sampling effort, an estimated total of 102 kg/km/yr of debris washes up in coastal Chatham County, and if this is extrapolated to include the total shoreline in Chatham County at high tide (approx. 400 km), then 40.8 tons of waste washes up on its coast each year. According to Beachsweep data of 1989, this is less than that reported for 12/22 coastal states. Two sites were located on FOPU, one on McQueens and one on Cockspur; Cockspur had the highest rate and McQueens had the third highest rate of marine debris accumulated of the four sites.

Gillis, K. and M. Millikin (1999). MRFSS State Fact Sheet, Georgia. Marine Recreational Fisheries Statistics Survey (MRFSS), National Marine Fisheries Service (NMFS), NOAA.

URL: http://www.st.nmfs.gov/st1/recreational/fact_sheets/1998/ga98fs.pdf
Keywords: Georgia, saltwater recreational fishing, age and income distribution of anglers, fish length, fish species
Summary: Provides information on both fish (5 most frequently encountered and the mean length of harvested fish) and anglers (income, age, and residence).

Goldberg, E. D., J. J. Griffin, V. Hodge, M. Koide and H. Windom (1979). "Pollution History of the Savannah River Estuary." Environmental Science & Technology 13(5): 588-594.

Govus, T.E (1998). Fort Pulaski National Monument Inventory Final Report, Part A: Plants, Prepared for the National Park Service, Southeast Region.
Keywords: Fort Pulaski NM, vegetation classifications, plants, habitat, salt marsh, maritime forest, shrub communities, maintained grasslands, spoil deposit, tidal shrubland, tidal herbaceous marsh, taxonomy
Summary: This report documents the plant communities that exist within Fort Pulaski NM and taxonomically identifies the plants observed in each habitat. As a result of this study, 134 new species were documented for Fort Pulaski NM, with 110 of those species observed during this study (the remaining 24 are likely to occur in the area and have not been confirmed). In addition, this study identified 2 species of concern (Florida privet Forestiera segregata and Swamp dock Rumex verticillatus), numerous exotic/nuisance species, but no federally registered threatened/endangered species within the park. Included in this report are lists of species and descriptions underneath their habitat types. This report helped to establish an ongoing monitoring program of exotic species by park officials.

Holland, A. F., D. M. Sanger, C. P. Gawle, S. B. Lerberg, M. S. Santiago, G. H. M. Riekerk, L. E. Zimmerman and G. I. Scott (2004). "Linkages between tidal creek ecosystems and the landscape and demographic attributes of their watersheds." Journal of Experimental Marine Biology and Ecology 298(2): 151-178.
Keywords:Tidal creeks, impervious cover, watershed development, landscape indicators, ecosystem responses, nursery habitat, carolina coastal estuaries, salt-marsh sediments, biological integrity, chesapeake bay, benthic index, quality, river, fluoranthene, tolerances, community
Abstract: Twenty-three headwater tidal creeks draining watersheds representative of forested, suburban, urban, and industrial land cover were sampled along the South Carolina coast from 1994 to 2002 to: (1) evaluate the degree to which impervious land cover is an integrative watershed-scale indicator of stress'. (2) synthesize and integrate the available data on linkages between land cover and tidal creek environmental quality into a conceptual model of the responses of tidal creeks to human development,- and (3) use the model to develop recommendations for conserving and restoring tidal creek ecosystems. The following parameters were evaluated: human population density, land use, impervious cover, creek physical characteristics, water quality, sediment chemical contamination and grain size characteristics, benthic chlorophyll a levels, porewater ammonia concentration, fecal coliform concentration, and macrobenthic and nekton population and community characteristics. The conceptual model was developed and used to identify the linkages among watershed-scale stressors, physical and chemical exposures, and biological responses of tidal creeks to human development at the watershed scale. This model provides a visual

representation of the manner in which human population growth is linked to changes in the physiochemical environment and ultimately the nursery habitat function of tidal creeks and the safety of seafood harvested from headwater tidal creeks. The ultimate stressor on the tidal creek ecosystem is the human population density in the watershed and associated increases in the amount of impervious land cover. Measurable adverse changes in the physical and chemical environment were observed when the impervious cover exceeded 10-20%, including altered hydrography, changes in salinity variance, altered sediment characteristics, increased chemical contaminants, and increased fecal coliform loadings. Living resources responded when impervious cover exceeded 20-30%. The impacts on the living resources included reduced abundance of stress-sensitive macrobenthic taxa, reduced abundance of commercially and recreationally important shrimp, and altered food webs. Headwater tidal creeks appear to provide early warning of ensuing harm to larger tidal creeks, tidal rivers and estuaries, and the amount of impervious cover in a watershed appears to be an integrative measure of the adverse human alterations of the landscape. Through education and community involvement, a conservation ethic may be fostered that encourages the permanent protection of lands for the services they provide.

Hyland, J. L., L. Balthis, C. T. Hackney, G. McRae, A. H. Ringwood, T. R. Snoots, R. F. Van Dolah and T. L. Wade. (1998). Environmental quality of estuaries of the Carolinian Province: 1995. Annual statistical summary for the 1995 EMAP Estuaries Demonstration Project in the Carolinian Province., NOAA Technical Memorandum NOS ORCA 123. NOAA/NOS, Office of Ocean Resources Conservation and Assessment, Silver Spring, MD.
Abstract: A study was conducted to assess the environmental condition of estuaries in the EMAP Carolinian Province (Cape Henry, VA St. Lucie Inlet, FL). A total of 87 randomly located stations were sampled from July 5 to September 14, 1995 in accordance with a probabilistic sampling design. Wherever possible, synoptic measures were made of: (1) general habitat condition (depth, physical properties of water, sediment grain-size, organic carbon content), (2) pollution exposure (sediment contaminant concentrations, sediment toxicity, low dissolved oxygen conditions in the water column, ammonia and sulfide in sediment porewater), (3) biotic conditions (diversity and abundance of macroinfauna and demersal biota, pathological disorders in demersal biota), and (4) aesthetic quality (presence of anthropogenic debris, visible oil, noxious sediment odor, water clarity). Percentages of degraded vs. undegraded estuarine area were estimated based on these various environmental indicators. The data also were compared to results of a related EMAP survey conducted in 1994 in this same region as part of a multi-year monitoring effort.

Jennings, C.A. and R.S. Weyers (2003). Temporal and Spatial Distribution of Estuarine-Dependent Species in the Savannah River Estuary: July 2000-December 2002., Georgia Cooperative Fish and Wildlife Research Unit, University of Georgia. Prepared for the Georgia Ports Authority, Savannah, GA.
URL: http://www.sysconn.com/harbor/Study%20Reports/SRE_EST-DEP_ANL-RPT_01.pdf
Keywords: Icthyoplankton, fish, Savannah River Estuary (SRE), species richness, density
Summary: Species richness and density of fish in the Savannah River channel, marsh edge, and tidal creeks was quantified by season, salinity zone, tidal zone, and by diel patterns (day vs. night) at 8 stations between approx. RKM 12-45 (salinity range 0-1 to >15 ppt). Overall, 43 families housing 91 species were found to use the SRE, most of which can be considered

estuarine-generalists (generally 5.0-15.0 ‰), inhabiting most habitats during most seasons. Some (>10%) marine fish utilized the SRE during high tide (moving in with the salt wedge), but few freshwater obligate species utilize the SRE. FMP (fishery management plan) species comprised 25% of the total species caught, >90% of the total number of fish caught (the majority were bay anchovy, Atlantic menhaden, Atlantic croaker, and spot). Density and species richness of fish in the channel were not statistically different between salinity zones, but were significantly lower during the fall (when spawning activity declined).

Johnstone, S (2004). Echoes from the Past: The Archeology of Fort Pulaski., NPS, Southeast Archeological Center.
URL: http://www.cr.nps.gov/seac/pulaski/
Keywords: Fort Pulaski NM, history, archeology, shell mounds, Civil War, management, Savannah
Summary: Provides information on history, cultural resources, archeology, and management of Fort Pulaski NM and the surrounding area. It also includes a section on future archeological research for the area.

Kevill, C. Personal Communication. Park Ranger, Fort Pulaski National Monument, June 14, 2004.

Kneib, R.T. (1997). The Role of Tidal Marshes in the Ecology of Estuarine Nekton. Oceanography and Marine Biology: an Annual Review. A.D. Ansell, R.N. Gibson and M. Barnes, UCL Press. 35: 163-220.
Keywords: Georgia, salt marsh, fish, invertebrates, transport chain
Summary: Discusses invertebrate and fish usage of the marsh, including the names of specific species. Describes how food/energy from the marsh gets transferred from residents and larvae to transients to open water species.

Krause, R.E. and J.S. Clarke (2001). Saltwater Contamination of GroundWater at Brunswick, Georgia and Hilton Head Island, South Carolina. Proceedings of the 2001 Georgia Water Resources Conference, held March 26-27, 2001, at the University of Georgia, Athens, GA.
URL: http://ga.water.usgs.gov/publications/gwrc2001krause.html

Kreuzwieser, Mark (2004). Jasper steams ahead on port. Carolina Morning News. Ridgeland, SC.
URL: www.lowcountrynow.com

Latham, P.J. and W.M. Kitchens (1996). Changes in vegetation and interstitial salinities in the lower Savannah River: 1986-1994. Final Report. Charleston, SC., U.S. Fish and Wildlife Service: 16 pp.

Latham, P.J., L.G. Pearlstine and W. M. Kitchens (1993). "Species association changes across a gradient of freshwater, oligohaline, and mesohaline tidal marshes along the lower Savannah River." Wetlands 14(3): 174-178.
Keywords: Savannah River, marsh, vegetation zonation, salinity

Abstract: In the present study, plant species patterns and associated environmental factors of freshwater, oligohaline, and mesohaline marshes of the Savannah National Wildlife Refuge were compared. DECORANA, an ordination method, was used to group vegetation classes. Discriminant function analysis was applied to resulting classes to quantify differences in salinity, elevation, and distance from tidal channels among classes. Nine vegetation classes across freshwater and brackish marshes corresponded significantly to salinity differences between sites. Combinations of elevation and distance from tidal channel were significant in separating vegetation classes within sites. Scirpus validus (Vahl) was the only species to occur over the entire range of measured physical parameters and accounted for much of the overlap between vegetation classes. The proportion of correctly classified vegetation classes between sites was 70%. Within each site, the proportion of correct classification was lower in the freshwater marsh (77% correct classifications) when compared with the oligohaline (82%), strongly oligohaline (83%), and mesohaline (85%) sites. Although overlap among classes was greater in the more diverse freshwater marsh, [results] may reflect differences in the steepness of environmental gradients between sites and the scale at which physical parameters were measured rather than actual plant distribution overlap. Results suggest that resources are more finely divided among species in the freshwater marsh, resulting in a less distinct dominance hierarchy when compared with the mesohaline marsh.

Loganathan, B.G., K.S. Sajwan, J.P. Richardson and C.S. Chetty (2001). "Persistent Oganochlorine Concentrations in Sediment and Fish from Atlantic Coastal and Brackish Waters off Savannah, Georgia, USA." Marine Pollution Bulletin 42(3): 246-250.

Long, E. R., D. D. Macdonald, S. L. Smith and F. D. Calder (1995). "Incidence of Adverse Biological Effects within Ranges of Chemical Concentrations in Marine and Estuarine Sediments." Environmental Management 19(1): 81-97.
Keywords: Sediment quality guidelines, ecological risk assessment, contaminants, biological effects, marine, estuarine, quality criteria, acute toxicity, harbor, fish
Abstract: Matching biological and chemical data were compiled from numerous modeling, laboratory, and field studies performed in marine and estuarine sediments. Using these data, two guideline values (an effects range-low and an effects range-median) were determined for nine trace metals, total PCBs, two pesticides, 13 polynuclear aromatic hydrocarbons (PAHs), and three classes of PAHs. The two values defined concentration ranges that were: (1) rarely, (2) occasionally, or (3) frequently associated with adverse effects. The values generally agreed within a factor of 3 or less with those developed with the same methods applied to other data and to those developed with other effects-based methods. The incidence of adverse effects was quantified within each of the three concentration ranges as the number of cases in which effects were observed divided by the total number of observations. The incidence of effects increased markedly with increasing concentrations of all of the individual PAHs, the three classes of PAHs, and most of the trace metals. Relatively poor relationships were observed between the incidence of effects and the concentrations of mercury, nickel, total PCB, total DDT and p,p'-DDE. Based upon this evaluation, the approach provided reliable guidelines for use in sediment quality assessments. This method is being used as a basis for developing National sediment quality guidelines for Canada and informal, sediment quality guidelines for Florida.

Malloy, K.J. (2004). Nekton community composition and the use of tidal marshes in the lower Savannah River during drought conditions, The University of Florida.

Meader, J.F (2003). Fort Pulaski National Monument: Administrative History. C. Brinkley, Southeast Region NPS, Cultural Resources Division.
URL: http://www.nps.gov/fopu/pdf/fopu_ah.pdf
Keywords: Fort Pulaski NM, history, Civil War, cultural resources, natural resources, development, park administration, management issues
Summary: This document outlines the history at Fort Pulaski, including human use during prehistoric and war times, and the acquisition, construction, and development of the park during the early 1900's to the present. Included are other government agencies that either have long-standing management or cooperation with the park, or have had rights to use/still use the park property for other issues. Information about visitor resources, statistics and trends are included. Lastly, current and long-standing management issues are addressed in this report.

Meyer, J., M. Alber, W. Duncan, M. Freeman, C. Hale, R. Jackson, C. Jennings, M. Palta, E. Richardson, R. Sharitz and J. Sheldon (2003). Summary Report Supporting the Development of Ecosystem Flow Recommendations for the Savannah River below Thurmond Dam., University of Georgia.
URL: http://outreach.ecology.uga.edu/publications/pdf/summaryreport.pdf
Keywords: Savannah River Basin, flow regulation, Thurmond Dam, hydrology, fish, floodplain, estuary, biological processes
Summary: Hydrological alteration from hydropower operation and channel modifications has changed the structure and function of floodplain and aquatic ecosystems of the Savannah River. This report was prepared to provide background information for participants in a workshop convened to develop science-based flow recommendations for Thurmond Dam that will enhance ecological conditions in ecosystems of the Savannah River below the dam.

Michener, W. K., E. R. Blood, K. L. Bildstein, M. M. Brinson and L. R. Gardner (1997). "Climate change, hurricanes and tropical storms, and rising sea level in coastal wetlands." Ecological Applications 7(3): 770-801.
Keywords: Climate change, coastal wetlands in southeastern united states, colonial waterbirds and hurricanes, comparative studies, conceptual models of, hurricanes, moisture-continuum model, sea level rise, space-for-time substitution, tropical storms, luquillo, experimental forest, southeastern united-states, puerto-rico, north-carolina, south-carolina, bird populations, environmental-research, spartina-alterniflora, conservation biology, caribbean hurricanes
Abstract: Global climate change is expected to affect temperature and precipitation patterns, oceanic and atmospheric circulation, rate of rising sea level, and the frequency, intensity, timing, and distribution of hurricanes and tropical storms. The magnitude of these projected physical changes and their subsequent impacts on coastal wetlands will vary regionally. Coastal wetlands in the southeastern United States have naturally evolved under a regime of rising sea level and specific patterns of hurricane frequency, intensity, and timing. A review of known ecological effects of tropical storms and hurricanes indicates that storm timing, frequency, and intensity can alter coastal wetland hydrology, geomorphology, biotic

structure, energetics, and nutrient cycling. Research conducted to examine the impacts of Hurricane Hugo on colonial waterbirds highlights the importance of longterm studies for identifying complex interactions that may otherwise be dismissed as stochastic processes.Rising sea level and even modest changes in the frequency, intensity, timing, and distribution of tropical storms and hurricanes are expected to have substantial impacts on coastal wetland patterns and processes. Persistence of coastal wetlands will be determined by the interactions of climate and anthropogenic effects, especially how humans respond to rising sea level and how further human encroachment on coastal wetlands affects resource exploitation, pollution, and water use. Long-term changes in the frequency, intensity, timing, and distribution of hurricanes and tropical storms will likely affect biotic functions (e.g., community structure, natural selection, extinction rates, and biodiversity) as well as underlying processes such as nutrient cycling and primary and secondary productivity. Reliable predictions of global-change impacts on coastal wetlands will require better understanding of the linkages among terrestrial, aquatic, wetland, atmospheric, oceanic, and human components. Developing this comprehensive understanding of the ecological ramifications of global change will necessitate close coordination among scientists from multiple disciplines and a balanced mixture of appropriate scientific approaches. For example, insights may be gained through the careful design and implementation of broad-scale comparative studies that incorporate salient patterns and processes, including treatment of anthropogenic influences. Well-designed, broad-scale comparative studies could serve as the scientific framework for developing relevant and focused long-term ecological research, monitoring programs, experiments, and modeling studies. Two conceptual models of broad-scale comparative research for assessing ecological responses to climate change are presented: utilizing space-for-time substitution coupled with long-term studies to assess impacts of rising sea level and disturbance on coastal wetlands, and utilizing the moisture-continuum model for assessing the effects of global change and associated shifts in moisture regimes on wetland ecosystems. Increased understanding of climate change will require concerted scientific efforts aimed at facilitating interdisciplinary research, enhancing data and information management, and developing new funding strategies.

Mitsch, W.J. and J.G. Gosselink (2000). Wetlands, (3rd edition) John Wiley and Sons, NY.

National Atmospheric Deposition Program (2004). National Trends Network.
URL: http://nadp.sws.uiuc.edu/
Keywords: Atmospheric deposition, non-point source pollution, long-term monitoring, precipitation
Summary: Atmospheric deposition data have been collected since 1978 through the inter-agency National Atmospheric Deposition Program /National Trends Network. Measured parameters include: calcium, magnesium, potassium, sodium, ammonium, nitrate, inorganic nitrogen (from ammonium and nitrate), chloride, sulfate, and hydrogen (calculated from both laboratory and field pH measurements). Data are collected daily, weekly, or monthly and are then summarized in an annual form for trend analysis. The monitoring stations closest to CUIS are: Fort Frederica National Monument ([GA23], 31.2253 lat., -81.3922 long, 2 m elevation. National Park Service, Air Resources Division. Operational from 9/1985 through 9/1988.), Sapelo Island ([GA33], 31.3961 lat., -81.2811 long, 3 m elevation. Georgia Department of Natural Resources. Operational since 11/2002), Okefenokee National

Wildlife Refuge ([GA09], 30.7403 lat., -82.1286 long, 47 m elevation. U.S. Fish and Wildlife Service, Air Quality Branch. Operational since 6/1997), and Bradford Forest ([FL03], 29.9747 lat., -82.1981 long, 44 m elevation. St Johns River Water Management District and the University of Florida. Operational since 10/1978).

Natural Resources Defense Council (NRDC) (1996). Flying Off Course - Environmental Impacts of America's Airports.
URL: http://www.eltoroairport.org/issues/nrdc-flying.html
Keywords: Airports, noise, volatile organic carbons, contaminants
Summary: This report provides information on noise, land use, air emissions, water quality, and climate change associated with airports. Also included is a ranking list of air emissions for several US airports of various sizes. Airports are exempt from reporting to the EPA Toxic Release Inventory database.

New Georgia Encyclopedia (NGE) (2004). Savannah; Rice; Cotton, The New Georgia Encyclopedia. Retrieved 2004.
URL: www.georgiaencyclopedia.org/
Keywords: Georgia, Savannah, cotton, rice, history
Summary: This website was created by Georgia Humanities Council in partnership with the Office of the Governor, the University of Georgia Press, and the University System of Georgia/GALILEO. It provides information on the arts, business and industry, cities and counties, education, folklife, government and politics, history and archaeology, land and resources, literature, media, religion, science and medicine, sports and recreation, and transportion for towns and cities throughout Georgia. For Savannah, it provided historical information from the colonial area to now. It also provided information on the history of cotton and rice grown in Georgia.

NMFS (pers. comm.). Landings by Distance from U.S. Shores 2002, State of Georgia, National Marine Fisheries Service (NMFS), Fisheries Statistics and Economics Division.
URL: http://www.st.nmfs.gov/pls/webpls/mf_8850_landings.results

NOAA - CSC (1997). C-CAP South Carolina Land Cover Project. Charleston, SC., NOAA Coastal Services Center.
URL: http://www.csc.noaa.gov/crs/lca/s_car.html
Keywords: South Carolina, landcover
Summary: Landcover of coastal South Carolina in GIS format for 1990, 1995, and change between the two.

NOAA - CSC (2001). Coastal Change Analysis Program, Georgia. Charleston, SC, NOAA Coastal Services Center.
URL: http://www.csc.noaa.gov/crs/lca/georgia.html
Keywords: Georgia, landcover
Summary: Landcover of coastal Georgia in GIS format for 1992, 1997, and change between the two.

NOAA - CSC (2005). State Hurricane History: Georgia, NOAA Coastal Services Center.

URL: http://www.csc.noaa.gov/hez_tool/states/georgia.html
Keywords: Georgia, hurricanes
Summary: Hurricane history for the state of Georgia from 1854 through 2004.

NOAA CO-OPS (2004). Station Data for Fort Pulaski, GA (8670870), NOAA, National Ocean Service (NOS). Retrieved 2004.
URL: http://co-ops.nos.noaa.gov
Keywords: Tides, water level, weather, winds, Fort Pulaski station
Summary: Provides weather and tidal information for the Fort Pulaski station in Georgia.

NPS (1995). Resource Managment Plan: Fort Pulaski National Monument. Department of the Interior.
Keywords: Fort Pulaski, natural resources, monitoring, cultural resources, history
Summary: This document contains information on park boundaries, historical features, natural resources, archeological and anthropological resources, and current monitoring programs within the park boundaries. Also included are the park's areas of concern, monitoring needs, and budget.

NPS (2001). Baseline Water Quality Data Inventory and Analysis: Fort Pulaski National Monument. Technical Report NPS/NRWRD/NRTR-99/250, Water Resources Division, United States Department of the Interior, Washington, D.C.
URL: http://nrdata.nps.gov/FOPU/nrdata/water/baseline_wq/docs/FOPUWQAA.PDF
Keywords: Water quality, Fort Pulaski NM
Summary: Horizon Systems Corporation gathered, formatted, and analyzed water quality data from 1971 to 1998, stored in 6 EPA databases for 3 miles upstream and 1 mile downstream of Fort Pulaski NM and on the park itself. There were 106 STORET stations for the whole study area, 9 within the park. Water quality parameters were compared to EPA criteria.

NPS (2003a). Fort Pulaski: Official Map and Guide.
Keywords: Fort Pulaski, park map and guide, history
Summary: Fort Pulaski brochure, provides overview of the park, a map, and information on historical sites.

NPS (2003b). FY 2003 Budget and Annual Performance Plan.
URL: http://www.nps.gov/fopu/pphtml/documents.html
Keywords: Fort Pulaski, budget, goals
Summary: This document contains highlights of the park's budget, which funds specific goals in the annual performance plan.

NPS (2004). Fort Pulaski National Monument. NPS website. Retrieved 2004.
URL: www.nps.gov/fopu
Keywords: Fort Pulaski NM, history, park information, natural resources, cultural resources

NPS - Southeast Coast Network (2005). "Vital signs monitoring in the Southeast coast inventory & monitoring network, phase II (draft) report."
URL: http://www.nature.nps.gov/im/units/secn/reports.htm

Summary (from source): "The Southeast Coast Network (SECN) monitoring plan is being developed over a multi-year period following specific guidance from the National Park Service, Washington Office (WASO). Networks are required to document monitoring planning progress in three distinct phases and to follow a standardized reporting outline. Each phase report requires completion of specific portions of the outline. This Phase I Report emphasizes work on Chapter 1 (Introduction and Background), Chapter 2 (Conceptual Models) and Chapter 11 (Literature Cited), but includes partial work on several other chapters (3, 6, and 8). Some chapters will remain unwritten until future Phase Reports are completed. This document presents the SECN framework and approach to vital signs monitoring planning and a summary of work accomplished to date. Specifically the Phase I Report summarizes existing information on National Park Service and related natural resource monitoring programs within the network, presents an overview of biological and physical resources of network parks, describes monitoring goals and needs, and presents a theoretical framework with conceptual models for guiding future efforts."

Peck, M.F. (1999). Water Levels in the Upper Floridan Aquifer in the Coastal Area of Georgia, 1990-98. Proceedings of the 1999 Georgia Water Resources Conference, held March 30-31, 1999, at the University of Georgia, Athens, GA.

Perry, M.J. and P.J. Mackun (2001). Population Change and Distribution, 1990-2000. Census 2000 Brief, U.S. Census Bureau.
Keywords: Population, growth rate, United States, Georgia
Summary: Describes population change throughout the United States between 1990 and 2000. It shows the distribution of people throughout the U.S. The period between 1990-2000 experienced the greatest population growth ever recorded; population growth rates were greatest in the West and the South. Georgia was the fastest growing state in the South.

Puckett, L.J. (1994). Nonpoint and Point Sources of Nitrogen in Major Watersheds of the United States. Water-Resources Investigations Report 94–4001. U.s. Geological Survey.
Abstract: Estimates of nonpoint and point sources of nitrogen were made for 107 watersheds located in the U.S. Geological Survey's National Water- Quality Assessment Program study units throughout the conterminous United States. The proportions of nitrogen originating from fertilizer, manure, atmospheric deposition, sewage, and industrial sources were found to vary with climate, hydrologic conditions, land use, population, and physiography. Fertilizer sources of nitrogen are proportionally greater in agricultural areas of the West and the Midwest than in other parts of the Nation. Animal manure contributes large proportions of nitrogen in the South and parts of the Northeast. Atmospheric deposition of nitrogen is generally greatest in areas of greatest precipitation, such as the Northeast. Point sources (sewage and industrial) generally are predominant in watersheds near cities, where they may account for large proportions of the nitrogen in streams. The transport of nitrogen in streams increases as amounts of precipitation and runoff increase and is greatest in the Northeastern United States. Because no single nonpoint nitrogen source is dominant everywhere, approaches to control nitrogen must vary throughout the Nation. Watershed-based approaches to understanding nonpoint and point sources of contamination, as used by the National Water-Quality Assessment Program, will aid water-quality and environmental managers to devise methods to reduce nitrogen pollution.

Rabolli, C. and K. Ellington (1998). Fort Pulaski National Monument Inventory Final Report, Part B: Vertebrate Animals, Prepared for the National Park Service, Southeast Region.
URL: http://www.nps.gov/fopu/pulaskione/Templates/1998%20Fauna%20Inventory.html
Keywords: Fort Pulaski NM, vertebrate animals, fish, birds, amphibians, reptiles, mammals, threatened and endangered species
Summary: This report was written in conjunction with the Fort Pulaski NM Inventory Final Report for Plants. The study updated and compared findings to a previous survey of vertebrate animals conducted by Southeastern Wildlife Services in 1981. These surveys were conducted mostly on upland areas that include maritime forest and shrub communities and mowed lawns and fields, except for one marsh upland survey and fish surveys that were done in 3 drainage canals, one of the mosquito ponds, and the South Channel of the Savannah River. The upland portions surveyed was primarily on Cockspur Island, though some was associated with the highway and former Central of Georgia Railroad Grade on McQueen's Island. Spotlight surveys documented deer and raccoons, traps captured smaller mammals, drift-fences caught amphibians and reptiles, point counts were used to survey birds, and fish were caught using seine, blocking, and dip nets. Ten of the 11 endangered or threatened species that potentially occur Fort Pulaski NM were either observed by this study or by park officials. Also included are special sections on deer, raccoons, exotic species (especially the European starling which competes with native birds for food and habitat), Hantavirus previously found to occur in marsh rice rats at Fort Pulaski by the CDC, lists of endangered species in Chatham County and their federal status, and previous vertebrate surveys done in Chatham County recorded at the UGA Museum of Natural History. Overall, the low diversity of vertebrates at Fort Pulaski was attributed to the recent establishment of upland habitat by humans.

Reinert, T. R., C. A. Jennings, T. A. Will and J. E. Wallin (2005). "Decline and potential recovery of striped bass in a southeastern US estuary." Fisheries 30(3): 18-25.
Keywords: Savanna river estuary, morone-saxatilis, environmental-conditions, speculative hypothesis, Chesapeake Bay, population, recruitment, retention, habitat, Georgia
Abstract: Declines in striped bass (Morone saxatilis) populations have been well documented over the past 30 years. During the 1980s, Savannah River striped bass also suffered a population decline, when catch per unit effort (CPUE; #/hr) of large adults declined by 97% and egg production declined by 96%. Loss of freshwater spawning habitat through harbor modifications was identified as the primary cause. Population restoration began in 1990 and included stock enhancement and environmental remediation. Salinity levels in historic spawning and nursery habitats are now similar to those prior to the decline. Recently, egg production and CPUE of large striped bass both seem to be increasing. The increasing abundance of larger fish should result in continued increases in egg production, and eventually recruitment, and recent captures of wild-spawned larvae and juveniles confirm natural reproduction. However, current efforts to deepen the Savannah Harbor may preclude striped bass recovery by once again allowing saltwater intrusion into upper estuary spawning and nursery habitats. This case history may serve as another example of successful striped bass recovery efforts yet also underscores the need for continued monitoring and innovative research where populations are at risk or imperiled.

Reinert, Thomas Robert (2004). Decline and Recovery of Striped Bass in the Savannah River Estuary: Synthesis and Re-analysis of Historical Information and Evaluation of Restoration Potential. Athens, GA, The University of Georgia: 121 pp.
Keywords: Savannah River history, striped bass, harbor deepening
Summary: Provides historical accounts of saltwater intrusion in the Savannah River since the 1700s, and the effects of deepening, dredging, and the tide gate on salinity and its impacts on the striped bass (*Morone saxatilis*) population. It concludes with the present status of striped bass (which appear to be recovering) and the potential effects of further deepening.

Richardson, J.P. and K. Sajwan (2001). Baseline Monitoring and Analysis of Health of the Salt Marsh Ecosystem of Fort Pulaski National Monument, Using Sediment, Oysters and Water Samples., Prepared for Fort Pulaski National Monument, NPS.
URL: http://www.nps.gov/fopu/pulaskione/Water_quality/WATER.HTM (text only)
Keywords: Water quality (DO, nutrients, turbidity, temperature, salinity, conductivity, nitrate, phosphate), heavy metals, organic compounds, oysters, sediments
Summary: Water quality, and heavy metals and organic compounds within sediment and oyster tissue were analyzed for 6 sites surrounding Fort Pulaski NM during November 2000. Water quality was within range of normal conditions. Organic compound analyses indicated that PCB's were below detection limits and AP's were relatively low (compared to industrial areas) for sediments and oysters, but PAH's in sediments ranged from 2.6-140 ng/g dry-wt and were even higher in oyster tissues ranging from 18-210 ng/g dry-wt (considerable), suggesting that bioaccumulation may have been occurring in oysters. Mercury accumulation was low.

Richardson, J.P. and K. Sajwan (2002). Baseline Monitoring and Analysis of Health of the Salt Marsh Ecosystem of Fort Pulaski National Monument, Using Sediment, Oysters and Water Samples; Year II, Prepared for Fort Pulaski National Monument, National Park Service.
Keywords: Water quality (DO, nutrients, turbidity, temperature, salinity, conductivity, nitrate, phosphate), heavy metals, organic compounds, oysters, sediments
Summary: This was a follow-up study to Richardson and Sajwan 2001, conducted in November 2001, that analyzed the same criteria for water quality, sediments, and oyster tissues at 3 additional sites within the Fort Pulaski NM. Again, they found water quality to be within the normal range. PCB's, AP's, and PAH's were low in sediments and oysters, but one PAH, DDE, was detectable in the soil and at considerable levels in oyster tissues (140-258 pg/g wet-wt). Mercury levels could not be analyzed for sediments during this study, but levels in oyster tissues ranged from 140-258 pg/g wet-wt. Arsenic in oyster tissues ranged form 350-3042 ppb (.3-3.0 ppm).

Sanger, D. M. and A. F. Holland. (2002). Evaluation of the impacts of dock structures on South Carolina estuarine environments. Technical report number 99. C. South Carolina Department of Health and Environmental Control, SC.
URL: http://mrl.cofc.edu/pdf/techreport99.pdf
Keywords: Vegetation, shading, tidal creek, dock, pier, sediment, leachate
Summary: (from document Introduction) The objective of this study was to evaluate the cumulative effect of docks on tidal creek and salt marsh ecosystems. The study was composed of three parts: (1) a Spartina Shading Study which evaluated the impacts of dock

shading on the dominant marsh plant; (2) a Small Tidal Creek Study which evaluated dock impacts on small tidal creek nursery habitats; and (3) a Large Tidal Creek Study which evaluated dock impacts on larger tidal creek nursery habitats. Shading impacts under individual docks were extrapolated to the tidal creek (local), county, and state-wide scales. In addition, wrack accumulation and construction damage were examined as part of the Spartina Shading Study. No new data were collected for the small and large tidal creek studies. Rather, existing research and monitoring data collected by the SCDNR were used. A bibliography of the relevant scientific literature and summarization of the science that supports the impacts of dock structures on the marine environment is also provided.

Savannah River Ecology Lab (2004). Herpetological Inventory of the Southeastern Coastal National Parks, University of Georgia, Savannah River Ecology Lab (SREL) and Davidson College, Biology Department. Retrieved 2004.
URL: http://www.bio.davidson.edu/people/midorcas/nps/fopu/fopu.htm
Keywords: National Park, Fort Pulaski, amphibians, reptiles
Summary: UGA-SREL and Davidson College are involved in a joint effort to create a herpetological inventory for southeastern coastal national parks. The results are intended to aid park officials in management.

Slotts, A. and B. Wilkes (2005). Major Construction Completed At SRS Tritium Extraction Facility. NNSA (National Nuclear Security Administration) News. Washington D.C.

South Carolina - Wildlife and Freshwater Fisheries Division (SC-WFFD) (2003). South Carolina Rare, Threatened, and Endangered Species Inventory website. Heritage Trust Program, Department of Natural Resources.
URL: http://www.dnr.state.sc.us/wild/index.html
Summary: The SC Heritage Trust Program is maintained under the Wildlife Diversity section. You may search species by county. The list includes listing of global and state rank and legal status.

Southeastern Wildlife Management (1981). A survey of the Vertebrate and Invertebrate Fauna of Fort Pulaski National Military Park, Prepared for the National Park Service.
Keywords: Fort Pulaski NM, wildlife, birds, insects
Summary: This study focused primarily on the bird species inhabiting or visiging the Park. A table of habitat, whether birds were nesting or not, and whether birds were seasonal, occasional, or usual inhabitants of the park was provided. In addition, they mention various species of insect pests and suggested managment.

Southern Company (2005). Southern Company webpage.
URL: www.southerncompany.com/southernnuclear
Keywords: Nuclear, energy
Summary: This website provides information on Southern Company and existing nuclear facilities along with materials on the environment and fission.

The Ocean Conservancy (2004). Issues - Marine Debris webpage.
URL: www.theoceanconservancy.org/

U.S. ACE (1989). Water Resources Development by the U.S. Army Corps of Engineers in Georgia, Savannah District.
Keywords: Savannah River, development, navigation, deepening, flood control (dams), hydropower, recreation, project costs
Summary: Describes development in the Savannah River (and other Georgia rivers), including details of costs and time spent on navigation, hydropower, and other projects. Also includes details of hydropower operations, i.e. dimensions of the dam, number of generators, how much power can be produced, and details of navigation projects, i.e. width, depth, location, etc.

U.S. ACE (2005). U.S. Army Corps of Engineers, Savannah District - Website.
URL: www.sas.usace.army.mil
Keywords: Savannah Harbor, deepening, tide gate

U.S. Census Bureau (2003). 100 Fastest Growing U.S. Counties with 10,000 or more population in 2002: April 1, 2000-July 1, 2002., Population Division.
URL: http://census.gov
Keywords: Effingham County, population
Summary: Effingham County ranks 83rd among the 100 fastest growing counties in the United States.

U.S. DOE, Savannah River Site (2005). Savannah River Site webpage.
URL: www.srs.gov
Keywords: Radioisotopes, Savannah River Site
Summary: This webpage is the Department of Energy's official webpage for the Savannah River Site and contains documents, publications, and information on the nuclear facility.

U.S. EPA (1997). Climate Change and Georgia. EPA 230-F-97-008j, Office of Policy, Planning, and Evaluation.
Keywords: Sea level rise, Fort Pulaski
Summary (from Source): The earth's climate is predicted to change because human activities are altering the chemical composition of the atmosphere through the buildup of greenhouse gases — primarily carbon dioxide, methane, nitrous oxide, and chlorofluorocarbons. The heat-trapping property of these greenhouse gases is undisputed. Although there is uncertainty about exactly how and when the earth's climate will respond to enhanced concentrations of greenhouse gases, observations indicate that detectable changes are under way. There most likely will be increases in temperature and changes in precipitation, soil moisture, and sea level, which could have adverse effects on many ecological systems, as well as on human health and the economy.

U.S. EPA (1999). Environmental Monitoring and Assessment Program (EMAP), 1993-1997, Environmental Protection Agency.
URL: http://oaspub.epa.gov/coastal/coast.search
Keywords: Carolinian Province, Savannah River Estuary, benthic trawls, fish trawls, sediment toxicity, water quality

Summary: EMAP's primary objectives were to "1) estimate current status, extent, changes and trends of the Nation's ecological resources on a regional basis, 2) monitor indicators of pollutant exposure and habitat condition, and to seek correlative relationships between human-induced stresses and ecological condition that identify possible cause of adverse effects, and 3) to provide periodic statistical summaries and interpretive reports on ecological status and trends to the EPA Administrator and to the public". Data was downloaded and analyzed from 3 stations within the SRE.

U.S. EPA (2002). Envirofacts Database - Toxic Release Inventory (TRI) database.
URL: http://oaspub.epa.gov/enviro/ef_home2.toxics

U.S. EPA (2004a). Assessment and monitoring - atmospheric deposition and water quality website.
URL: http://www.epa.gov/owow/oceans/airdep/air1.html, http://www.epa.gov/owow/oceans/airdep/air2.html#mercury
Keywords: Airshed, mercury, atmospheric deposition, pollutants
Summary (from Source): "Atmospheric deposition plays a major role in delivering mercury to ecosystems. Up to 83% of the mercury load to the Great Lakes comes from atmospheric deposition (see Shannon and Voldner, 1995). Approximately half of the mercury in Chesapeake Bay is deposited from the atmosphere directly to the surface of the bay (see Mason et. al., 1997). The National Atmospheric Deposition Program (NADP) estimated that mercury was deposited at the rate of 4-20 micrograms per square meter in the United States in 1998."Also, "There are five categories of atmospheric pollutants with the greatest potential to harm water quality. The categories include: nitrogen compounds, mercury, other metals, pesticides, and combustion emissions. These categories are based on both method of emission and other characteristics of the pollutants. Mercury is in its own category since it behaves so much differently in the environment than other metals. Combustion of fossil fuels is a major source of nitrogen oxides to the atmosphere. However, nitrogen is in its own category since its effects on ecosystems is so much different than other combustion emissions. Pesticides and combustion emissions are exclusively man-made while mercury, other metals, and nitrogen compounds arise from both natural and man-made sources."

U.S. EPA (2004b). Envirofacts database -Pemit Compliance System. NPDES permittees.
URL: http://oaspub.epa.gov/enviro/ef_home2.water

U.S. EPA (2004c). Environmental Monitoring and Assessment Program website.
URL: http://www.epa.gov/emap/index.html
Summary: (From Source) "The Environmental Monitoring and Assessment Program (EMAP) is a research program to develop the tools necessary to monitor and assess the status and trends of national ecological resources. EMAP's goal is to develop the scientific understanding for translating environmental monitoring data from multiple spatial and temporal scales into assessments of current ecological condition and forecasts of future risks to our natural resources. EMAP aims to advance the science of ecological monitoring and ecological risk assessment, guide national monitoring with improved scientific understanding of ecosystem integrity and dynamics, and demonstrate multi-agency monitoring through large regional projects. EMAP develops indicators to monitor the condition of ecological resources. EMAP

also investigates designs that address the acquisition, aggregation, and analysis of multiscale and multitier data."

U.S. EPA (2004d). National Coastal Condition Report II., EPA-620/R-03/002. Office of Water, Washington, D.C.
URL: http://www.epa.gov/owow/oceans/nccr2/
Summary: (from Executive Summary) "The NCCR II presents three main types of data: (1) coastal monitoring data, (2) offshore fisheries data, and (3) assessment and advisory data. The ratings of coastal condition in the report are based primarily on coastal monitoring data because these are the most comprehensive and nationally consistent data available related to coastal condition. One source of coastal monitoring data is obtained through EPA's National Coastal Assessment (NCA) Program, which provides information on the condition of coastal estuaries for most regions of the United States. The NCCR II relies heavily on NCA estuarine data in assessing coastal condition and uses NCA and other data to evaluate five indicators of condition—water quality, sediment quality, benthic community condition, coastal habitat loss, and fish tissue contaminants—in each region of the United States (Northeast Coast, Southeast Coast, Gulf Coast, West Coast, Great Lakes, and Puerto Rico)." "In addition to rating coastal condition based on coastal monitoring data, the NCCR II summarizes available information related to offshore fisheries and beach advisories and closures. This information, together with descriptions of individual monitoring programs, paints a picture of the overall condition of coastal resources in the United States."

U.S. FWS (2004). Endangered Species in Georgia - County by County index. USFWS website.
URL: http://www.fws.gov/athens/endangered.html
Summary: Information on listed species includes federal status, state status, habitat, and threats. The website is searchable by county.

U.S. FWS (2005). Savannah National Wildlife Refuge Homepage. SNWR website.
URL: http://www.fws.gov/savannah/
Keywords: SNWR facts, threatened and endangered species, managment, map
Summary: Information is provided on National Wildlife Refuge date of establishment, location, acreage, types of habitats, and types of wildlife that use the refuge. Various publications concerning the refuge are also available via a link on the homepage.

USDA (2002). 2002 Census of Agriculture, State Profile, Georgia Agicultural Statistics Service.
Keywords: Georgia, agriculture, farms, AFO, poultry, demographics
Summary: Provides information about farm demographics, size, and revenue; also information on major commodities produced in Georgia, including quantity, revenue, US rank.

USGS (2000a). Chinese tallow: invading the Southeastern coastal plain. National Wetlands Research Center FactSheet. Lafayette, LA.
URL: http://www.nwrc.usgs.gov/factshts/154-00.pdf
Keywords: *Triadica sebifera*, Chinese tallow, invasive species, nonnative
Summary: *Triadica sebifera*, Chinese tallow, is an aggressive invader, an ornamental tree introduced to North America from Asia more than 200 years ago. It is difficult to control, especially when present in large stands. It has negative impacts on Southeastern Coastal

Plain species by shading desirable vegetation and perhaps also through the toxins present in its leaves, berries and sap. This short article describes the plants natural history in the SE United States, how it is controlled, how it spreads, and what research efforts are underway.

USGS (2000b). Evaluation of Ground-Water Flow, Saltwater Contamination, and Alternative Water Sources in the Coastal Area of Georgia - Georgia Coastal Sound Science Initiative. Project Proposal submitted to Georgia Department of Natural Resources Environmental Protection Division Georgia Geologic Survey.
Summary: This document describes a comprehensive program to evaluate ground-water resources in the coastal area of Georgia. The program consists of six major elements; workplans for each of the elements are included with this document. The approach presented herein reflects planned activities based on the stated problems and objectives, and on presently available data regarding hydrologic and geologic conditions and may occasionally require revision as additional data are collected that may alter the present understanding of the hydrologic system and the methods of analysis. These changes will be documented in quarterly status reports prepared by project staff and in the minutes of Technical Advisory Committee meetings.

USGS (2004a). Georgia Water Information Network (GWIN). GA USGS website, Water Resources of Georgia,. Retrieved 2004.
URL: http://ga.water.usgs.gov/
Keywords: Streamflow, Clyo, Effingham County, Savannah River
Summary: Annual and monthly streamflow reported at Clyo, USGS station 02198500; data from 1930-2002.

USGS (2004b). Nonindigenous Aquatic Species Database.
URL: http://nas.er.usgs.gov/

USGS (2005). National Water Information System (NWIS) Web Data for the Nation - Water Quality.
URL: http://waterdata.usgs.gov/nwis
Summary: USGS sites with recent data (since 2000) near FOPU are 0219897998 and 0219897996. USGS sites with recent data (since 2000) in the channel are 0219897992, 02198975, and 0219897991.

Van Dolah, R.F., P.C. Jutte, G.H.M. Riekerk, M.V. Levisen, L.E. Zimmerman, J.D. Jones, A.J. Lewitus, D.E. Chestnut, W. McDermott, D. Bearden, G.I. Scott and M.H. Fulton (2002). The Condition of South Carolina's Estuarine and Coastal Habitats During 1999-2000: Technical Report. Charleston, SC, South Carolina Marine Resources Division: 132 pp.

Verity, P. G. (2002a). "A decade of change in the Skidaway River estuary. I. Hydrography and nutrients." Estuaries 25(5): 944-960.
Keywords: Dissolved organic nitrogen, harmful algal blooms, salt-marsh ecosystem, groundwater discharge, water-quality, coastal embayment, south-carolina, atmospheric deposition, phytoplankton growth, marine environments

Abstract: The Skidaway River estuary is a tidally-dominated subtropical estuary in the southeastern USA surrounded by extensive Spartina salt marshes. Weekly sampling at high and low tide began in 1986 for hydrography, nutrients, chlorophyll a, particulate matter, and microbial and plankton biomass and composition; hydrographic and nutrient data during 1986-1996 are reported here. Salinity varied inversely with river discharge and exhibited variability at all time scales but with no long-term trend. Water temperature typically ranged over 25degreesC and was without apparent long-term trend. Seasonal cycles in concentrations of NO3, NH4, PO4, Si(OH)(4), and DON were observed, with annual maxima generally occurring in late summer. Superimposed on seasonal cycles, all five nutrients exhibited steady increases in minimum, mean, and maximum concentrations; mean concentrations increased c. 50-150% during the decade. Nutrient concentrations were highly correlated with water temperature over the ten-year period, but weakly related to salinity and discharge. Nutrients were strongly correlated with one another, and the relative ratios among inorganic nutrients showed little long-term trend. Correlations among temperature and nutrient concentrations exhibited considerable inter-annual variability Major spikes in organic and inorganic nutrient concentrations coincided with significant rainfall events; concentrations increased hyperbolically with rainfall.. Although pristine compared to more heavily impacted waterways primarily outside the region, residential development and population density have been increasing rapidly during the past 15-20 years. Land use is apparently altering nutrient loading over the long-term (months-years), and superimposed on this are stochastic meteorological events that accelerate these changes over the short term (days-weeks).

Verity, P. G. (2002b). "A decade of change in the Skidaway River estuary. II. Particulate organic carbon, nitrogen, and chlorophyll a." Estuaries 25(5): 961-975.
Keywords: Phytoplankton biomass, Chesapeake Bay, south-carolina, productivity, sea, eutrophication, inputs, ratio
Actract: A sampling program was initiated in 1986 in the Skidaway River estuary, a tidally dominated subtropical estuary in the southeastern USA. Hydrography, nutrients, particulate organic matter (POM), and microbial and plankton abundance and composition were measured at weekly intervals at high and low tide on the same day at a single site. Hydrographic and nutrient data during 1986-1996 were given in Verity (2002); particulate organic carbon (POC), nitrogen (PON) and chlorophyll a (chl a) are presented here; plankton data will be presented elsewhere. Chl a was fractionated into < 8 μm and > 8 mum size classes. All classes of POM exhibited distinct seasonal patterns superimposed upon significant long-term increases during the study period. Total chl a, < 8 μm chl a, and > 8 mum chl a increased 36%, 61%, and 18%, respectively, however the fraction of total biomass attributable to small phytoplankton (< 8 μm) increased 25%. The annual amplitude between minimum and maximum stock sizes increased significantly, meaning that bloom events became larger. POC and PON also increased 16% over the decade and, as observed with patterns in chl a, exhibited increases in annual amplitude. The C:N ratio was typically 6.4-6.6 (wt:wt) and did not change significantly, while the annual mean C:Chl a ratio decreased 19% from 165 to 140. These characteristics indicated highly labile POM composed of significant amounts of detritus, but which became increasingly autotrophic with time. Averaged over the decade, temperature explained 45-50% of the variance in POM. Nutrients were even better predictors of POM, as 60-75% of the variance in chl a, POC, and

PON were explained by ambient concentrations of DIN or PO4. Combined with significant increases in NO3, NH4, PO4, Si(OH)(4), and DON during 1986-1996, these data strongly suggest that anthropogenic activities contributed to increased loading of dissolved nutrients, which became incorporated into living and nonliving particulate organic matter.

Walters, L., L. Coen, P. Sacks, J. Grevert and J. Stiner (2004). Impact of Boat Wakes on Intertidal Reefs of the Oyster Crassostrea virgnica: A Comparison of Reefs in South Carolina Tidal Channels versus a Florida Estuary. Presented to the American Malacological Society. Sanibel, FL.

Wells, H.W. (1961). "The Fauna of Oyster Beds, With Special Reference to the Salinity Factor."
Keywords: Oyster reef, North Carolina, salinity, fauna
Summary: This study discusses the distribution of oyster reefs and associated fauna along a salinity gradient. Their conclusion was that oyster bed communities are most likely limited in upstream areas by low salinity. Salinities of oyster reefs tested in their study ranged form 18 to 32. The total number of different species collected from oyster reefs in NC was 303, with 220 collected from the most saline site.

Wiebe, W. J. and J. E. Sheldon (Unpublished data). Georgia Rivers Land Margin Ecosystem Research (LMER) nutrient data. Athens, GA, Dept. of Marine Science, University of Georgia.
Keywords: Nitrate; nitrite; ammonium; phosphate; silicate; total dissolved nitrogen;TDN; Savannah River
Summary: During Georgia Rivers LMER program cruises, samples for dissolved nutrients were taken approximately every 4 km between the estuary mouth and the head of seawater intrusion. Analyses included ammonium, nitrate, nitrite, orthophosphate, and silicate. The Savannah River estuary was sampled in Nov. 1994, Apr. 1995, Oct. 1995, July 1996, and Feb. 1999. Total dissolved nitrogen was also analyzed for the first 3 cruises.

Wiegert, R.G. and B.J. Freeman (1990). Tidal Salt Marshes of the Southeast Atlantic Coast: A Community Profile., U.S. Fish and Wildlife Service Biological Report.
URL: http://cuadra.cr.usgs.gov/Techrpt/85-7-29.pdf
Summary (from Profile): This report is part of a series of community profiles produced by the U.S. Fish and Wildlife Service on the ecology of wetland and marine communities. This profile considers those tidal salt marshes of the southeastern Atlantic coast, from northern North Carolina south to northern Florida.

Williams, Austin B. (1984). Shrimps, Lobsters, and Crabs of the Atlantic Coast of the Eastern United States, Maine to Florida. Washington, D.C., Smithsonian Institution Press.
Keywords: Atlantic coast, shrimp, lobster, crab, arthropods
Summary: Provides detailed summaries of individual species, including habitat, range in which they are found in, food, size, and other features.

Winger, P. V., P. J. Lasier, D. H. White and J. T. Seginak (2000). "Effects of contaminants in dredge material from the lower Savannah River." Archives of Environmental Contamination and Toxicology 38(1): 128-136.

Keywords: Polycyclic aromatic-hydrocarbons, fresh-water sediments, south-carolina, striped bass, pore-water, toxicity, mercury, increases, diversion, estuarine
Abstract: Contaminants entering aquatic systems from agricultural, industrial, and municipal activities are generally sequestered in bottom sediments. The environmental significance of contaminants associated with sediments dredged from Savannah Harbor, Georgia, USA, are unknown. To evaluate potential effects of contaminants in river sediments and sediments dredged and stored in upland disposal areas on fish and wildlife species, solid-phase sediment and sediment pore water from Front River, Back River, an unnamed Tidal Creek on Back River, and Middle River of the distributary system of the lower Savannah River were tested for toxicity using the freshwater amphipod Hyalella azteca. In addition, bioaccumulation of metals from sediments collected from two dredge-disposal areas was determined using the freshwater oligochaete Lumbriculus variegatus. Livers from green-winged teals (Anas crecca) and lesser yellowlegs (Tringa flavipes) foraging in the dredge-spoil areas and raccoons (Procyon later) from the dredge-disposal/river area and an upland site were collected for metal analyses. Survival of H. azteca was not reduced in solid-phase sediment exposures, but was reduced in pore water from several locations receiving drainage from dodge-disposal areas. Basic water chemistry (ammonia, alkalinity, salinity) was responsible for the reduced survival at several sites, but PAHs, metals, and other unidentified factors were responsible at other sites. Metal residues in sediments from the Tidal Creek and Middle River reflected drainage or seepage from adjacent dredge-disposal areas, which could potentially reduce habitat quality in these areas. Trace metals increased in L. variegatus exposed in the laboratory to dredge-disposal sediments; As, Cu, Hg, Se, and Zn bioaccumulated to concentrations higher than those in the sediments. Certain metals (Cd, Hg, Mo, Se) were higher in livers of birds and raccoons than those in dredge-spoil sediments suggesting bioavailability. Cadmium, Cr, Hg, Pb, and Se in livers from raccoons collected near the river and dredge-disposal areas were significantly higher than those of raccoons from the upland control site. Evidence of bioaccumulation from laboratory and field evaluations and concentrations in sediments from dredge-disposal areas and river channels demonstrated that some metals in the dredge-disposal areas are mobile and biologically available. Drainage from dredge-disposal areas may be impacting habitat quality in the river, and fish and wildlife that feed and nest in the disposal areas on the lower Savannah River may be at risk from metal contamination.

Zimmerman, R., T. Minello, T. Baumer and M. Castiglione (1989). Oyster Reef as Habitat for Estuarine Macrofauna, NOAA.
Keywords: Oyster reef, Texas, seasonal habitat, fish, crustacean
Summary: This study compared oyster reef habitat utility to that of adjacent salt marshes and mud flats in Texas. They found that although all 3 habitats were widely used, species differed significantly. Structured habitats (reef and marsh) appeared to have higher overall numbers of fauna. Habitat usage by various species differed seasonally. Stone crabs appeared to favor oyster reef habitat year round.

As the nation's principal conservation agency, the Department of the Interior has responsibility for most of our nationally owned public lands and natural resources. This includes fostering sound use of our land and water resources; protecting our fish, wildlife, and biological diversity; preserving the environmental and cultural values of our national parks and historical places; and providing for the enjoyment of life through outdoor recreation. The department assesses our energy and mineral resources and works to ensure that their development is in the best interests of all our people by encouraging stewardship and citizen participation in their care. The department also has a major responsibility for American Indian reservation communities and for people who live in island territories under U.S. administration.

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