U.S. Army Corps of Engineers
Charleston District

APPENDIX H

CHARLESTON HARBOR POST 45

CHARLESTON, SOUTH CAROLINA

Essential Fish Habitat Assessment

03 October 2014

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1.0 INTRODUCTION

The South Carolina State Ports Authority (SCSPA) has requested the United States Army Corps of Engineers (USACE) to study the feasibility of further deepening the federal system of channels within the Charleston Harbor. The objective of the study includes evaluation of the potential navigation benefits derived from deepening the main shipping channel at one-foot increments from the 45-foot existing depth to depths of up to 50 feet. The proposed project would include deepening sections of the federal channel, widening portions of the channel and expanding existing turning basins (Figure 1). The excavation work would be performed utilizing a combination of hopper, cutterhead, and clamshell dredges.

The Magnuson-Stevens Act's final rule, to manage fishery resources and their habitats, was released on January 17, 2002. The National Marine Fisheries Service (NMFS) and affiliates, the South Atlantic Fishery Management Council (SAFMC) and the Mid-Atlantic Fishery Management Council (MAFMC), oversee the managed species and their habitats potentially found within the proposed project's footprint. In addition, the Atlantic States Marine Fisheries Commission (ASMFC) serves as a roundtable for cooperative discussion between 15 Atlantic states, coordinating the protection and administration of the states' shared near shore fishery resources. This Essential Fish Habitat (EFH) assessment describes the habitat(s) and managed fishery resource(s) that are potentially present within the project footprint.

The combination of fishery and habitat management with emphasis on healthy and diverse estuarine and marine ecosystems meets the EFH mandates of the Magnuson-Stevens Act. If a construction, permitting, funding, or other proposed action potentially affects EFH(s), then applicable federal permitting agencies must consult with the NMFS. The EFH consultation ensures the potential action considers the effects on important habitats and supports the management of sustainable marine fisheries [South Atlantic Region (SAR) 2008a].

2.0 PROJECT DESCRIPTION

Additional channel depth would allow current and future shippers to more fully utilize larger class vessels and would reduce anticipated future congestion and increase transportation cost savings. The current depth of the existing inner harbor channel is 45 feet. The Entrance Channel (Figure 1) from the Atlantic Ocean through the jetties is 47 feet deep to allow for wave action. In addition to the future-without-project (FWOP) alternative (synonymous with NEPA No Action Alternative), USACE studied an extensive array of alternatives that were eventually narrowed down to six potential construction alternatives that met the objectives of the project. Differences among alternatives are primarily due to varying project depths. The benefits and costs of these and other alternatives will be fully evaluated in the Feasibility Study. The alternatives, named according to the depths of the (1) lower harbor to the Wando Welch Terminal and the former Navy Base Terminal and (2) the former Navy Base Terminal to Ordnance Reach, analyzed include the following:

- Alternative 48-47: Channel widths are maximum widenings, transitions, bend easings and turning basin enlargements. Design depth is 50 feet MLLW in the entrance channel, 48 feet MLLW from Mt Pleasant range to Wando River up to Wando Welch Terminal (includes turning basin) and to Cooper River at the former Navy Base terminal (includes turning basin). This includes the widener area in Customs House Reach, but the remainder of Customs House Reach, as well as Tidewater Reach, Town Creek Turning Basin and Lower Town Creek Reach remain at the Existing Condition design depths. Design depth is 47 feet MLLW from Daniel Island bend to Ordnance reach (includes turning basin). Assume SLR is 0.57 feet above existing level.

- Alternative 48-48: Channel widths are maximum widenings, transitions, bend easings and turning basin enlargements. Design depth is 50 feet MLLW in the entrance channel, 48 feet MLLW from Mt Pleasant range to Wando River up to Wando Welch Terminal (includes turning basin) and to Cooper River at the former Navy Base Terminal (includes turning basin). Design depth is 48 feet MLLW from Daniel Island bend to Ordnance reach (includes turning basin). Assume SLR is 0.57 feet above existing level.

- Alternative 50-47: Channel widths are maximum widenings, transitions, bend easings and turning basin enlargements. Design depth is 52 feet MLLW in the entrance channel, 50 feet MLLW from Mt Pleasant range to Wando River up to Wando Welch Terminal (includes turning basin) and to Cooper River at the former Navy Base Terminal (includes turning basin). Design depth is 47 feet MLLW from Daniel Island bend to Ordnance reach (includes turning basin). Assume SLR is 0.57 feet above existing level.

- Alternative 50-48: Channel widths are maximum widenings, transitions, bend easings and turning basin enlargements. Design depth is 52 feet MLLW in the entrance channel, 50 feet MLLW from Mt Pleasant range to Wando River up to Wando Welch Terminal (includes turning basin) and to Cooper River at the former Navy Base Terminal (includes turning basin). Design depth is 48 feet MLLW from Daniel Island bend to Ordnance reach (includes turning basin). Assume SLR is 0.57 feet above existing level. [This is the tentatively selected plan.]

- Alternative 52-47: Channel widths are maximum widenings, transitions, bend easings and turning basin enlargements. Design depth is 54 feet MLLW in the entrance channel, 52 feet MLLW from Mt Pleasant range to Wando River up to Wando Welch Terminal (includes turning basin) and to Cooper River at the former Navy Base Terminal (includes turning basin). Design depth is 47 feet MLLW from Daniel Island bend to Ordnance reach (includes turning basin). Assume SLR is 0.57 feet above existing level.

- Alternative 52-48: Channel widths are maximum widenings, transitions, bend easings and turning basin enlargements. Design depth is 54 feet MLLW in the entrance channel, 52 feet MLLW from Mt Pleasant range to Wando River up to Wando Welch Terminal (includes turning basin) and to Cooper River at former Navy Base Terminal (includes turning basin). Design depth is 48 feet MLLW from Daniel Island bend to Ordnance reach (includes turning basin). Assume SLR is 0.57 feet above existing level.

For each of the above alternatives, two or three contraction dikes may be constructed near the Wando Welch Terminal and the Wando Reach of the Navigation Channel in order to minimize shoaling and reduce maintenance costs. The dikes will be extended shore perpendicular from the west bank of the river and will range from 350 ft to 840 ft in length. Prior to implementing this measure, ship simulation will be performed to examine possibilities to reduce certain widening measures. Reducing wideners will reduce the amount of shoaling and therefore could eliminate the need for contraction dikes.

Figure 1. Charleston Harbor Post 45 Study Area, including Federal Channels

After an extensive alternatives analysis, the tentatively selected plan (TSP) was selected to be Alternative 52-48, which is also the locally preferred plan. Details on this process can be found within Section 3 of the Draft Feasibility Report / Environmental Impact Statement (EIS). This EFH assessment focuses on assessing the effects of the TSP, or proposed project, on EFH and managed species.

The expected dredged material for the TSP is estimated to be 40,423,442 cubic yards (CY). Most of this material will consist of rock and unconsolidated substrate which will be disposed of in the following locations:

- Existing Charleston Harbor Ocean Dredged Material Disposal Site (ODMDS)
- Proposed Expanded Charleston ODMDS
- Existing Clouter Creek Disposal Area
- Existing Yellow House Creek Disposal Area
- Hardbottom mitigation sites and additional hardbottom reefs
- Potential Beneficial Use of Dredged Material in Charleston harbor locations, including Crab Bank

The recommended plan contains the following navigation improvements and is referenced as the 52'/48' plan (Figures 2 and 3): Deepen the existing entrance channel from a project depth of 47 feet to 54 feet over the existing 800-foot bottom width, while reducing the existing stepped 1000-foot width to 944 feet from an existing depth of 42 feet to a depth of 49 feet. The deepening of the entrance channel also includes 1 to 2 feet of required overdepth dredging and up to 2 feet of allowable overdepth dredging as shown on Figure 4-1; Extend the entrance channel approximately three miles seaward to match to about the -57 foot contour; Deepen the inner harbor from an existing project depth of 45 feet to 52 feet MLLW to the Wando Welch Terminal on the Wando River and the new SCSPA Navy Base Terminal on the Cooper River, and from 45 feet to 48 feet for the reaches above that facility to the Northern Charleston Terminal (over varying expanded bottom widths ranging from 400 to 1,800 feet); Enlarge the existing turning basins to an 1,800-foot diameter at the Wando Welch and new Navy Base Terminals to accommodate Post Panamax Generation 2 and 3 container ships; Enlarge the North Charleston Terminal turning basin to a 1650-foot diameter to accommodate Post Panamax Generation II and Generation III containerships. A turning basin at the new Navy Base Terminal will be part of the existing condition prior to the base year of the study (2022); Raise dikes and place dredged material from the upper harbor at the existing upland confined disposal facilities at Clouter Creek, Yellow House Creek, and/or Daniel Island; place material dredged from the lower harbor and sediment from the entrance channel at the expanded Ocean Dredged Material Disposal Site (ODMDS). Place some of the rock dredged from the entrance channel along the outside of the entrance channel and along the edges of the ODMDS to create hardbottom habitat.

Figures 2 and 3 depict the locations of the proposed construction activities and channel features. New work material from channel deepening and widening would be distributed among the ODMDS, mitigation site, additional reef sites, and upland confined disposal areas. The amount of material from each reach and the location of the disposal are documented in Table 2.

A mitigation reef will be created in between the Entrance Channel and the ODMDS. The objective of the mitigation is to create a marine patch reef feature in mound formations that will compensate for the lost functions of the hardbottom dredged from the entrance channel. The designated mitigation area would be surveyed and reviewed prior to construction and must not contain existing hardbottom habitat or support other traditional uses of the marine environment such as trawling or sand mining areas. The sites will be coordinated with the resource agencies prior to construction. The selected alternative involves using dredged limestone rock from the entrance channel and depositing it in a designated mitigation area adjacent to the Charleston Post 45 entrance channel, between the Charleston ODMDS and the entrance channel. The material would be placed or discharged, likely by scow or barge to reach the designed configuration. An excavator or clamshell dredge would permit the largest diameter material to comprise the reef; however, a cutterhead suction dredge could also be used. USACE anticipates mitigating for impacts to 28.6 acres of hardbottom habitat within the entrance channel. Water depths in the mitigation area are between 35 and 50 feet. The new reef feature will consist of individual low relief mounds separated by existing bottom service area. The reef feature is designed to provide bathymetric anomalies, hard bottom surfaces material, habitat diversity, and stability. A simple patch reef design and a simple operational plan compatible with dredge plant and transportation capabilities is required. Accordingly, a grid placement plan will be used. The grid will consist of 300-foot by 300-foot cells. The cells will be two (2) across by eight (8) long. This would create approximately 33 acres of patch reef habitat (project footprint). The patch reef area would be 600 feet by 2,400 feet long. At a minimum two scow loads of material dredged from rock areas would be discharged at about the center of each cell. Accordingly, the 16 cells would require 32 - 4,000 to 6,000 cy scow loads, or approximately 128,000 to 192,000 cy. Filling the scows to maximum capacity with each load is not a likely occurrence. The desired peak vertical relief is 3.5 – 4.5 feet and the desired aerial coverage within each cell is 75% coverage. However, placing the load directly on top of each other will be a challenge. Placing more than two loads in each cell can be done in order to make a higher mound or to cover more area. Additional loads could be placed on specific cells if the two loads do not achieve desired areal coverage. This will be monitored during construction and if necessary, will be adapted.

It is anticipated that the material will be dredged mechanically by a rock bucket clamshell dredge, in which case the rock may be removed in softball and larger basketball size pieces. The scows would be 4,000 to 6,000 cyd vessels. Dredged materials for the patch reef will be new work (not previously dredged) rock to the extent practicable, although some overlying and intermixed sediments will be dredged along with the rock. The scow will transport the dredged material to the placement location. A placement grid will be developed to provide the patch reef design. Grids will be divided into sequentially numbered cells. Each cell would be a placement target. One or more scow placements would occur in a manner that will produce discrete mounds. A second 33 acre reef will be created using the same methods.

In addition to the mitigation reefs, USACE will construct 6 other similar reefs for a total of 8 new 33-acre reefs and 264 acres of new hardbottom habitat. Four will be located along the north side of the channel and 4 will be located along the south side of the channel. The exact location of these reefs is unknown at this time because surveys haven't been completed for existing hardbottom and cultural resources. For a conceptual depiction of the location of these reefs see Figure 4. As stated earlier, prior to construction the locations of these reefs will be refined and coordinated with the resource agencies. At the request of the SCDNR Artificial Reef Program, approximately 240,000 cy of rock material will also be deposited at the 25 acre Charleston Nearshore Reef site. Details on the monitoring and adaptive management pursuant to this action can be found in Appendix P of the Charleston Harbor Post 45 EIS.

Construction Methods

The type of dredging equipment considered depends on the type of material, the depth of the channel, the depth of access to the disposal or placement site, the amount of material, the distance to the disposal or placement site, the wave-energy environment, etc. A detailed description of types of dredging equipment, which includes mechanical-clamshell, hydraulic hopper, cutter-suction, dredges with spider barges for transportation of dredged material to designated disposal sites, can be found in Engineer Manual, EM 1110-2-5025, *Engineering and Design - Dredging and Dredged Material Disposal.*

Mechanical – Clamshell Dredging

Mechanical dredges are classified by how the bucket is connected to the dredge. The three standard classifications are structurally connected (backhoe), wire rope connected (clamshell), and chain and structurally connected (bucket ladder). The advantage of mechanical dredging systems is that very little water is added to the dredged material by the dredging process and the dredging unit is not used to transport the dredged material. This is important when the disposal location is remote from the dredging site. The disadvantage is that mechanical dredges require sufficient dredge cut thickness to fill the bucket to be efficient and greater re-suspended sediment is possible when the bucket impacts the bottom and as fine-grained sediment washes from the bucket as it travels through the water column to the surface. Clamshell excavators are likely to be employed on portions of the Charleston Harbor project. These dredges are able to work in confined areas, can pick up large material, and are less sensitive to sea conditions than other dredges.

For cost estimating purposes, it was anticipated that a clamshell dredge would be used in two separate manners for the construction of this project. The first would be within the lower harbor. Material from these reaches would be placed in a scow or on a barge for transport to the ODMDS. The second area of would be in the entrance channel. Rock from this reach would be excavated and placed in a scow and transported to the hardbottom reef sites or the ODMDS to construct fish habitat or sediment containment berms.

Hydraulic – Hopper Dredging

Hopper dredges include self-propelled ocean-going vessels that hydraulically lift dredged material from the bottom and deposit it into an open hopper within the ship. The draghead(s) operates like a vacuum cleaner being dragged along the bottom. When the hopper is full, the dredge transits to a disposal location and releases the dredged material into an underwater disposal site by opening doors on the hopper bottom or in some cases the vessel is designed to split open longitudinally. Hopper dredges can also be designed to hydraulically pump the material from the hopper to an upland location. This is often used for beach nourishment projects. Since hopper dredges are self-propelled, they are more maneuverable than dredges that rely upon tug boats to move. However, they require numerous passes over the same area to remove the required material; they are inefficient in small confined dredging areas and are most effective in removing sand and other unconsolidated materials.

A hopper dredge is anticipated to be used to remove unconsolidated overburden material from the entrance channel. Material would be transported to the ODMDS and disposed of according to the Site Management and Monitoring Plan (SMMP) that is approved by the EPA.

Hydraulic – Cutter-Suction Dredge

Large cutter-suction dredges, or cutterhead dredges, are mounted on barges. The cutter suction head resembles an eggbeater with teeth. It mobilizes the dredged material as it rotates. The mobilized material is hydraulically moved into the suction pipe for transport. The cutter suction head is located at the end of a ladder structure that raises and lowers it to and from the bottom surface. The cutter suction dredge moves by means of a series of anchors, wires, and spuds. The cutter suction dredges as it moves across the dredge area in an arc as the dredge barge swings on the anchor wires. The discharge pipeline connects the cutter suction dredge to the disposal area. The dredged material is hydraulically pumped from the bottom, through the dredge, and through the discharge pipeline to the disposal location. Booster pumps can also be added along the discharge pipeline to move the material greater distances. Cutter-suction dredges are limited to dredging depths within reach of the ladder.

It is anticipated that a cutter-suction dredge would be used in two distinct areas for this project. The first area is the upper harbor reaches in the Cooper River (Figure 2 and Table 1). In this area of the Channel, material would be disposed of in upland confined disposal facilities (either Yellow House Creek or

Clouter Creek Disposal Areas). The second distinct dredging area for a cutter-suction dredge would be in the Entrance Channel, where a rock cutterhead would be used to excavate consolidated limestone rock from the channel. Material would be placed in a spider barge and transported to the ODMDS for disposal. Material may also be placed at the mitigation site if rock size restrictions can be met.

Post-Dredging Operations

Since dredging equipment does not typically result in a perfectly smooth and even channel bottom (see discussion above); a drag bar, chain, or other item may be pulled along the channel bottom to smooth down high spots and fill in low spots. This finishing technique also reduces the need for additional dredging to remove any high spots that may have been missed by the dredging equipment. It may be more cost-effective to use a drag bar or other leveling device (and possibly less hazardous to sea turtles) than to conduct additional hopper dredging.

Table 1. TSP Dredge Quantities, Placement Area, and Dredge Type

52'/48' Project with Max Wideners						
Channel Reach	Dredge Plant Type	# of Dredges	Estimated # of transits	Placement Area	Deepening Dredge Quantity in Cubic Yards (CY)	Duration (Months)
Fort Sumter Reach EC1	Large Hopper	1	524	ODMDS	2,357,022	4.06
Fort Sumter Reach EC1	Medium Hopper	3	1,571	ODMDS	3,928,371	4.24
Fort Sumter Reach EC1	Rock cutter	1	378	ODMDS Berm	2,266,766	8.72
Fort Sumter Reach EC1	Rock cutter	1	10	DNR Site	60,000	0.34
Fort Sumter Reach EC1	Rock cutter	1	70	Reef Placement	420,000	1.77
Ft. Sumter - Reach EC1	Clamshell with bucket	1	110	ODMDS Berm	660,000	6.51
Ft. Sumter - Reach EC1	Clamshell w/ rock bucket	1	60	Mitigation Site	360,000	3.98
Ft. Sumter - Reach EC1	Clamshell w/ rock bucket	1	30	DNR Site	180,000	1.99
Fort Sumter Reach EC2	Large Hopper	1	432	ODMDS	1,943,512	3.54
Fort Sumter Reach EC2	Medium Hopper	3	1,166	ODMDS	2,915,267	3.70
Fort Sumter Reach EC2	Rock cutter	1	557	ODMDS Berm	3,346,872	12.77
Fort Sumter Reach EC2	Rock cutter	1	70	Reef Placement	420,000	1.91
Fort Sumter Reach EC2	Clamshell w/ rock bucket	1	180	Reef Placement	1,080,000	10.97
Mount Pleasant Reach	Clamshell	1	140	ODMDS	840,083	1.52
Rebellion Reach	Clamshell	1	180	ODMDS	1,081,341	1.96
Bennis Reach	Clamshell	2	324	ODMDS	1,942,858	2.80
Horse Reach	Clamshell	2	59	ODMDS	350,996	0.53
Hog Island Reach	Clamshell	2	352	ODMDS	2,109,994	3.15
Wando River Lower Reach	Clamshell	2	295	ODMDS	1,769,070	2.55
Wando River Upper Reach	Clamshell	2	106	ODMDS	636,251	1.05
Wando River Turning Basin	Clamshell	2	547	ODMDS	3,284,633	4.52
Segment 1 Total					**31,953,036**	**82.58**
Drum Island Reach	Clamshell	2	153	ODMDS	917,473	1.45
Myers Bend	Clamshell	2	142	ODMDS	853,689	1.28
Daniel Island Reach	Pipeline	2	N/A	Daniel Island	2,211,957	2.17
Segment 2 Total					**3,983,119**	**4.90**
Daniel Island Bend	Pipeline	2	N/A	Daniel Island	74,551	0.28
Clouter Creek Reach	Pipeline	2	N/A	Daniel Island	583,150	1.23
Navy Yard Reach	Pipeline	2	N/A	Clouter Creek	358,816	0.74
North Charleston Reach	Pipeline	2	N/A	Clouter Creek	532,693	0.61
Filbin Creek Reach	Pipeline	2	N/A	Yellowhouse	405,420	0.75
Filbin/Port Terminal Intersect	Pipeline	2	N/A	Yellowhouse	31,692	0.08
Port Terminal Reach	Pipeline	2	N/A	Yellowhouse	160,376	0.30
Ordnance Reach	Pipeline	2	N/A	Yellowhouse	118,091	0.33
Ordnance Reach Turning Basin	Pipeline	2	N/A	Yellowhouse	1,549,313	1.70
Segment 3 Total					**3,814,102**	**5.99**
North Charleston Terminal Berthing Area Dredging	Pipeline	1	N/A	Yellowhouse	41,001	0.21
Navy Base Terminal Berthing Area Dredging	Pipeline	1	N/A	Daniel Island	474,551	1.03
Wando Terminal Berthing Area Dredging	Pipeline	1	N/A	Daniel Island	157,633	0.32
Berthing Areas Total					**673,185**	**1.56**
Total Construction					**40,423,442**	**95.03**

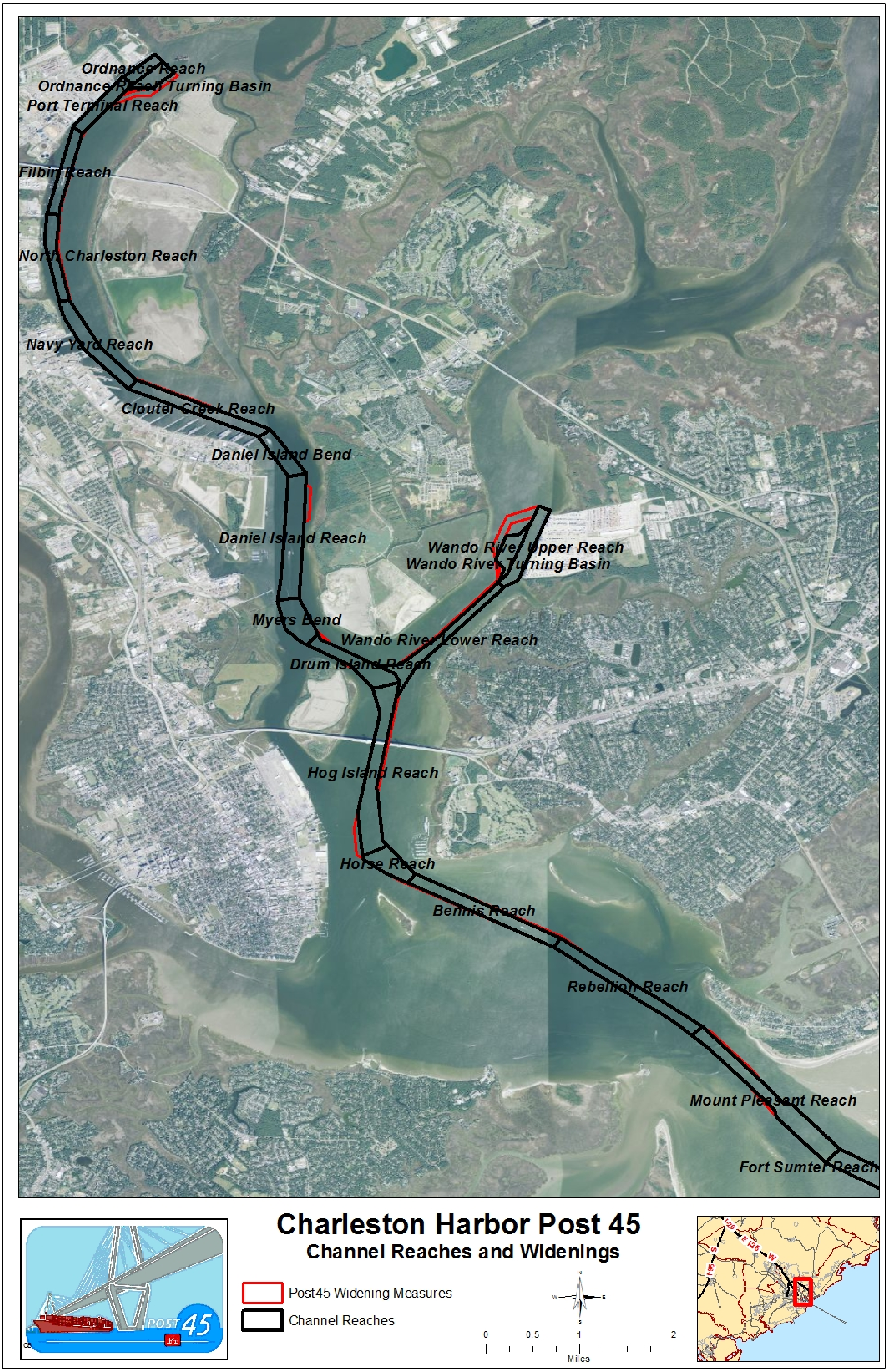


Figure 2. Post 45 channel reaches and widening measures

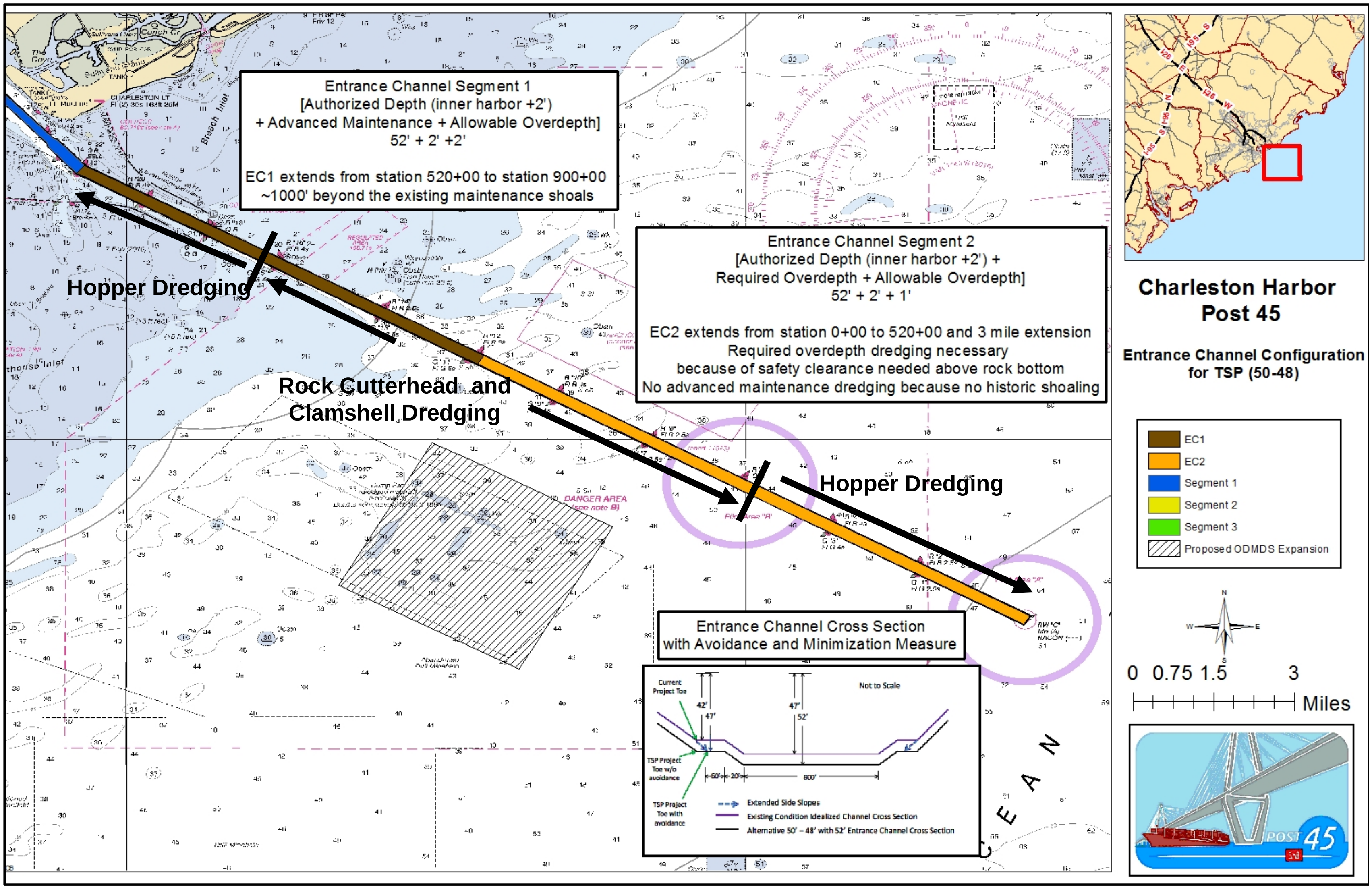


Figure 3. Post 45 entrance channel segments, approximate location of hopper, cutterhead and clamshell dredging, and proposed ODMDS

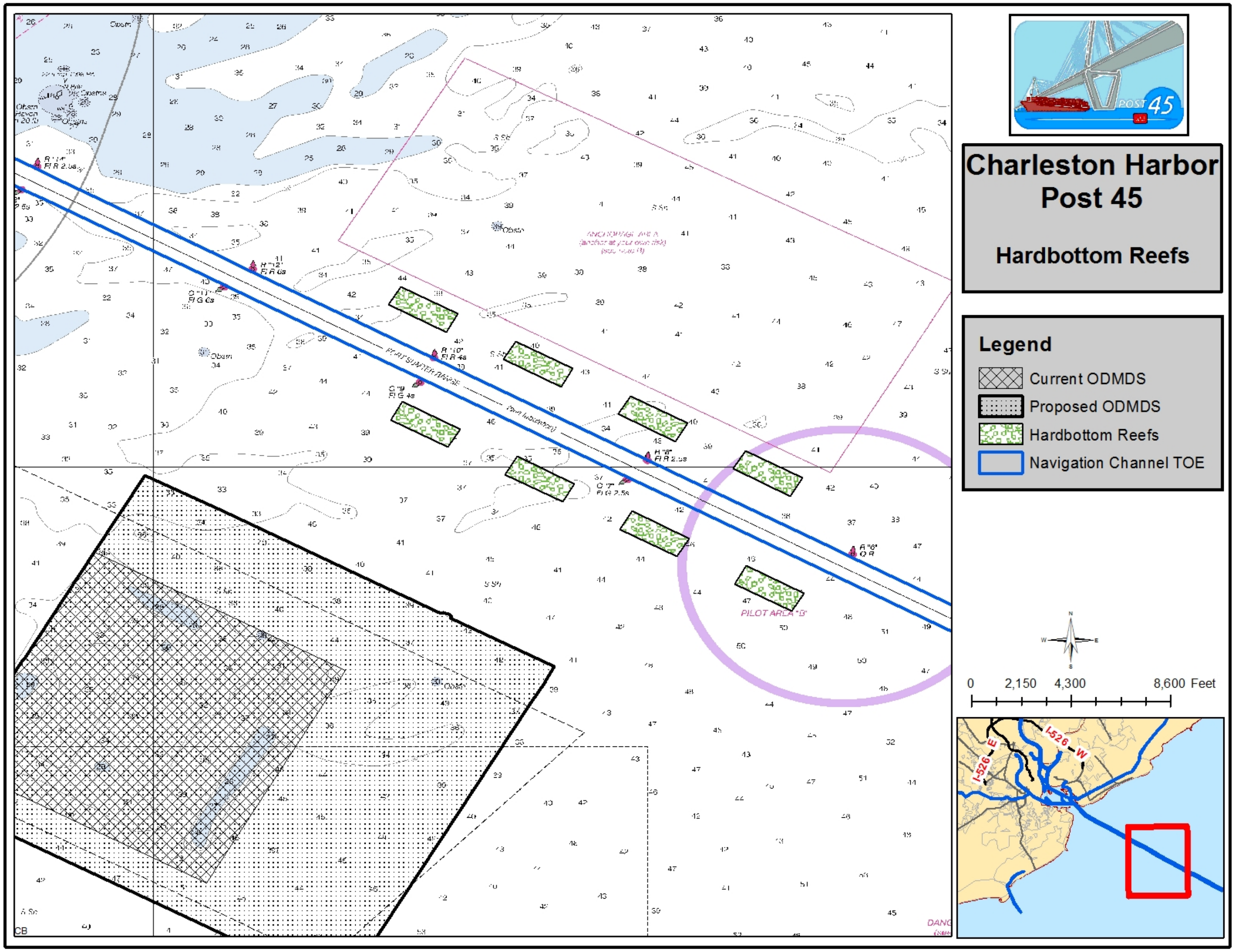


Figure 4. Theoretical depiction of locations for hardbottom reefs

Maintenance dredging would generally be conducted by hopper, clamshell and cutterhead dredges and would operate essentially the same as current practices documented in the Charleston Harbor DMMP Preliminary Assessment. Maintenance dredging would utilize the same placement areas as those utilized for existing conditions, and the duration and frequency of dredging events would be within the range occurring under current conditions. Dredging of the Entrance Channel would generally be performed by a hopper dredge, and material would be placed in the ODMDS located south of the navigation channel. Maintenance material from the lower reaches in the Harbor would be dredged with a clamshell and transported via scow to the ODMDS. Maintenance material from the upper reaches would be dredged with a pipeline cutterhead dredge and transported to upland confined disposal facilities, including Clouter Creek, Yellow House, Daniel Island, and Morris Island. The 50 year placement plan is summarized within Table 3 below. Maintenance dredging will continue to operate under the most current South Atlantic Regional Biological Opinion.

Table 2. O&M Quantities and Placement Areas for 50 years

Channel Reach	Shoaling Rate in CY/year	Placement Area (PA)	Dredge Type	Dredge Cycle (months)	Estimated Number of Cycles in 50 years	Quantity per Cycle (CY)	Total O&M Quantity in 50 years (CY)
Fort Sumter Reach/Entrance Channel	519,000	ODMDS	Hopper	24	25	1,038,000	25,950,000
Mount Pleasant Reach	0	ODMDS	Clamshell	15	40	0	0
Rebellion Reach	923	ODMDS	Clamshell	15	40	1,154	46,150
Bennis Reach	37,264	ODMDS	Clamshell	15	40	46,580	1,863,200
Horse Reach	16,035	ODMDS	Clamshell	15	40	20,044	801,750
Hog Island Reach	179,838	ODMDS	Clamshell	15	40	224,798	8,991,900
Wando River Lower Reach	69,984	ODMDS	Clamshell	15	40	87,480	3,499,200
Wando River Upper Reach	101,985	ODMDS	Clamshell	15	40	127,481	5,099,250
Wando River Turning Basin	263,097	ODMDS	Clamshell	15	40	328,871	13,154,850
Drum Island Reach	131,287	ODMDS	Clamshell	15	40	164,109	6,564,350
Myers Bend	55,119	ODMDS	Clamshell	15	40	68,899	2,755,950
ODMDS Total	**1,374,532**						**68,726,600**
Daniel Island Reach	231,652	Clouter Creek	Cutterhead	19	32	366,782	11,582,600
Daniel Island Bend	10,497	Clouter Creek	Cutterhead	19	32	16,620	524,850
Clouter Creek Reach	33,501	Clouter Creek	Cutterhead	19	32	53,043	1,675,050
Navy Yard Reach	21,520	Clouter Creek	Cutterhead	19	32	34,073	1,076,000
North Charleston Reach	5,104	Clouter Creek	Cutterhead	19	32	8,081	255,200
Filbin Creek Reach	10,742	Clouter Creek	Cutterhead	19	32	17,008	537,100
Filbin/Port Terminal Intersect		Clouter Creek	Cutterhead	19	32	0	0
Port Terminal Reach	14,581	Clouter Creek	Cutterhead	19	32	23,087	729,050
Ordnance Reach	166,433	Clouter Creek	Cutterhead	19	32	263,519	8,321,650
Ordnance Reach Turning Basin	532,713	Clouter Creek	Cutterhead	19	32	843,462	26,635,650
Upland Disposal Areas	**1,026,743**						**51,337,150**

2.3. Potential Additional Beneficial Uses

Opportunities for beneficial use of dredged material exist in the project vicinity. It is the policy of the Corps that, “all dredged material management studies include an assessment of potential beneficial uses for environmental purposes including fish and wildlife habitat creation, ecosystem restoration and enhancement and/or hurricane and storm damage reduction” (ER 1105-2-100 at E-69). In accordance with ER 1105-2-100, USACE is considering beneficial use of dredged material as a part of the Charleston Harbor Post 45 Project. During the PED phase of the project, there may be an option to further pursue beneficial uses if cost-effective and regulatory and environmental protection requirements are met. Many beneficial use options were considered and during the NEPA scoping process, agencies and the general public expressed interest in the following options:

- Crab Bank
- Sandbar complex b/w east end of southern jetty and Cummings Point
- Morris Island Lighthouse
- Castle Pinckney
- Feeder berms for barrier islands
- Offshore fish habitat berms
- Augmenting ODMDS berms
- Fort Sumter

After a meeting with the Interagency Coordination Team for the project and after external and internal prioritization the following options were carried forward:

- ODMDS berm creation
- Hardbottom habitat creation
- Crab Bank enhancement
- Shutes Folly enhancement
- Nearshore placement off Morris Island

2.3.2 ODMDS Berm Creation

To protect hardbottom habitat, from being buried by sediment migrating from the ODMDS, limestone rock from the entrance channel would also be used to construct an “L” shaped berm along the south and west perimeters of the ODMDS (Figure 5). The dimensions would be roughly 15,000 ft x 16,000 ft x 603 ft. This area represents approximately 427 acres of the ODMDS. The dimensions would be roughly 15,000 ft x 16,000 ft x 600 ft. The berm would be built on roughly a 3:1 slope, and would rise to about 10 feet above the natural bottom elevation but no higher than -25 ft MLLW. The reef would serve multiple purposes, including hardbottom habitat, fish habitat, and sediment containment. An excavator or clamshell dredge would allow the largest material to be used to construct the berm; however, use of a cutterhead suction dredge could minimize costs and produce smaller size material. This beneficial use project would use smaller material to create the base of the berm and the outer portion of the berm would be created with larger rock dredged with a clamshell dredge. This would serve to increase the surface area of the reef, thereby enhancing habitat value. The reef would serve multiple purposes, including hardbottom habitat, fish habitat, and sediment containment.

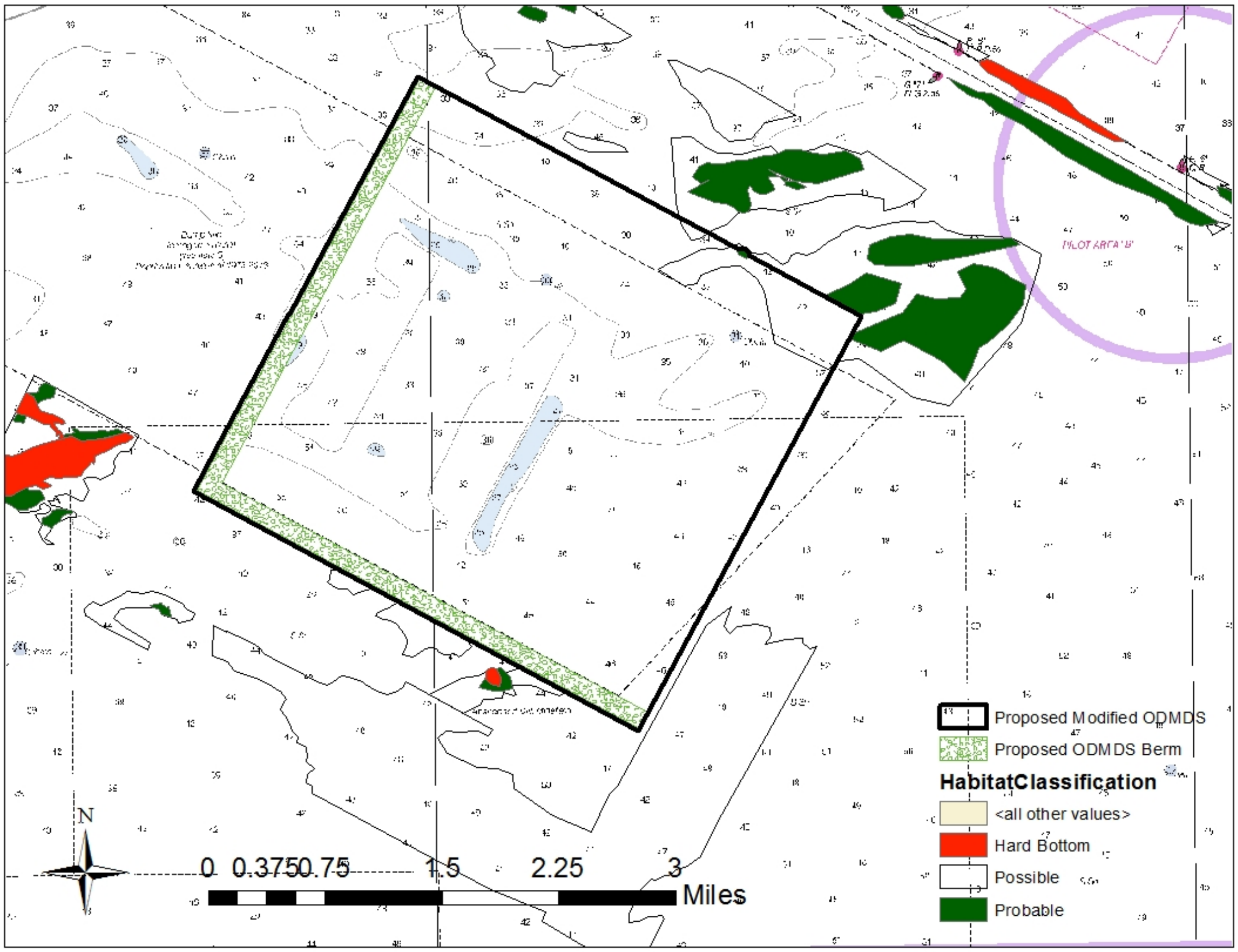


Figure 5. Proposed ODMDS and location of hardbottom habitat and the habitat berm

2.3.2 Hardbottom Habitat Creation

Limestone rock would be dredged from within the entrance channel and used to create as substrate for sessile invertebrates, and structure for fish species after being placed within strategic locations nearby the channel. USACE would construct 8 new 33-acre reef sites. Four would be located along the north side of the channel and 4 would be located along the south side of the channel. For a conceptual depiction of the location of these reefs see Figure 4. Prior to construction the locations of these reefs would be refined and coordinated with the resource agencies. At the request of the SCDNR Artificial Reef Program, approximately 240,000 CY of rock material would also be deposited at the 25 acre

Charleston Nearshore Reef site. These reefs would provide extensive bathymetric features located between approximately 6 nm offshore of Charleston Harbor out to approximately 10 nm. Two of the reefs would be constructed to optimize hardbottom habitat for use as mitigation sites and the other six sites would be specifically for beneficial use of dredged material. More detail on the hardbottom reef sites can be found in Appendix H of the DEIS (Hardbottom Resources) and Appendix P of the DEIS (Mitigation). The SCDNR Charleston Nearshore Reef site is discussed in Appendix M2 (404(b)(1) evaluation), because it is within state waters inside of the 3 nautical mile limit.

Two Mitigation Sites: A grid-based approach would be used to construct the reef structures at the mitigation sites. Each site would consist of sixteen (16) 300-foot by 300-foot cells that combine to create a 33 acre patch reef area about 600 feet wide and 2,400 feet long. The cell arrangement would be two (2) across by eight (8) long. The 16 cells would each require 8,000 to 12,000 CY, or approximately 128,000 to 192,000 CY to create the desired peak vertical relief of 3.5 – 4.5 feet (after settling) and the desired aerial coverage within each cell of 75%. All of the material used to construct the mitigation sites would be excavated using a clamshell dredge to maximize the size of the material used to construct the reef and minimize dispersal of the material.

Six Placement Sites: The six (6) 33-acre placement sites would each have the same dimensions as the mitigation sites (600 feet wide by 2,400 feet long). However, dredged material would be placed to cover the entire area to a peak relief height of about 10 feet (after settlement) and tapering to natural contours/conditions at the site margins. Each site would utilize about 320,000 cubic yards of material. Smaller material generated by the hopper dredges would be used to create a base that would be covered with larger material dredged using clamshell dredges to create the desired habitat. To estimate volumes it was assumed that the average height of material would be about 6 feet based on a peak relief height of about 10 feet and tapering to 0 feet at the margins of the sites.

2.3.3 Crab Bank Enhancement

Dredged material could be used to enlarge Crab Bank by placing material on the channel side of the island running from north to south. This would help support the avian species that utilize the island for nesting, roosting, and foraging (Figure 4-4). Crab Bank has been designated as an "Important Bird Area" in South Carolina and is established as "Crab Bank Seabird Sanctuary". SCDNR indicates that, "Crab Bank supports colonies of nesting waterbirds because of its isolated nature and lack of mammalian predators. Although all species may not nest on the island each year, examples of species that have used the island include: brown pelican, least tern, royal tern, black skimmer, gull-billed tern, sandwich tern, common tern, laughing gull, Wilson's plover, American oystercatcher, willet, great egret, snowy egret, tricolored heron and ibis. Besides providing nesting habitat, the sanctuary provides winter loafing and feeding areas for numerous species. (https://www.dnr.sc.gov/mlands/managedland?p_id=215). While the island fluctuates in size constantly, it has largely been migrating towards the north over the last 15 years. Further demonstrating a need for beneficial use of dredged material at Crab Bank, USACE performed a shoreline change assessment for this study and determined that the island has decreased in size from 17.94 acres of dry beach habitat in 1994 to 5.01 acres in 2011. (Appendix A). While not specifically studied during this project, this beneficial use concept could involve enlarging Crab Bank to roughly 58 acres at approximately +8 feet MLLW based on the southern shoreline of Crab Bank in the early 1990's (shown by the green line in Figure 4-4). The precise size and scope of the project would be determined during the PED phase, and would be dependent on a source of suitable material.

Figure 6. Crab Bank beneficial use concept

2.3.3 Shutes Folly Island Enhancement

Placement of dredged material around Shutes Folly and Castle Pinckney to prevent erosion could provide a beneficial use of dredged material option. Shutes Folly provides nesting habitat for colonial seabirds due to its isolated nature, small size, and lack of predators. It is one of only nine active nesting sites in the entire state. Skimmers and oyster catchers like the shell hash that effaces the eastern side of Shutes Folly. The USACE has an existing shoreline protection project at the site. It was designed and constructed primarily to protect Castle Pinckney. The island has been noted by the group, Charleston Harbor Wildlife, as being "often considered for restoration." They state that, "in 1997, wildlife biologists pressed for the island as a site for dredge spoil to boost the small seabird colony there…" (http://charlestonharborwildlife.com/iwa/cp-sf/). Additionally, Castle Pinckney, an historic site, sits atop the island. The size and scope of the project would be determined during the PED phase, dependent on a source of suitable material.

Figure 7. Shutes Folly beneficial use concept

2.3.4 Bird Nesting Island Creation

There are a few locations near the mouth of the harbor that could support the creation of a bird nesting island, similar to Tompkins Island created by the Savannah District. However, this alternative would be more expensive and more complicated from an environmental permitting perspective. The size, scope, and environmental benefits associated with this option would be determined during the PED phase and would depend on a source of suitable material.

2.3.5 Nearshore Placement off Morris Island

Dredged material could be placed offshore of Morris Island where natural processes could sort and transport it. However, this alternative would require extensive modeling and coordination with multiple resource agencies to resolve major and complex concerns. It would also be expensive and complicated from an environmental permitting perspective. The size, scope, and benefits associated with this option would be determined during the PED phase and would depend on a source of suitable material.

2.3.5 Beneficial Use Analysis

Typically design of beneficial use projects require a grain size/compatibility analysis and potentially modeling of sediment transport and fate to be completed for these types of projects. Due to the accelerated schedule and limited budget for this study, this work would be performed during the PED phase. As a result, the measures are discussed in the Feasibility Report/EIS without detailed analysis, but with a commitment to perform additional analysis of these projects during the PED phase. Final designs, decisions to implement or not and permit acquisition would take place during the PED phase.

3.0 ESSENTIAL FISH HABITATS

Significance. Charleston Harbor supports significant fish and wildlife resources including many marine and estuarine species. The estuary supports large populations of penaeid shrimp and blue crabs which are economically important species. Demersal fish species include Atlantic croaker (*Micropogonias undulates*), bay anchovy (*Anchoa mitchilli*), Atlantic menhaden (*Brevoortia tyrannus*), spotted hake (*Urophycis regia*), weakfish (*Cynoscion regalis*), spot (*Leiostomus xanthurus*), blackcheek tonguefish (*Symphurus plagiusa*), white catfish (*Bagre marinus*), and silver perch (*Bairdiella chrysoura*). Other fish of commercial or recreational value are commonly found in Charleston Harbor, including southern flounder (*Paralichthys lethostigma*), red drum (*Sciaenops ocellatus*), spotted seatrout (*Cynoscion nebulosus*), bluefish (*Pomatomus saltatrix*), spot, and black drum (*Pogonias cromis*). Several anadromous species including two federally protected species, Atlantic sturgeon (*Acipenser oxyrinchus*) and shortnose sturgeon (*A. brevirostrum*), use Charleston Harbor.

All of Charleston Harbor's tidally influenced reaches and adjacent wetlands are considered EFH. The National Marine Fisheries Service (NMFS) provided USACE with a National Environmental Policy Act (NEPA) Scoping letter on November 2, 2011. In this letter NMFS indicated that "Essential Fish Habitat (EFH) within the project area includes estuarine and marine emergent vegetation, tidal freshwater wetlands, tidal creeks, oyster reefs, water column, intertidal and subtidal mudflats (unconsolidated bottom), coastal inlets, coral and artificial reefs, and hardbottom." Many of these habitats foster growth and provide food and protection from predators and are integral to producing healthy populations of commercially and recreationally important species.

Tidal oligo-, meso-, and polyhaline wetlands in Charleston Harbor include estuarine emergent marshes dominated by cordgrass species (*Spartina alterniflora*) and black needlerush (*Juncus roemerianus*). Higher emergent marsh areas contain sea oxeye (*Borrichia frutescens*), salt grass (*Distichlis spicata*) and salt meadow hay (*Spartina patens*). Estuarine scrub shrub wetlands are dominated by wax myrtle (*Myrica cerifera*), salt marsh elder (*Iva frutescens*), and groundsel tree (*Baccharis halimifolia*). Common reed (*Phragmites australis*) is also found along the fringe of the high marsh. No wetlands directly abut the Federal navigation channel. NOAA defines estuarine emergent wetlands as "Deepwater tidal habitats and adjacent tidal wetlands that are usually semi-enclosed by land but have open, partly obstructed, or sporadic access to the ocean, with ocean-derived water at least occasionally diluted by freshwater runoff from the land. The upstream and landward limit is where ocean-derived salts measure less than .5 ppt during the period of average annual low flow. The seaward limit is (1) an imaginary line closing the mouth of a river, bay, or sound; and (2) the seaward limit of wetland emergents, shrubs, or trees when not included in (1).”

Tidal freshwater emergent wetlands include intertidal emergent species, floating leaf vegetation, and submerged aquatic vegetation. Typically tidal freshwater wetlands/marshes are more species rich than their brackish or saltwater counterparts, and include such species as white marsh/cutgrass (*Zizaniopsis miliacea*), wild rice, sawgrass (*Cladium sp.*) and bulrush (*Scirpus sp.*). Also present and often mixed in with these common freshwater plants are big cordgrass, black needlerush, and salt-marsh bulrush. These wetlands frequently have an understory of green arrow arum (*Peltandra virginica*), water-primrose (*Ludwigia sp.*), water hyacinth (*Eichhornia sp.*), pickerelweed (*Pontederia sp.*), sensitive fern (*Onoclea sensibilis*), arrowhead/duck potato (*Sagittaria sp.*), water hemlock (*Cicuta sp.*), lizard's tail (*Saururus cernuus*), alligator weed (*Alternanthera philoxeroides*), obedient plant (*Physostegia virginiana*), spider lily (*Lycoris radiata*), smartweed (*Polygonum sp.*), beard grass (*Andropogon sp.*), false indigo (*Amorpha sp.*), and groundnut (*Apios americana*). Submerged aquatic vegetation primarily includes hydrilla (*Hydrilla verticillata),* Brazilan elodea *(Egeria densa), p*ondweed (*potamogeton sp.),* and Carolina fanwort (*Cabomba sp.).* While floating leaf vegetation primarily included species such as water-primrose, water hyacinth, pickerelweed, and smartweed. Extensive studies have been conducted in salt marsh systems, while tidal freshwater and oligohaline marshes have been the focus of far fewer investigations. However, the existing studies that focus on tidal freshwater and oligohaline areas have concluded that they also provide important habitat that is utilized by fish and crustacea (McIvor et al 1989, Odum et al 1988).

Palustrine freshwater forested wetlands are also present along the freshwater portion of these river systems. These wetlands by definition are, “All nontidal wetlands dominated by trees, shrubs, persistent emergents, emergent mosses, or lichens, and all such tidal wetlands where ocean-derived salinities are below 0.5 ppt [parts per thousand]” (Cowardin et al., 1979). They occur at the interface of tidal aquatic and terrestrial ecosystems (James et al., 2012). Field et al., (1991) conservatively estimated that there are 40,000 hectares of tidal freshwater forested wetlands in South Carolina.They are deciduous forested wetlands, made up of different species of gum (*Nyssa* sp.) and oak (*Quercus* sp.) and bald cypress (*Taxodium distichum*), as well as tupelo, red maple, eastern red cedar, Atlantic white cedar, wax myrtle, sweet bay, red bay, pine, magnolias, etc. The Cooper, Ashley, and Wando Rivers all have palustrine wetlands (tidal and non-tidal) within their watersheds.

Tidal Creeks. Variable in size and water depth, coastal tidal creeks are nursery grounds for larvae and juvenile fish species. As an interface between estuarine habitats and the freshwater confluence of upstream flow, tidal creeks are characterized by their oyster bars, mud flats, and intertidal rivulets. At high tide when predators can access these creeks, juvenile fishes take advantage of the protection afforded by the marsh. As the tide ebbs and predators are forced to leave the shallow creeks, juveniles move off the marsh surface and concentrate in the creeks where their abundances can be quite high.

Oyster Reefs. The term oyster reef often is interchanged loosely with other terms for local estuarine areas inhabited by oysters, including oyster bar, oyster bed, oyster rock, and oyster ground. Typically, oyster reefs are defined as natural bivalve structures found between the tide lines which can be composed of oyster shell, live oysters, and other organisms that form contiguous from scattered oysters in marshes and mud flats. Figure 8 shows the distribution of live oyster bars and remnant habitats ("wash").

Estuarine Water Column. The estuarine water column is classified as essential fish habitat. It is located between the sediment-water interface and the surface of the water. The EFH estuarine water column provides both migrating and residential species of varying life stages the opportunity to survive in a productive, active, unpredictable, and at times strenuous environment. As the transport medium for nutrients and organisms between the ocean and inland freshwater systems, the estuarine water column is as essential a habitat as any marsh, seagrass bed, or reef (SAFMC 1998a). Section 5 of this document details the potential short-term and long-term impacts the project would have on the water column.

Intertidal and Subtidal Mudflats (Unconsolidated Bottom). Intertidal flats are the unvegetated bottoms of estuaries and sounds that lie between the high and low tide lines. These flats occur along mainland or barrier island shorelines or can emerge in areas unconnected to dry land. Intertidal flats are most extensive where tidal range is greatest, such as near inlets and in the southern portion of the coast. Because the influence of lunar tides is minimal in the large sounds, true intertidal flats are not extensive, except for the area immediately adjacent to inlets (Peterson and Peterson 1979).

Figure 8. Locations of oyster reef systems within the Charleston Harbor Post 45 study area

Coastal Inlets. Sand spits, jetties, islets, tidal flats, shoals, and sandbars are often associated with coastal inlets which themselves are restricted areas of intense ebb and flow tidal changes. Inlets are often the bottlenecked area where the currents of the ocean, driven by tides, meet the freshwater flow from upland and upstream rivers, tidal creeks, and streams. Coastal inlets are areas of intense changes in energy caused by the daily tidal changes. Inlet habitats in the southeastern United States are frequently affected by waterway and beach nourishment projects.

Hardbottom: Natural. On a continental scale, "hardbottom" refers to a classification of benthic communities that occur in temperate, subtropical, and tropical regions that lack the coral diversity, density, and reef development of other types of coral communities (SAFMC 1998a). The South Carolina Department of Natural Resources (SCDNR) defines hardbottom habitat as "exposed areas of rock or consolidated sediments, distinguished from surrounding unconsolidated sediments, which may or may not be characterized by a thin veneer of live or dead biota, generally located in the ocean rather than in the estuarine system." These hardbottom reefs are an important component of South Carolina's offshore resources, which provide habitat and foraging grounds for a diverse array of invertebrate and fish species (Wenner et al. 1983; Sedberry and Van Dolah 1984). These communities support habitat-structuring sessile epifauna such as sponges, corals, bryozoans, and ascidians (Burgess et al. 2011). Burgess et al. (2011) state that nearshore hardbottom habitat is typically patchy and surrounded by large expanses of sand, and that the reef organisms are often exposed to sediment movement resulting from winds, tides and storms. Hardbottom communities off of Charleston County currently comprise 311,262 acres of *known* habitat and 53,918 acres of *probable* habitat (Figure 9). There is a substantial concentration of these habitats offshore of Charleston Harbor and to the south of the existing entrance channel. USACE conducted an evaluation of impacted hardbottom areas as well as needs for compensatory mitigation (see appendices of the EIS).

Hardbottom: Artificial. Man-made structures, such as artificial reefs, wrecks, and jetties, provide additional suitable substrate for development of hardbottom communities. Artificial reefs are structures constructed or placed in waters for the purpose of enhancing fishery resources and providing opportunities for commercial and recreational fisheries. Although the purpose of artificial reef placement is primarily fishery enhancement, colonization of the structures by marine life results in establishment of hard bottom habitat. Dozens of artificial reefs have been created in the county's waters. Vessels that have run aground or sunk and remain on the seafloor can also provide a base for hardbottom communities.

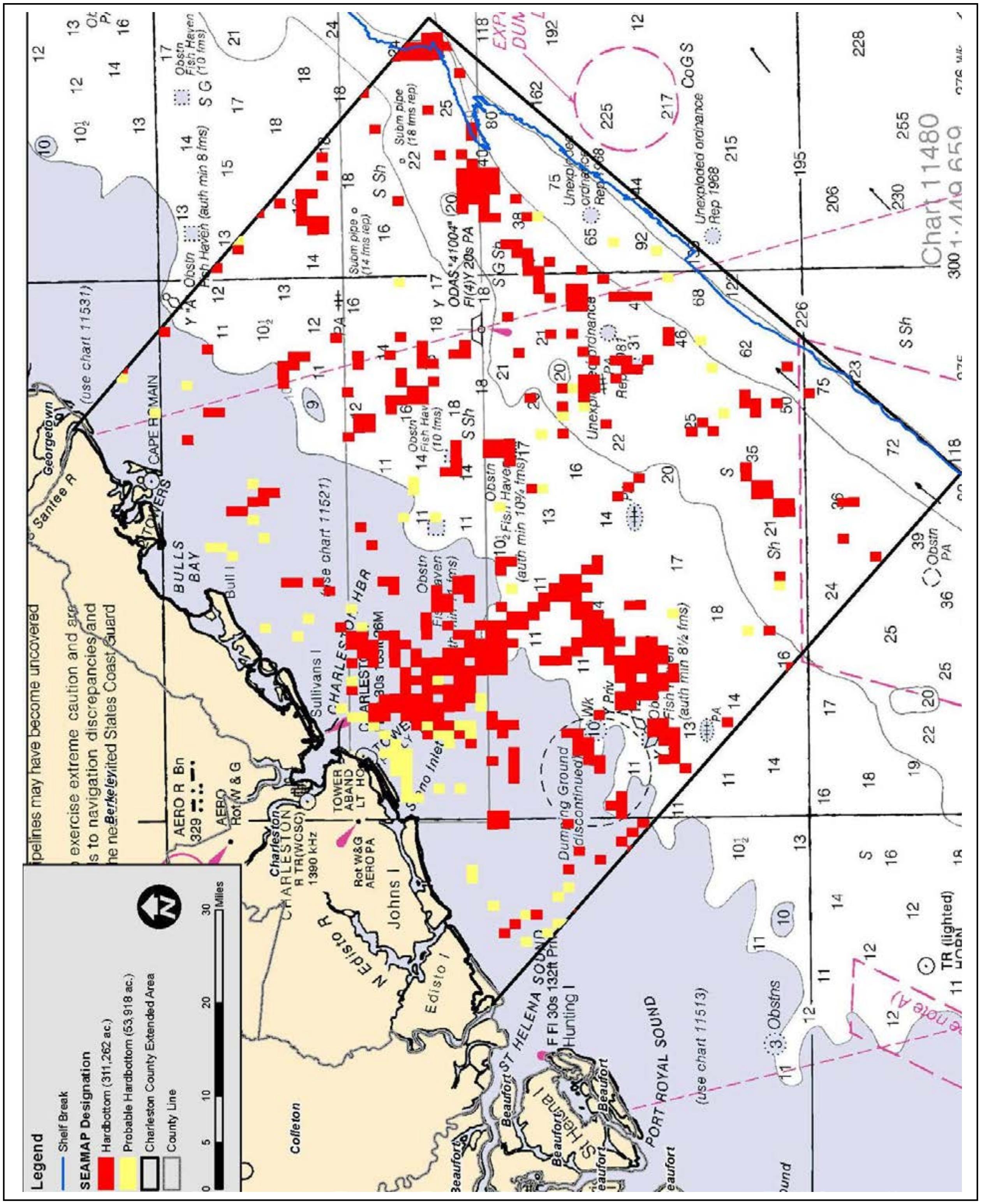


Figure 9. Charleston County hardbottom

4.0 HABITAT AREAS OF PARTICULAR CONCERN

Within the areas designated as Essential Fish Habitat, there are concentrated habitats that provide important ecological functions called Habitat Areas of Particular Concern (HAPC). The Fisheries Management Councils may designate a specific habitat based on one or more of the following criteria: importance of the ecological function provided by the habitat; extent to which the habitat is sensitive to human-induced environmental degradation; whether, and to what extent, development activities are, or will be, stressing the habitat type; and rarity of the habitat type.

The HAPC designation does not necessarily confer additional protection or restrictions upon an area, but helps prioritize and focus conservation efforts. Although these habitats are particularly important for healthy fish populations, other EFH areas that provide suitable habitat functions are also necessary to support and maintain sustainable fisheries and a healthy ecosystem. HAPC can be geographically grouped by managed species to better describe needs/uses of these sensitive habitats:

- **Shrimp**- All coastal inlets, all state-designated habitats of particular importance to shrimp, state-identified overwintering areas
- **Snapper Grouper Complex**- medium to high profile offshore hardbottoms where spawning normally occurs; localities of known or likely periodic spawning aggregations; nearshore hardbottom areas; The Charleston Bump (South Carolina); seagrass habitat; oyster/shell habitat; all coastal inlets; all state-designated nursery habitats of particular importance to snapper grouper; pelagic and benthic Sargassum; Hoyt Hills for wreckfish; the Oculina Bank HAPC; all hermatypic coral habitats and reefs; manganese outcroppings on the Blake Plateau; and Council-designated Artificial Reef Special Management Zones (SMZs). For **Black Sea Bass**, estuarine ebb and flows are critical to provide transport, refuge, and feeding/development areas for all life stages
- **Coastal Migratory Pelagics**- the Charleston Bump and Hurl Rocks (South Carolina); Pelagic Sargassum; and Atlantic coast estuaries with high numbers of Spanish mackerel and cobia (Broad River, SC)
- **Bluefish**- surf zone seaward of intertidal beaches and coastal inlets where ebb and flow currents are created by a bottleneck area of intense currents
- **Summer Flounder**- coastal inlets, estuarine systems for juvenile and adult development

Areas designated by NMFS and the FMCs affecting the South Atlantic area, and more specifically within South Carolina, include the Broad River, the Charleston Bump, and Hurl Rocks. Area-wide geographically defined HAPCs include Council-designated artificial reef special management zones, hermatypic coral habitat and reefs, hardbottoms, Hoyt Hills, *Sargassum* habitat, state-designated areas of importance to managed species, and submerged aquatic vegetation (SAV).

5.0 MANAGED SPECIES

5.1 Penaeoid Shrimps

In the southeastern United States, the shrimp industry is based on the white shrimp (*Litopenaeus setiferus*), brown shrimp (*Farfantepenaeus aztecus*), pink shrimp (*Farfantepenaeus duorarum*), and the deeper water rock shrimp (*Sicyonia brevirostri*). The royal red shrimp (*Pleoticus robustus*) also occurs in deeper water and sustains a limited harvest. For the above species, coastal inlets have been classified as HAPC. Within the project area, this includes the estuarine and marine water columns within the inlet which includes the navigation channel. These areas are the connecting waterbodies between inshore estuarine nursery areas and offshore marine habitats used for spawning and growth to maturity. Essential Fish Habitat for rock shrimp and royal red shrimp occurs in deeper offshore waters. None of these offshore areas occur within the study area.

Representative species profile: white shrimp. White shrimp are especially important in South Carolina. The species is subject to both recreational and commercial fisheries. The local agency responsible for management of white shrimp stocks within South Carolina waters is the SCDNR. Below are several important life-history, environmental, and resulting management considerations for the species (text relevant to the project area/proposed project excerpted and transcribed from Whitaker 2012):

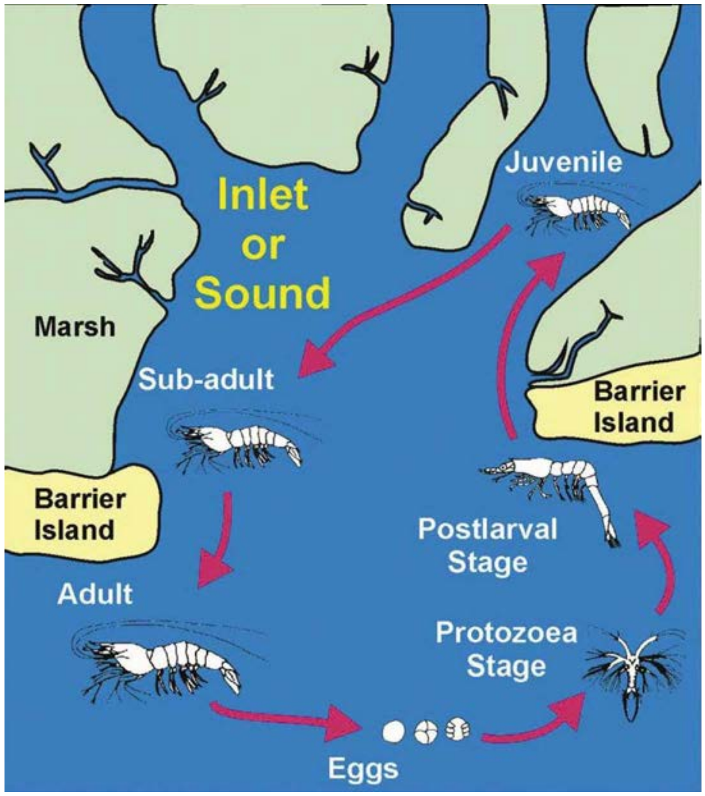
> "The spawning season for white shrimp during spring is obvious by the large catches of mature shrimp by the commercial fleet. The exact timing of the spawning period seems to be set by water temperature during spring, but white shrimp typically spawn during May and early June with a few individuals spawning as late as July and early August…Post larval shrimp seem to settle out in the shallow waters in the upper ends of saltmarsh tidal creeks. Shrimp will remain in this "nursery habitat" about two or three months until they are about four inches in length. During high tide, juveniles move into the marsh grass to feed and escape predators. At low tide, when the water level is below the saltmarsh grass, shrimp concentrate in creek beds. The smallest shrimp remain near the creek bank while larger juveniles tend to be in deeper creek waters…Both brown and white shrimp seem to prefer muddy bottom...
>
> "As shrimp become larger, they leave the brackish waters and move gradually toward the higher salinity waters of the ocean…Shrimp usually begin moving into coastal rivers when they reach about 4 inches in length. Further growth occurs in the rivers until the shrimp are ready to move into the lower reaches of sounds, bays and river mouths. These lower reaches, termed "staging areas" by some biologists, serve to accumulate shrimp just prior to dispersal into the ocean. When white shrimp are in the staging areas, many will move into the shallow peripheral areas to feed at night…In years when shrimp are very abundant, they may migrate into the ocean at a size of about 4 to 5 inches in length. When not abundant, however, average size of shrimp may be 6 inches or more before they leave the estuaries. The difference in size between the years of high stock abundance and low abundance seems to be related to…density-dependent growth…Heavy rainfall, resulting in very low salinities, can force juvenile shrimp from nursery areas. When forced into the inhospitable open-water areas, growth and survival rates are poorer because of less available food and suitable habitat.

“Extreme environmental conditions such as droughts or unusually warm fall weather may result in delaying emigration of white shrimp into the ocean. Tagged white shrimp released into coastal waters of South Carolina in September have been observed to remain in the estuaries for two months or more before moving seaward. Heavy rainfall or river discharge along with the accompanying drops in water salinity (salt content of the water) have been known to cause shrimp to move into the ocean prematurely…In a wet year, the majority of the white shrimp may move into the ocean in August, about a month ahead of normal. The result would be a poor shrimp baiting season and poor harvest by commercial trawlers in October, normally one of the better months for shrimping. The areas typically most severely affected are Charleston Harbor and Winyah Bay, which receive relatively large amounts of upstate river discharge…Without significant rainfall and/or river discharge during fall, white shrimp appear to remain in the estuaries until water temperature falls to about 60-65˚F and then migration seems to occur primarily during the large tides associated with new and full moons...”

“White shrimp abundance fluctuates more than that of brown shrimp. The primary cause of these large fluctuations is the occasional near-total loss of spawning stocks. The white shrimp is a subtropical species and, being such, is susceptible to cold temperatures. During late fall, larger white shrimp that aren’t caught by recreational or commercial fishermen migrate south as far as Cape Canaveral, Florida. This has been repeatedly documented by tagging studies. Unfortunately, most of these shrimp are caught before they have an opportunity to return north the next spring (assuming they would if allowed). Therefore, we in South Carolina are dependent upon the small white shrimp that overwinter in our estuaries to be our primary spawning stock. During winters in which water temperature falls to 46˚F or below for seven or more days, most of the overwintering brood stock are wiped out. In some years, cold-related mortalities have been noted as far south as the Georgia-Florida border. Following cold kills, the roe shrimp harvest is usually less than 50,000 pounds and often zero. Fall commercial landings also suffer, being less than 20 percent of the long-term average.

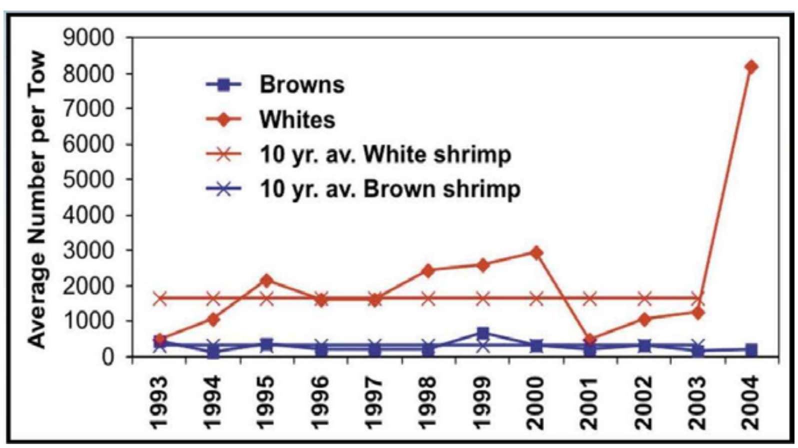
“If an adequate number of spawners is present, the next most important factor for white shrimp abundance seems to be water salinity in the nursery habitat in August and perhaps July. Low landings seem to be related to unusually dry summers resulting in higher than average salinity values. However, unusually wet summers can be detrimental also. Moderate rainfall and river discharge appear to create ideal conditions for white shrimp in most of the state’s coastal marshes.”

In addition to providing a generalized schematic for white shrimp life-history stages (Figure 10), Wenner (2004) discusses the state’s fishery assessment program and the significance of the blend of environmental variables affecting white shrimp abundance in Charleston Harbor. Notably, he cites water temperatures as a critical parameter (see years 2001 and 2003 in Figure 11), one that is compounded when low salinities are present. He stated, “The poor survival in areas south of Charleston following cold winter temperatures is most likely due to the shallowness of rivers and less river flow” (Wenner 2004). Figure 12 shows where white shrimp have been captured in the Charleston Harbor estuary during SCECAP and other inshore fisheries sampling efforts. Only approximately two-dozen sites produced samples with white shrimp. For white shrimp species summary, see the SCDNR website (https://www.dnr.sc.gov/marine/species/whiteshrimp.html).



Provided by SCDNR Division of Marine Resources (Wenner 2004)

Figure 10. Schematic of white shrimp development



Provided by SCDNR Division of Marine Resources (Wenner 2004)

Figure 11. Catch (via trawl) of white shrimp in tidal creeks near Charleston, SC

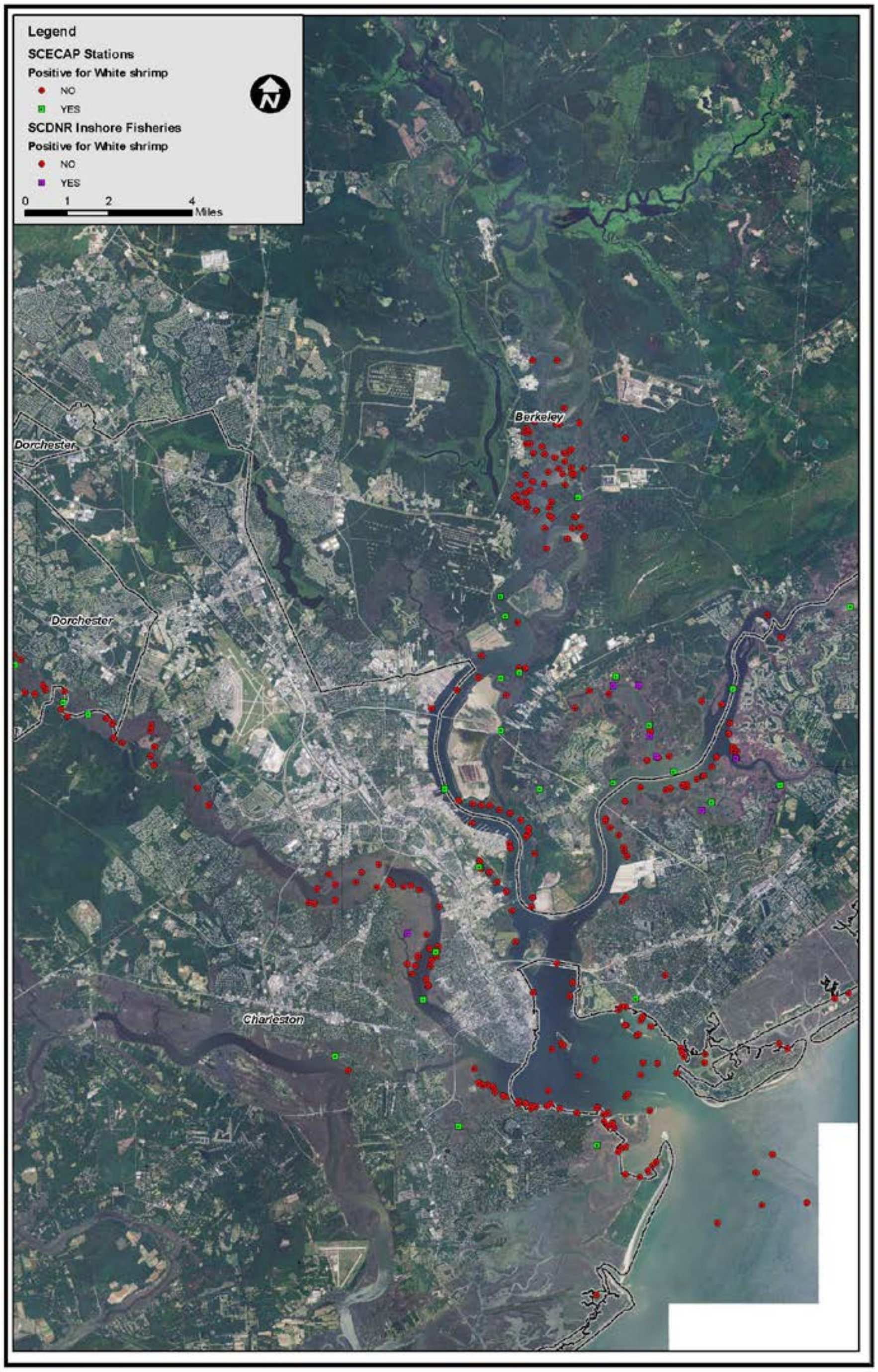


Figure 12. Project area white shrimp capture sites

5.2 Snapper Grouper Complex

Ten families of fish containing 73 species are managed by the South Atlantic Fishery Management Council (SAFMC). There is variation in specific life history patterns and habitat use among the snapper grouper species complex. Snapper grouper species utilize both benthic and pelagic habitats during their life cycle. They live in the water column and feed on zooplankton during their planktonic larval stage, while juveniles and adults are demersal and usually associate with hard structures with high relief. EFH for these species in South Carolina includes estuarine emergent wetlands, estuarine scrub/shrub wetlands, and shellfish beds. Coastal inlets, including those waters of the Cooper River are considered Habitat Area of Particular Concern (HAPC). These areas are critical for spawning activity as well as feeding and daily movements.

5.2.1 Balistidae

Collectively, triggerfishes (fishes of the family Balistidae) inhabit shallow inshore areas (e.g., bays, harbors, lagoons, sandy areas, grassy areas, rubble rock, coral reefs, artificial reefs, or dropoffs adjacent to offshore reefs) to offshore waters as deep as 275 m. These triggerfish, especially the gray and queen triggerfish are an important component of the reef assemblage of both natural and artificial reefs (Vose and Nelson 1994). Information regarding balistid reproduction is limited and varied (Thresher 1984). The basic balistid (e.g., gray triggerfish) spawning behavior involves the production of demersal, adhesive eggs that are thought to stick to corals and algae near or on the bottom. On the other hand, spawning of both the ocean and queen triggerfish takes place well off the bottom over relatively deep water where pelagic eggs are released. Unfortunately, egg and larval development is poorly understood regarding most species; however, a long (≥ 1 yr) planktonic stage appears common for many species.

It has been suggested that juvenile triggerfish are planktonic, taking refuge among floating masses of *Sargassum* (Johnson and Saloman 1984). During this stage of development, the diet consists of primarily zooplankton associated with *Sargassum* or drifting in the water column. The exact timing of the environmental cues that trigger settlement is not well understood. However, juvenile gray triggerfish as small as 16-17 cm standard length (SL) have been reported to colonize hardbottom habitats (Thresher 1984). After juveniles take on a benthic existence, their diet shifts to benthic fauna including algae, hydroids, barnacles, and polychaetes. All triggerfish feed diurnally and are well adapted to prey upon hard-shell invertebrates, especially adults. The diet of adult ocean triggerfish includes large zooplankton and possibly drifting seagrasses, algae, mollusks, and echinoderms. Adult gray and queen triggerfish feed primarily on sea urchins, but in their absence, will shift to other benthic invertebrates such as crabs, chiton, and sand dollars (Frazer et al. 1991; Vose and Nelson 1994). All three triggerfishes are commercially important (especially the queen triggerfish) in the aquarium trade and to some extent as a gamefish.

5.2.2 Carangidae

The project are comprises EFH for carangid species (commonly referred to as “jacks”) because they utilize the offshore and possibly inshore areas adjacent to the proposed project area. Spawning of the bar jack, yellow jack, blue runner, and the crevalle jack takes place in offshore waters associated with a major current system such as the Gulf Stream from February through September (Berry 1959). Consequently, these four species have an offshore larval existence. Data indicate that peak spawning months for blue runners are May through July (Shaw and Drullinger 1990). Although spawning data regarding the greater amberjack doesn't exist, it is assumed that it is similar to the other four species. As young juveniles, crevalle jack migrate into inshore waters at about 20 mm SL; whereas, blue runners don't migrate into inshore areas until their late juvenile stage (Berry 1959). Young bar jacks have a tendency to remain offshore and yellow jacks occur inshore only occasionally as juveniles (Berry 1959).

Based on collections of juveniles regarding these four species, there is some indication a mobile population (north of Florida) of developing young in the Gulf Stream developed from spawning occurring in more southern waters (Berry 1959).

As juveniles and sub-adults, blue runners occur singly or in schools while juveniles have a high affinity for *Sargassum* and other floating objects in the Gulf Stream (Goodwin and Finucane 1985). Blue runners are a fast growing, long-lived species which attains 75% of its maximum size in its first 3 - 4 years of life (Goodwin and Johnson 1986). The greater amberjack is a far ranging species that inhabits inlets, shallow reefs, rock outcrops, and wrecks with reef fishes such as snappers, sea bass, grunts, and porgies (Manooch and Potts 1997a). They are generally restricted to the continental shelf to depths as great as 350 m (Manooch and Haimovici 1983). Small individuals (< 1 m SL) are usually found in water < 10 m deep while larger individuals frequent waters 18 - 72 m deep (Manooch and Potts 1997b). Greater amberjack are a fast growing species and are recruited to the headboat fishery in the Gulf by age 4 and fully recruited to the fishery by age 8 (Manooch and Potts 1997a; Manooch and Potts 1997b).

All carangids are popular sport fishes among recreational fishers, but not as popular commercially where they are harvested using handlines, bottom longlines, and in some cases traps and trawls. Some Florida fishers feel that amberjack are being exposed to too much fishing pressure, especially owing to their attraction to reefs which make them an easy target for overfishing (Manooch and Potts 1997a). However, as of 1997 there is no evidence of overfishing in either the Gulf of Mexico or southeast Florida (Manooch and Potts 1997b).

5.2.3 Ephippidae

Charleston Harbor and its tributaries are designated as EFH for the spadefish because as a juvenile, it inhabits shallow sandy beaches, estuaries, jetties, wharves, and other inshore areas, as well as deeper offshore habitats as adults. Spawning, which takes place from May to September, involves an offshore migration as far as 64.4 km (Chapman 1978; Thresher 1984). Although no data exists regarding egg and larvae development in nature, small individuals (approximately 1-2 cm TL) appear inshore in early summer (Walker 1991). These small juveniles are commonly observed drifting motionless alongside vegetation (e.g., *Sargassum*). It has been suggested that spadefish mimic floating debris and vegetation to escape predation. As spadefish mature, they move further offshore where large schools will take residence around wrecks, oil and gas platforms, reefs, and occasionally open water. Spadefish are opportunistic feeders; preying upon a variety of items including small crustaceans, worms, hydroids, sponges, sea cucumbers, salps, anemones, and jellyfish. In certain areas, the spadefish is an important game fish.

5.2.4 Haemulidae

Collectively, grunts inhabit shallow inshore areas (e.g., estuaries, mangroves, jetties, piers, and seagrass beds), coral reefs, rock outcrops, and offshore waters as deep as 110 m. Although most of the life history data concerning grunts (Cummings et al. 1966; Manooch and Barans 1982; Darcy 1983; McFarland et al. 1985; Sedberry 1985) are from studies of tomtate, white grunt, French grunt, blue stripe grunt, and the margate, the general information can probably be applied to the other species as well. As a reef-dwelling species, grunts are probably similar to other roving benthic predators such as snappers and groupers that migrate to select spawning sites along the outer reef and participate in group spawning at dusk. Some data suggest that spawning takes place over much of the year, while other data suggest spawning peaks in later winter and spring (Manooch and Barans 1982; Darcy 1983). The eggs are pelagic as well as the planktonic larvae. After this pelagic larval stage that may last several weeks, they settle to the bottom as benthic predators (Darcy 1983). The juveniles are commonly found in seagrass beds, near mangroves and other inshore, shallow areas. Studies in the Caribbean regarding French grunt suggested that fertilization and settlement was associated with the lunar cycle (quarter moon, rather than the full or new moon) and daily tidal cycles (rising and falling tides) (McFarland et al. 1985).

Juveniles are diurnal planktivores that tend to feed higher in the water column than adults on amphipods, copepods, decapods, and small fishes (Darcy 1983; Sedberry 1985). The transformation to adult involves a change in feeding strategy from diurnal planktivore to nocturnal benthic foraging. Most grunts take refuge near the reef in schools, but at dusk they disperse and forage over the reef, along sandy flats, and grass beds for crustaceans, fishes, mollusks, polychaetes, and ophiuroids. Because of these nocturnal foraging migrations, grunts are a major source of food for higher tropic level piscivorous fishes. In addition, they are very important to hardbottom reef-related fisheries regarding the energy transfer from sandy expanses to these reefs (Darcy 1983).

Several species of grunt such as the tomtate and white grunt have some commercial and recreational importance. Tomtate are commonly caught by sport fishers from shore, bridges, jetties, and inshore waters by boat. In the southeastern United States, the hook and line fishery is the most important method of commercial harvest regarding tomtate (Darcy 1983). In addition, tomtate are collected using traps, trawls, and seines off southeast Florida. Commercially, tomtate are usually discarded or cut up and used as bait for the grouper or snapper fishery. Similarly, white grunt are commercially harvested by hook and line along the southeast United States and is also a common sport species.

5.2.5 Labridae

Fishes of the Labridae family are included within the snapper grouper complex. In particular, species such as the puddingwife and hog snapper are of particular importance. While not common within the St. Johns River, they are included for life history comparisons to other species of the complex found within the proposed project area.

The EFH for both species ranges from shallow reef and patch reefs, areas of hard sand and rock, and/or along areas inshore or offshore of the main reef. The puddingwife appears to be depth restricted, as it is rare to find this species in waters deeper than 13.3 m; while the hogfish inhabits areas as shallow as 3.3 m deep (Thresher 1980). Reproduction in wrasses involves a complex reproductive system based on protogynous hermaphroditism which features a complex socio-sexual system involving sex reversal, alternate spawning systems and variable color patterns (Thresher 1980). Both species participate in group (the dominant or terminal male with a harem of females) broadcast spawning that occurs along the outer edge of a patch reef or on an extensive reef complex along the outer shelf during the summer months (Thresher 1984). Hogfish spawn during the late afternoon or early evening hours, while puddingwife spawning is synchronized with strong tidal or shoreline currents. Although the exact duration of both the planktonic egg and larval stages is unknown, some records suggest that the latter may be as short as one month before the larvae settle out. Newly settled hogfish and puddingwifes use common areas around grass flats and the shallow reef, respectively. The smallest juveniles on record collected on reefs are approximately 10 mm SL. Other data suggest that puddingwifes as small as 30 mm SL may be sexually active. As a benthic predator, the diet of adult hogfish consists of mollusks, echinoderms, and small crustaceans (primarily crabs). Owing to their large size, hogfish are popular with sport fishers.

5.2.6 Lutjanidae

The EFH of snappers ranges from shallow estuarine areas (e.g., vegetated sand bottom, mangroves, jetties, pilings, bays, channels, mud bottom) to offshore areas (e.g., hard and live bottom, coral reefs, and rocky bottom) as deep as 400 m (Allen 1985; Bortone and Williams 1986). Like most snappers, these species participate in group spawning, which indicates either an offshore migration or a tendency for larger, mature individuals to take residency in deeper, offshore waters. Data suggest that adults tend to remain in one area. Both the eggs and larvae of these snappers are pelagic (Richards et al. 1994). After an unspecified period of time in the water column, the planktivorous larvae move inshore and become demersal juveniles. The diet of these newly settled juveniles consists of benthic crustaceans and fishes. Juveniles inhabit a variety of shallow, estuarine areas including vegetated sand bottom, bays, mangroves, finger coral, and seagrass beds. As adults, most are common to deeper offshore areas such as live and hardbottoms, coral reefs, and rock rubble. However, adult mutton, gray, and lane snapper also inhabit vegetated sand bottoms with gray snapper less frequently occurring in estuaries and mangroves (Bortone and Williams 1986). The diet of adult snappers includes a variety fishes, shrimps, crabs, gastropods, cephalopods, worms, and plankton. All species are of commercial and/or recreational importance. In particular, the mutton, gray, lane, and yellowtail snapper are targeted species.

Representative species profile: gray snapper. Gray snapper (*Lutjanus griseus*) is a popular gamefish, and one of many species that makes use of both inshore/estuary habitats as well as deeper, offshore habitats. In South Carolina waters, they are generally affiliated with reefs, oyster bars, rocky areas, and estuaries, particularly among seagrass beds if present as well as over soft and sand-bottom areas (Bester 2014). Spawning (broadcast, with demersal eggs) occurs April through November and peaks during summer in estuaries. When individuals reach approximately 8 cm, they move toward shallow rocky areas and coastal reefs (Bester 2014). As the fish approach 20 cm, they may have a preference for habitats with salinities between 9 and 23 ppt (Serrano et al. 2010). Figure 13 shows SCDNR inshore fisheries catch data for gray snapper; apparently approximately 8 to 10 miles upstream of Daniel Island in the Cooper River, there are important gray snapper nurseries.

5.2.7 Serranidae

The EFH of sea bass ranges from shallow estuarine areas (e.g., seagrass beds, jetties, mangrove swamps) to offshore waters as deep as 300 m (Heemstra and Randall 1993; Jory and Iverson 1989; Mercer 1989). Like all other serranids, the six species are protogynous hermaphrodites; functioning initially as females only to undergo a sexual transformation at a later time to become functional males. In addition, like all other serrranids, these species produce offshore planktonic eggs, moving into shallow, inshore water during their post-larval benthic stage. Juveniles inhabit estuarine, shallow areas such as seagrass beds, bays, harbors, jetties, piers, shell bottom, mangrove swamps, and inshore reefs. Juveniles feed on estuarine dependent prey such as invertebrates, primarily crustaceans, which comprise the majority of their diet at this developmental stage. As sub-adults and adults, migration occurs further offshore as refuge consists of rocky, hard, or live bottom, on artificial or coral reefs, in crevices, ledges, or caverns associated with rocky reefs. During this stage in their lives, the bulk of their diet consists of fishes supplemented with crustaceans, crabs, shrimps, and cephalopods. Except for the Goliath grouper, the sea bass species have some importance to commercial and/or recreational fisheries.

5.2.8 Sparidae

EFH for porgies ranges from shallow inshore waters (e.g., vegetated areas, jetties, piers, hard and rock bottoms), to deeper offshore waters with natural or artificial reefs, offshore gas and oil platforms, or live bottom habitat (Darcy 1986). Although nothing is known regarding the sexuality of the jolthead porgy, it is most likely a hermaphroditic species which is widely documented in sparids (Thresher 1984). On the other hand, the sheepshead has been determined to be a protogynous hermaphrodite through histological investigations (Render and Wilson 1992). Information regarding tropical sparids is limited, but in general, it suggests long spawning seasons. Little is known about spawning behavior, but it is presumed that both the sheepshead and the jolthead porgy produce pelagic eggs some distance off the bottom. Aggregations have not been documented. Settlement of sheepshead larvae to the bottom occurs at about 25 mm TL (Thresher 1984). Based on their dentition, both species are well suited for benthic feeding of sessile and motile invertebrates (e.g., copepods, amphipods, mysids, shrimp, bivalves, gastropods) which are bitten off from hard substrates and vegetation. Neither sparid is considered a schooling species, although they will form small groups composed of several individuals occasionally. There is no direct commercial or sport fishery associated with either sparid; however, both are fished in coastal waters. Both species are an important constituent of communities in shallow water and live bottom communities in deeper water (Darcy 1986).

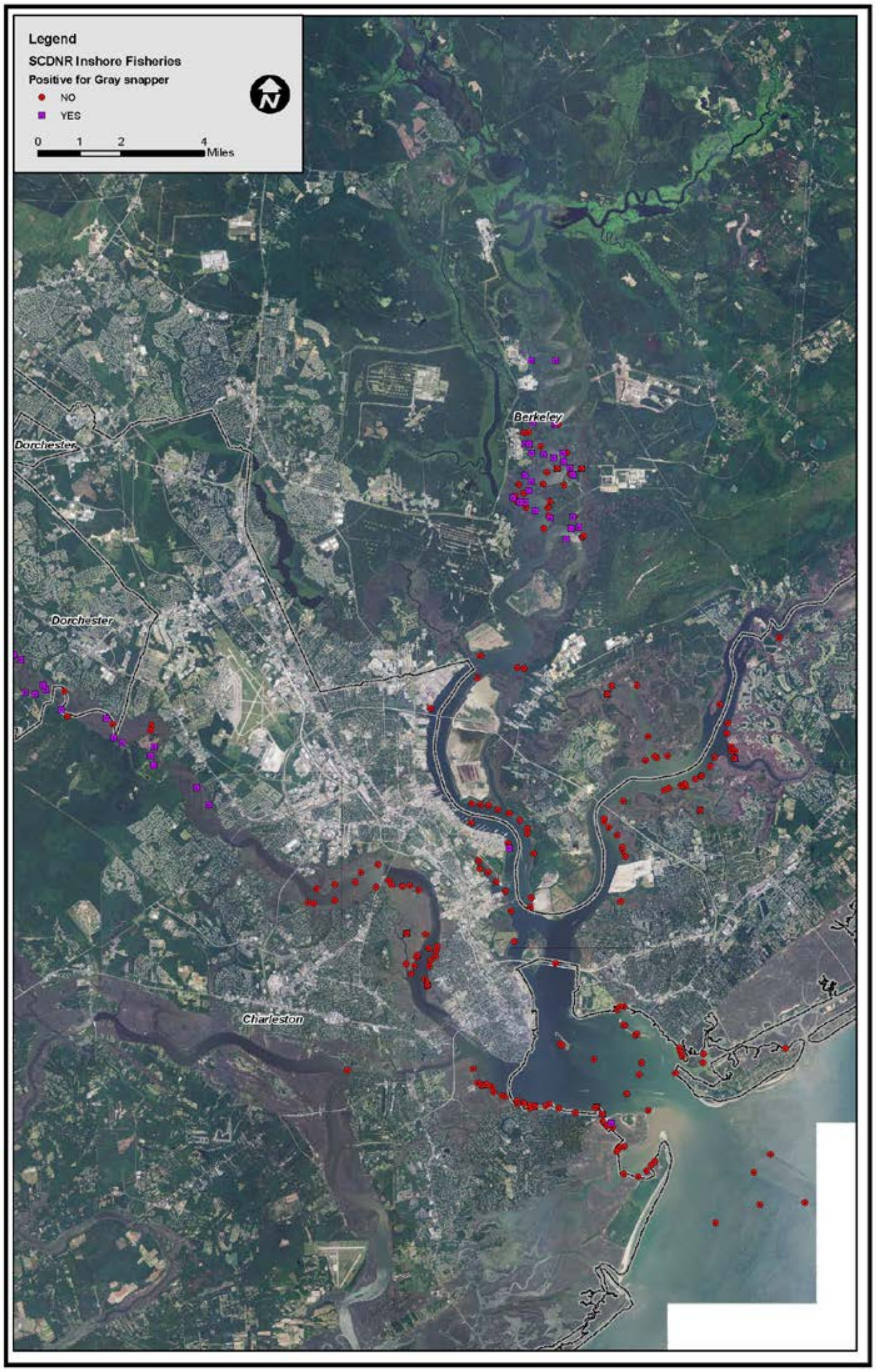


Figure 13. Project area gray snapper capture sites

5.3 Coastal Migratory Pelagics

King mackerel, Spanish mackerel, and cobia are coastal migratory pelagic species managed by the SAFMC. EFH for these species include the inlet and, in a more general sense, any high-salinity bays which may occur in the project vicinity. Many coastal pelagic prey species are estuarine-dependent in that they spend all or a portion of their lives in estuaries. Accordingly, the coastal pelagic species, by virtue of their food source, are to some degree also dependent upon estuaries and, therefore, can be expected to be detrimentally affected if the productive capabilities of estuaries are greatly degraded.

Representative species profile: king mackerel. King mackerel was selected as the representative species for further examination due to a marked decrease in landings since 1998 (see figure below). Conservation may be relatively more important for this species (than other similar species), and assessing if or how the proposed action may affect the species is therefore important. Below are several important life-history, environmental, and resulting management considerations for the species (excerpted and transcribed from SCDNR 2013b):

- Habitat. "King mackerel prefer warm, clear waters; all phases of development occur over continental shelf, including both nearshore and offshore habitats and live bottom…Older fish inhabit high salinity, green ocean waters, near the surface or at moderate depths. May move inshore on higher tides and during summer. Often associated with outer reefs, wrecks, towers, and buoys. Juveniles occur from mid-shelf to inshore waters and from the surface to moderate depths in water column. Individuals caught near fishing piers are typically older juveniles.
- Spawning and larvae. "Spawning occurs between Gulf Stream and high turbidity zone in nearshore waters. In South Carolina, spawning occurs April – September. Larvae remain in high salinity waters throughout development. Larvae may be present across continental shelf, but are often most abundant in middle to outer shelf waters.
- Distribution and Vulnerability. "Distribution is governed by temperature and salinity. Annual migration from South Carolina waters to overwintering grounds in south Florida occurs during fall. Northward migration occurs during spring and early summer. Tendency to associate with hard structure such as fishing piers may increase fishing pressure. Potential for overfishing (especially in south Florida overwintering grounds); migratory nature increases management difficulty."

SCDNR (2013a) explained recreational and commercial fishing trends for the past 35 years (see Figure 14):

- Recreational catch. "The recreational catch, while variable year-to-year, has been on a declining trend since the mid 1980's. The relatively low recent 10 year average (compared to the entire time series) reflects the low total catch in the last ten years. The most recent 10 year average total catch (2002-2012) was one-third the average catch for the entire time series.
- Commercial landings. "Commercial landings for king mackerel reflect a similar trend to the recreational landings with peak landings occurring in the 1980's and early 1990's. There has

been a steady decline in commercial landings since 1990 with the latest 10 year average (2002-2012) landings at 23,400 lbs versus 115,873 lbs for the previous ten years (1991-2001)."

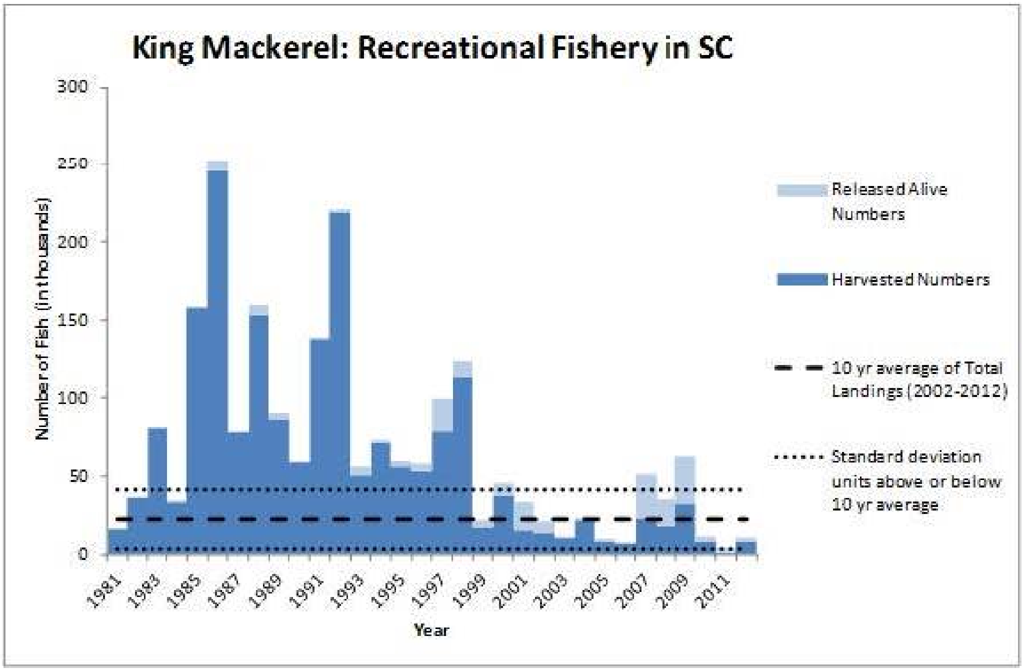


Figure: SCDNR (2013a)

Figure 14. King mackerel recreational fishery catch in South Carolina (1981-2013)

5.4 Bluefish

Bluefish are managed in the U.S. by the Mid-Atlantic Fishery Management Council. Bluefish are a migratory and pelagic species inhabiting most temperate coastal regions and are found along the entire east coast of the United States. Populations along the U.S. Atlantic Coast range from Maine to Florida with many wintering or spawning near the Mid-Atlantic Bight (Shepherd et. al., 2006). Bluefish can reach an age of 12 years and a size of over 100 cm standard length (SL). Adult populations head north from the Bight to winter while others migrate south to the Florida coast (NMFS 2006). By summer, bluefish move north into the Middle Atlantic Bight, although some medium size fish may remain off Florida (Shepherd 2006; Shepherd et al. 2006). A second spawning occurs in the offshore waters of the Mid-Atlantic Bight during summer. The result of these two spawning events is the appearance of two distinct size groups of juvenile bluefish during autumn; a spring spawned cohort with fish approximately 15-25 cm in length and a summer spawned cohort with fish approximately 4-14 cm in length (Able and Fahay 1998). Shepherds (2006) summarized that fish from the two spawning cohorts mix extensively during the year and constitute a single genetic stock (Graves et al. 1992). Bluefish are voracious predators and feed primarily on squid and fish (Buckel et al. 1999; Fahay et al. 1999).

EFH is identified for major estuaries between Penobscot Bay, Maine and the St. Johns River, Florida for juvenile and adult forms of bluefish (NMFS 2010a). Egg and larval forms of bluefish have designated EFH restricted to the pelagic waters over the continental shelf along Florida’s coast. Inshore EFH has not been designated and; therefore, is not within the proposed project area. In general, juvenile bluefish occur in South Atlantic estuaries March through December and adults occur from May through January within the "mixing" and "seawater" zones (Shepherd 2006; Shepherd and Packer 2006). NMFS (1999) included a compendium of other authors’ finding on environmental affiliations of life-history traits of the species. Minimum salinities listed for various stages were 26.2, 31, 35, and 33 ppt, for eggs, larvae, pelagic juveniles, and juveniles/older individuals, respectively. The same table indicated that individuals had been captured in DO levels as low as 4.5 mg/L (NMFS 1999).

Local representative species profile: Bluefish. NMFS (1999) noted that isolated, yet significant, spawning events for bluefish occurred during summer of 1976 and in April of 1979. Larvae were captured by Isaacs-Kidd midwater trawl. Juveniles were also captured in apparently high densities in South Carolina waters, but Clark (1973) believed this to be due to greater sampling effort (NMFS 1999). Juvenile bluefish may be encountered in the areas offshore of the project area, while adult bluefish may be encountered year round in the vicinity of the proposed project area. Figure 15 illustrates that the species could be captured in any of Charleston’s rivers or estuary areas.

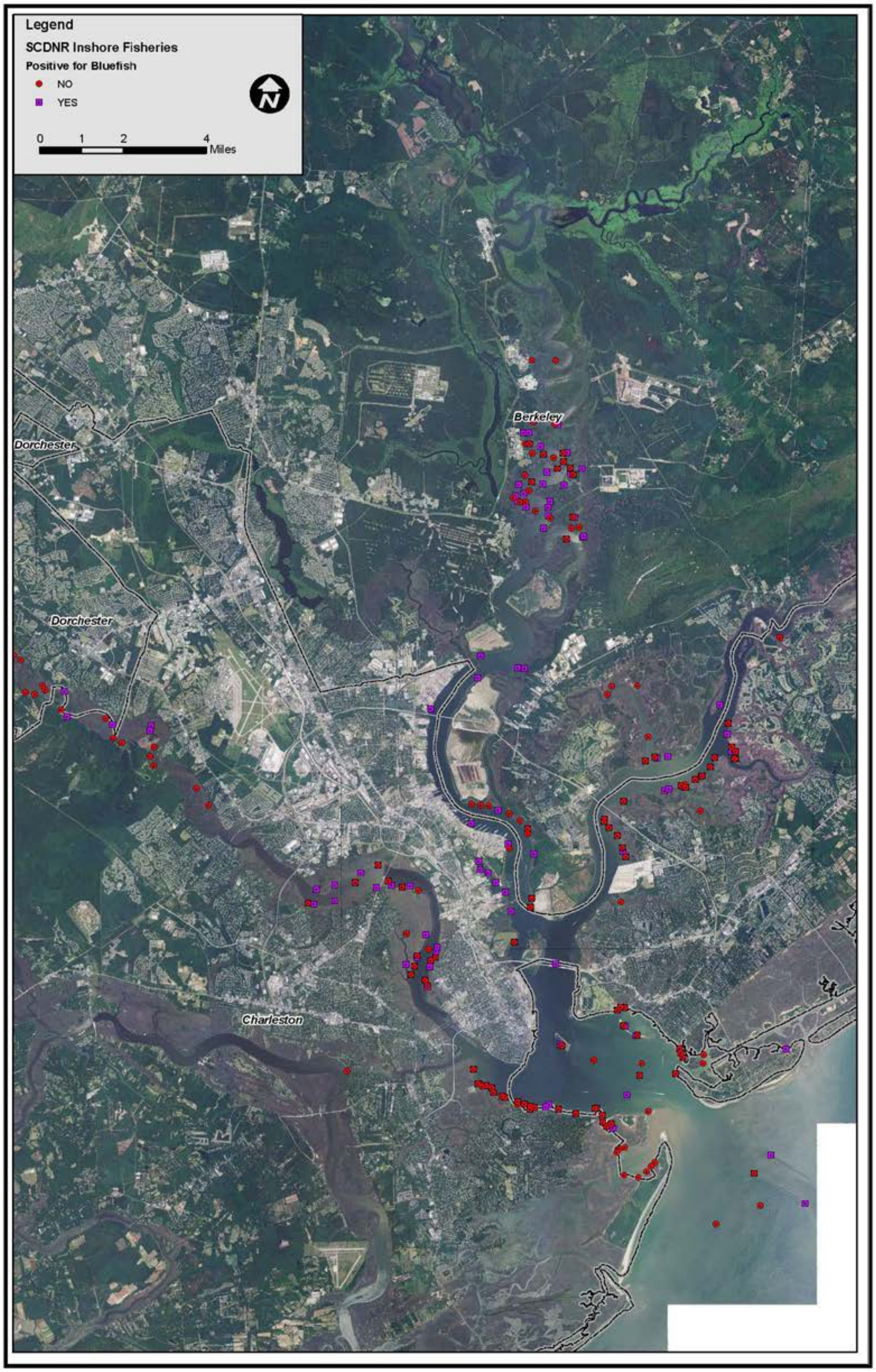


Figure 15. Charleston Harbor Bluefish Captures

5.5 Summer Flounder

Summer Flounder are managed in U.S. waters by the Mid Atlantic Fishery Management Council Species. Summer flounder generally occur in shallow coastal and estuarine waters during warmer months and occupy outer continental shelf areas in colder months. Their range has been shown to extend from Nova Scotia to Florida (Packer et al. 1999). All estuaries where summer flounder were identified as being present have been designated EFH for larvae, juveniles, and adults. HAPCs are designated within juvenile and adult EFH to include all species of macroalgae, seagrasses, and freshwater and tidal macrophytes in any size bed, as well as loose aggregations (NMFS 2010b). These HAPCs may be encountered within the proposed project area outside of the main navigation channel (Figure 1).

Local representative species profile: summer flounder. Below are several important life-history, environmental, and resulting management considerations for the species (excerpted and transcribed from SCDNR 2013c):

- Habitat. "Adults inhabit lower to middle reaches of estuaries, coastal bays, and shallow nearshore shelf waters; typically burrow into sandy to slightly muddy bottoms; occupy a variety of estuarine habitats including tidal creeks and areas with submerged vegetation; also around inlets, jetties, beaches and nearshore reefs. Juveniles utilize bays, estuaries, tidal creeks, submerged vegetation and oyster reefs as nursery habitats. Larvae enter lower salinity waters in upper reaches of estuary whereas juveniles typically reside in moderate salinity waters.
- Spawning and larvae. "Spawning occurs "along continental shelf during seasonal migrations to offshore overwintering grounds; exact spawning locations unknown. In the South Atlantic Bight, spawning occurs November – February. Fish return to inshore habitats during spring. Young larvae develop offshore as plankton; older larvae utilize tidal currents and vertical migrations in water column to enter estuaries during winter and spring. Postlarvae complete metamorphosis to bottom-dwelling fish after settlement in the estuary.
- Distribution and Vulnerability. "Less abundant in South Carolina waters than *P. lethostigma* (southern flounder)... In South Carolina, may overwinter in estuaries or deeper nearshore waters…Tolerate a wide salinity range; however, typical habitat is higher salinity than that of the southern flounder and growth is apparently optimal at intermediate (≥ 10 ppt) salinities. Adults generally prefer salinities ≥ 28 ppt. Conservation concerns: lack of knowledge regarding summer flounder biology and movements in South Carolina waters; degradation or loss of estuarine nursery habitat."

SCDNR (2013d) explained recreational and commercial fishing trends for the past 35 years (see Figure 16):

- Recreational catch. "Recreational catch in South Carolina for summer flounder is highly cyclical due to South Carolina being at the southern end of their distribution range. Peak years occurred in 1984, 1991, and 2004-2006, with catch levels in most of the other years well below the most recent 10 year average (47,141 fish per year). Catches after 2006 dropped off and has stayed well below the 10 year average.

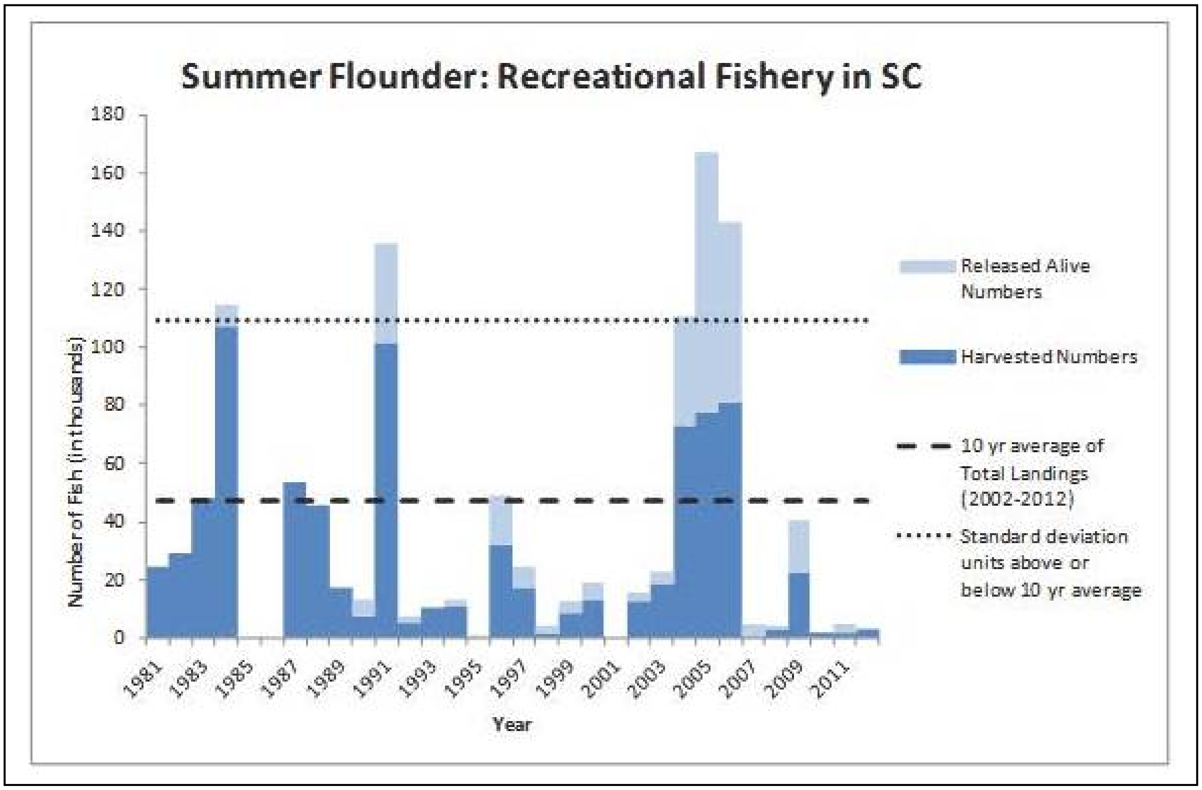


Figure: SCDNR (2013d)

Figure 16. Southern flounder recreational fishery catch in South Carolina (1981-2013)

- Commercial landings. "Commercial flounder landings are not tracked by species, but combined as group to include all species of the genus *Paralichthys*. Total commercial landings for flounder in South Carolina have been steadily declining since the 1980's. The recent 10 year average (2001-2011) of 3,148 live pounds is significantly less than landings in the 1980's (52,972 live pounds) and the 1990's (12,108 live pounds). The primary gear targeting flounder in South Carolina in recent years include both trawls and gigs.

Summer flounder are a popular target for Charleston-area anglers. Figure 17 shows locations where they have been captured during SCECAP and other inshore sampling efforts. The species appears to be distributed in the lower estuary and in the Wando Rivers. Their incidence of capture decreases farther upstream in the Ashley and Cooper rivers.

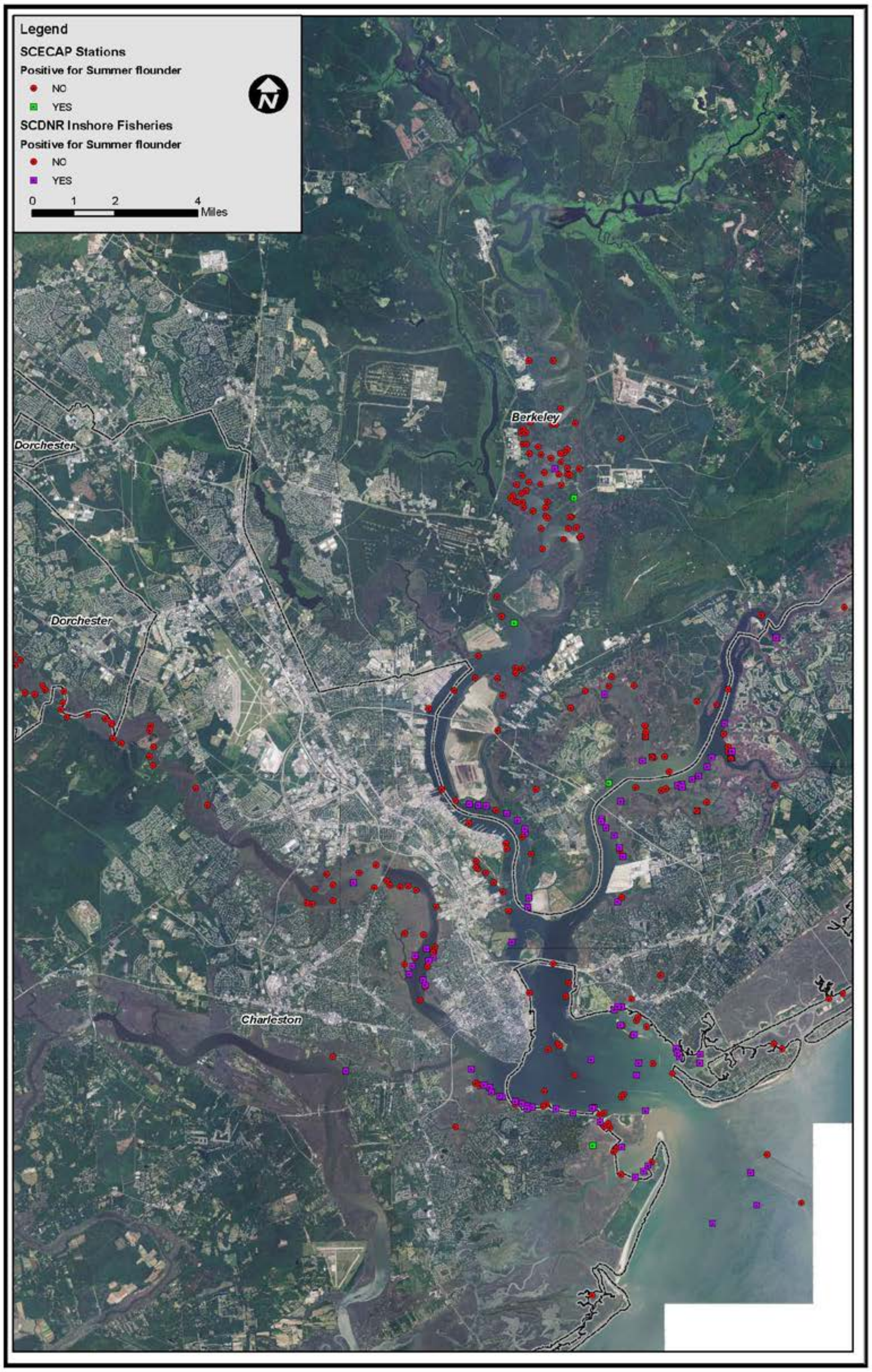


Figure 17. Southern flounder catch in project area

5.6 Black Sea Bass

Black sea bass (*Centropristis striata*) are members of the family Serranidae, which includes groupers (see Section 5.2.7). Black sea bass are jointly managed under the Summer Flounder, Scup and Black Sea Bass Fishery Management Plan by the ASMFC and the MAFMC. The species is distributed from Nova Scotia to Florida and into the Gulf of Mexico, with Cape Hatteras serving as a geographic boundary between overlapping northern and southern stocks. The northern population migrates seasonally and spawns off New England, whereas the southern population migrates and spawns off the Chesapeake Bay area (ASMFC 2009i). Genetic analysis infers a single stock. However, they are managed independently as northern (Nova Scotia to Cape Hatteras, North Carolina), southern (south of Cape Hatteras to Florida), and Gulf of Mexico stocks (ASMFC 2009a).

Black sea bass, a temperate reef fish, prefer a habitat of structures such as oyster beds, wrecks, rock bottom piles, or reefs. Black sea bass spend summers inshore and as coastal water temperatures decline, they migrate and winter in offshore waters (ASMFC 2009a).

A process not yet fully understood, black sea bass (being protogynous hermaphroditic) will change their sex from female to male between the ages of two and five. Studies have determined that 38% of the northern population demonstrates sex reversal, which occurs between August and April following the spawn (ASMFC 2009i). Black sea bass spawn from February to May on the continental shelf; these ocean waters are EFH for black sea bass eggs and larvae (NOAA 2009b). Eggs are suspended in the water column until hatching a few days after fertilization. Young black sea bass will migrate into estuaries and bays, seeking shelter in various habitats such as oyster reefs, anthropogenic structures, and SAVs (ASMFC 2009i).

Estuarine habitats provide post-larvae and juveniles an environment suitable for development and growth. Rough shell/sandy bottoms, SAVs, and man-made structures are EFH for juvenile black sea bass (NOAA 2009f). With falling water temperatures, black sea bass migrate to the edge of the continental shelf and deeper offshore waters, returning to generally the same coastal region the following spring. Offshore structures, man-made or natural, are EFHs to offshore wintering black sea bass (NOAA 2009f). During summer periods, adults are normally associated with inshore structured habitats such as SAVs, oyster beds, hard bottoms, and anthropogenic structures such as piers, pilings, jetties, and wrecks (ASMFC 2009a). As opportunistic feeders, adult black sea bass will feed on a variety of crab, shrimp, fish, and clams (SAFMC 2009, NEFSC 2009c).

Black sea bass life stages depend on the estuarine systems. Tidally influenced estuarine EFHs provide transport, refuge, and feeding/development areas for post-larval, juvenile, and adult black sea bass. All South Carolina coastal inlets and state designated primary/secondary nursery areas are considered HAPCs for many managed species (SAFMC 1998b). Species such as black sea bass, are dependent on the estuarine systems for post-larval, juvenile, and adult developmental success (SAR 2008a, SAR 2008b, and ASMFC 2009a).

5.7 Sharks

The Atlantic Highly Migratory Species Management Division of the National Marine Fisheries Service manages Atlantic highly migratory species (HMS) including tunas, sharks, swordfish and billfish. EFH for HMS principally comprises the marine and estuarine water column habitats within and adjacent to the proposed project area. EFH also includes the inlet (including the navigation channel) and estuarine and shallow coastal waters. Seven species of sharks (all included in the HMS Fishery Management Plan, i.e., "federally implemented FMP, see Table 3 below) (NMFS 2006) are relatively common in the Charleston Harbor. Lemon sharks (*Negaprion brevirostris*) were captured at only four sites in the harbor, including one site adjacent to Crab Bank (Figure 18), and sand tiger shark (*Carcharias taurus*) was captured at only one site (Figure 19). Unidentified sharks were mostly captured at the mouth of the harbor and at several sites in the Ashley River and along the shores of the harbor (Figure 20).

Table 3. Fishery management plans and managed species that may occur in the project area.

Table 1 - Fishery Management Plans (FMPS) and Managed Species for the South Atlantic that may Occur in the Project Area

Common Name	Species
Shrimp	
brown shrimp	*Farfantepenaeus aztecus*
pink shrimp	*Farfantepenaeus aduorarum*
rock shrimp	*Sicyonia brevirostris*
royal red shrimp	*Pleoticus robustus*
white shrimp	*Litopenaeus setiferus*
Snapper Grouper Complex	
Jack crevalle	*Caranx hippos*
gag grouper	*Mycteroperca microlepis*
black sea bass	*Centropristis striata*
mutton snapper	*Lutjanus analis*
red snapper	*Lutjanus campechanus*
lane snapper	*Lutjanus synagris*
gray snapper	*Lutjanus griseus*
yellowtail snapper	*Ocyurus chrysurus*
spadefish	*Chaetodipterus faber*
white grunt	*Haemulon plumieri*
sheepshead	*Archosargus probatocephalus*
hogfish	*Lachnolaimus maximus*
Coastal Migratory Pelagics	
king mackerel	*Scomberomorus cavalla*
Spanish Mackerel	*Scomberomorus maculatus*
cobia	*Rachycentron canadum*
Mid-Atlantic FMP species which occur in South Atlantic	
bluefish	*Pomatomus saltatrix*
summer flounder	*Paralichthys dentatus*
Federally Implemented FMP	
lemon shark	*Negaprion brevirostris*
bull shark	*Carcharhinus leucas*
blacknose shark	*Carcharhinus acronotus*
finetooth shark	*Aprionodon isodon*
dusky shark	*Carcharhinus obscurus*
bonnethead shark	*Sphyrna tiburo*
Atlantic sharpnose shark	*Rhizoprionodron terraenovae*

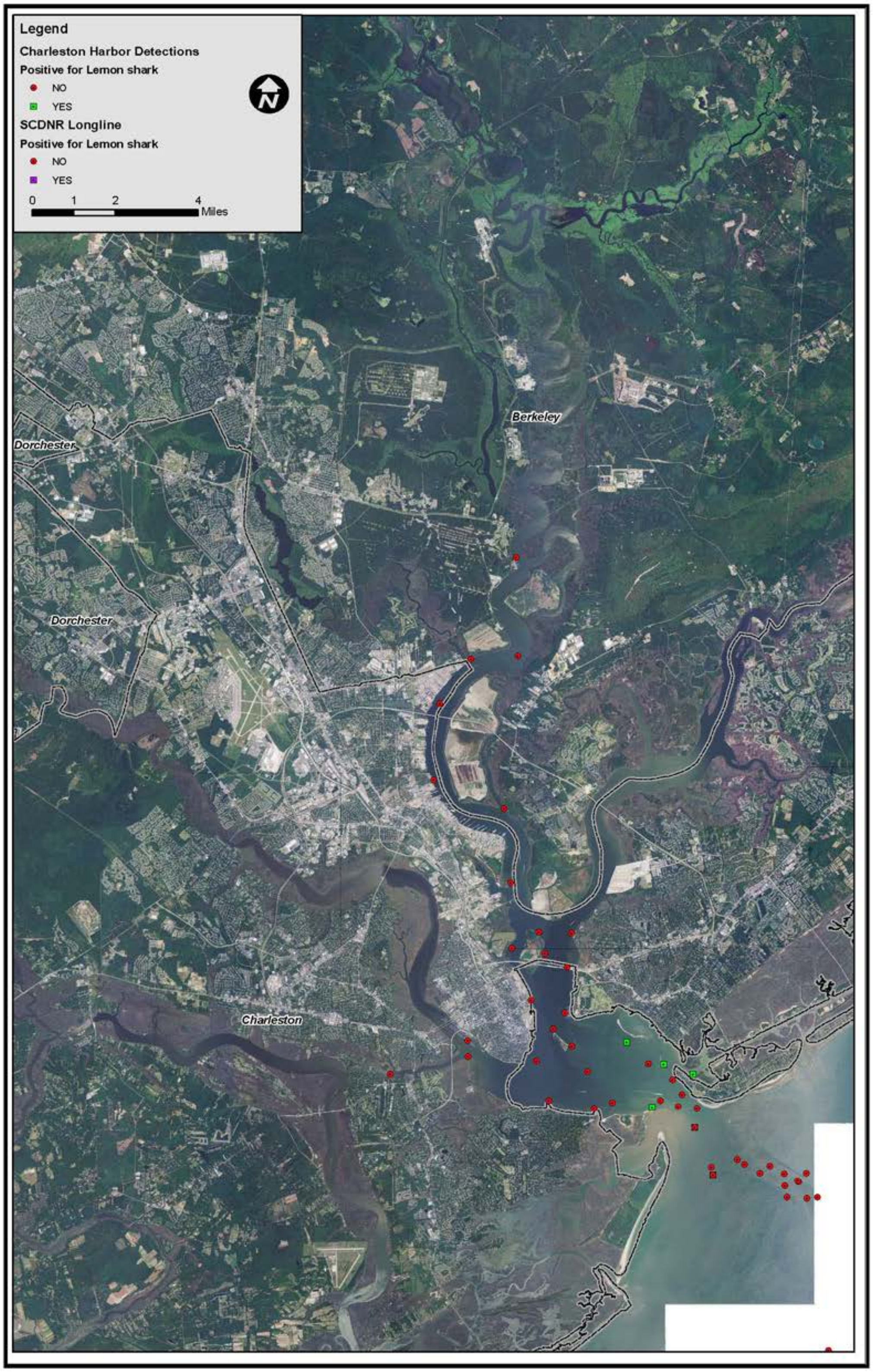


Figure 18. Lemon shark catch in project area

Figure 19. Sand tiger shark catch in project area

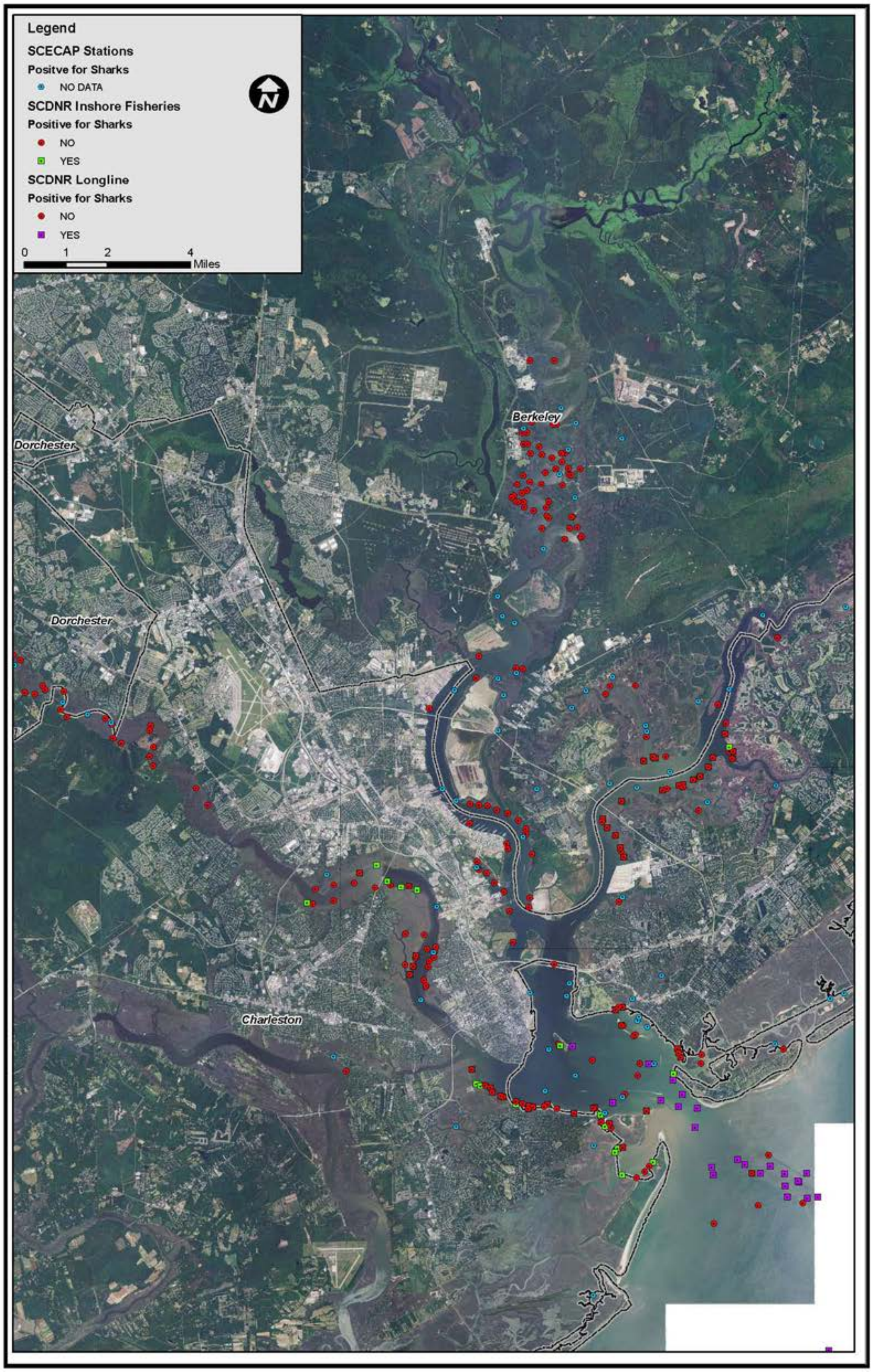


Figure 20. Unidentified sharks captured in project area

6.0 POTENTIAL EFFECTS TO ESSENTIAL FISH HABITAT

Scope. This assessment considers potential direct, indirect, permanent, and temporary impacts associated with construction (as well as operations due to maintenance activities), and assesses potential effects to EFH and resulting uses (or loss thereof) by managed fish species. EFH impacts may occur either from disturbance or modification of habitat used by managed fish species, or from effects of activities that limit use of EFH by managed fishery species. The potential for adverse and substantial effects may be distinguished based on the following criteria guidance from NMFS (2004):

> "Adverse effect means any impact that reduces quality and/or quantity of EFH, including direct or indirect physical, chemical, or biological alterations of the waters or substrate and loss of, or injury to, benthic organisms, prey species and their habitat, and other ecosystem components, if such modifications reduce the quality and/or quantity of EFH. Adverse effects to EFH may result from actions occurring within EFH or outside of EFH and may include site-specific or habitat-wide impacts, including individual, cumulative, or synergistic consequences of actions (50 CFR 600.810(a)).
>
> "Substantial adverse effects are defined as effects that may pose a relatively serious threat to EFH and typically could not be alleviated through minor modifications to a proposed action; e.g., major harbor development with significant dredging and filling, channel realignments, or shoreline stabilization near EFH."

The below assessment addresses EFHs specifically, and also representative species from among the various fishery management plans that use those EFHs in the project area.

Freshwater Wetlands. Tidally influenced wetlands comprising emergent and forested vegetation will not be directly impacted during dredging or maintenance operations for the proposed projects. However, due to slight increases in salinity of wetland pore water, wetlands may be indirectly affected. Specifically, changes in the salinity level of a wetland can alter the vegetative composition, soils, and habitat function of the system. Most of these effects would occur within tidal freshwater systems, as these systems are not typically adapted to experience high salinity concentrations for increased frequencies or durations. Plants that are not adapted to tolerate higher salinities will generally succumb and be replaced by those with higher tolerances. Higher salinities can increase the mineralization of nitrogen and phosphorous in soils, leading to "tree stress and senescence" as well as conversion to oligohaline marsh (Noe 2013). Modeling indicated that approximately 281 acres of tidal and non-tidal freshwater wetlands would be affected in this manner.

With coordination from the Interagency Coordination Team, USACE developed a method to determine indirect impacts to freshwater marshes in the system (Wetland Impact Assessment Appendix L, Main Report). The method involved the following rough steps: 1. Wetland delineation and classification, 2. Determining assessment reaches, 3. Determining length of river in assessment reaches, 4. Determining wetlands per river foot ratios, 5. Determining habitat coverage associated with assessment reaches, 5. Interpolating isopleths, and 7. Assessing wetland areas affected by the alternatives. As recommended by the ICT, mitigation was determined based on impacts at the time of construction (year 2022). Modeling efforts indicated that if the proposed project is constructed (the 52'/48' Alternative), approximately 6.13

and 14.73 acres of forested wetlands and non-forested freshwater marshes, respectively, along the Ashley River would be affected, and approximately 107.34 and 152.76 acres of forested wetlands and non-forested freshwater marshes, respectively, along the Cooper River would be affected. In affected areas, some plant species intolerant of salinities ranging from 0.5 ppt to 5.0 ppt may decrease in percent coverage while others with tolerance would increase. Population densities and diversity of fish and wildlife are not anticipated to be adversely affected, as the areas will remain vegetated and provide expected wetland functions (bank stability, water storage, nutrient cycling, refuge and forage, etc.).

The analysis provides a conservative estimate of impacts, especially to freshwater forested wetlands due to three main reasons. First, the method described above uses the 5 ft elevation contour to determine the landward extent of wetlands within the area of potential affect. Every assessment reach (polyhaline through freshwater) in the existing condition had forested wetlands noted within the 5 ft contour (see Appendix L of the DEIS). Many of these forested wetland areas include both tidal and non-tidal systems but were determined to be connected to the river. Second, the impact assessment uses low flow conditions as per Cowardin et al., (1979) wetland classification system. Low flow assumes salinity would migrate further up the rivers. Third, the hydrodynamic model is not a reactive model and cannot account for increased freshwater releases from the Pinopolis Dam that may occur as a result of the existing salinity alert system. The presence of this system could limit the influence of salinity upstream in the Cooper River, where the majority of impacts are predicted. [**For future reference, this same delineation was performed to determine extent of wetlands within the mitigation/preservation tracts. Therefore, impacted wetlands are considered similar to the mitigation wetlands**]

After evaluating the costs, functional lift, and logistical challenges with various mitigation measures, USACE selected preservation of land and conveyance to the USFS as the preferred mitigation alternative after carefully considering the hierarchy defined in the 2008 Mitigation Rule. Although restoration is preferred over preservation for wetland mitigation, opportunities for in kind restoration are limited, and owing to the type of aquatic resource to be restored, the chances for successful mitigation are not certain. Complicated real estate considerations cause further difficulties. If restoration would take place on private lands, there would either have to be a land purchase or easement granted. Many of the restoration options that were considered would not allow for appropriate in kind mitigation and would therefore require multiple land purchases, in addition to the potentially costly restoration and monitoring work, to become feasible. For these reasons, the Charleston District is proposing preservation to mitigate for the wetland impacts anticipated from this project. This approach is appropriate considering that 33 CFR 332.3 (h) (1) (i-v) states, "*Preservation may be used to provide compensatory mitigation for activities authorized by DA [permits] when all the following criteria are met: (i) The resources to be preserved provide important physical, chemical or biological functions for the watershed; (ii) The resources to be preserved contribute significantly to the ecological sustainability of the watershed. In determining the contribution of those resources to the ecological sustainability of the watershed, the district engineer must use appropriate quantitative assessment tools, where available; (iii) Preservation is determined by the district engineer to be appropriate and practicable; (iv) The resources are under threat of destruction or adverse modifications; and (v) The preserved site will be permanently protected through an appropriate real estate or other legal instrument (e.g., easement, title transfer to state resource agency or land trust).*"

Preservation of large tracts with significant aquatic resources is beneficial on a watershed scale. As previously stated the impacts from this proposed project are different from typical wetland impacts; there is no dredging, filling, nor clearing of any wetland. The proposed project's impacts represent a vegetation change that could occur across the wetlands; there would be no new loss of overall EFH.

The Charleston District has determined that preservation of land within the proclamation boundary of the Francis Marion National Forest best meets the compensatory mitigation requirements. This approach would be in accordance with the goals set forth in the Charleston Harbor Special Area Management Plan (SCDHEC 2000). One of the action areas was to integrate ecosystem-level planning for the watershed. The report states that, "although tidal wetlands have been relatively well protected, significant losses have occurred in freshwater non-tidal areas". The proposed mitigation of preserving ecologicaly significant parcels would provide important physical, chemical and biological functions for the Cooper River Basin and will contribute to the sustainability of the watershed by ensuring the functions of bottomland hardwood and emergent wetlands on these properties are sustained in perpetuity. While the exact location, or parcel idenfication, can be disclosed at this time, the potential parcels have complex mosaics of upland and wetland communities, with extensive northeast-southwest trending ecotones. Wetlands include both tidal and non-tidal palustrine systems. The preservation parcels will also enhance lands already within the Francis Marion National Forest by functioning as a buffer to future development. During PED, USACE will identify the proposed parcel and perform the UMAM assessment on the specific parcel and then coordinate the results with the resource agencies. More details can be found in Appendix P of the DEIS.

Estuarine and Marine Emergent Vegetation. No estuarine or marine emergent vegetation is expected to be directly impacted by the proposed action or subsequent operations and maintenance activities. Indirect adverse impacts are also not anticipated, as emergent vegetation characteristic of marine waters typically tolerate a wide range of salinities, and slight increases in salinity beyond that predicted for the future-without-project condition is not likely to result in a vegetation community change. In fact, a net increase in estuarine and marine emergent vegetation would be expected if salinity changes occur in the system. The net increase in this habitat would likely be commensurate with the predicted reduction in freshwater wetlands (e.g., 281 acres).

Table 4. Size (in acres) of indirect wetland impacts by alternative (2022 Condition)

Alternatives: Impacts at Time of Construction (Year 2022)			
Wetland Impacts	**48/48**	**50/48**	**52/48**
Ashley River forested wetlands	3.35 acres	4.88 acres	6.13 acres
Ashley River marsh wetlands	8.05 acres	11.71 acres	14.73 acres
Cooper River forested wetlands	45.09 acres	76.59 acres	107.34 acres
Cooper River marsh wetlands	64.17 acres	108.99 acres	152.76 acres
Total	**120.66 acres**	**201.77 acres**	**280.96 acres**

Tidal Creeks. Tidal creek habitats will not be directly affected by the proposed action. Neither construction nor maintenance dredging due to the proposed action will occur in tidal creeks. Currents and water column velocities (as indicated by hydrodynamic modeling) are not significantly altered by the proposed action. However indirect effects to the water column in some tidal creeks may occur. See discussion regarding estuarine water column below.

Oyster Reefs. Oyster reefs are HAPC for species of the snapper grouper complex. No direct or indirect effects related to oyster reefs are anticipated. No temporary or permanent impacts from dredging or maintenance activities are likely to occur due to the proposed action. In fact, oyster habitat may actually be expanded by slightly increasing average salinity in the Harbor.

Estuarine Water Column. Temporary impacts to the estuarine water column are anticipated during construction and subsequent maintenance dredging for the proposed action. Turbidity levels near the dredge will be elevated. However, these effects will be monitored in order to ensure compliance with state water quality certification conditions. Models indicate that permanent affects include slightly increased water-column salinity and decreased dissolved oxygen (DO) in certain parts of the estuary. Areas principally affected by these changes are detailed in the DEIS. Aquatic organisms may experience physiological stress and/or mortality as a result of substantial reductions and/or low levels of dissolved oxygen (DO). The SCDHEC instantaneous and daily average water quality standards for DO are 4 and 5 mg/L, respectively. Areas in the harbor that have lower existing levels of DO may be found in Table 3; respective segment locations are found in Figure 16. The segments represent modeled data of a low flow year within cells used for TMDL DO analysis from the months of March through October (defined by SCDHEC as the critical months for DO). Table 3 lists mean DO levels as well as the modeled 10^{th} percentile DO levels during low flow conditions. Segments A39 to A60 are shown in the model to have the lowest mean DO concentrations in the study area; these are far upstream in the Ashley River. These areas may or may not be more sensitive to further decreases in DO depending on the tolerance of resident fauna, but it is possible that DO levels in these and some other areas may decrease in response to the proposed project, relative sea level rise, and/or both of these factors. Detailed data for the months of July, August and September bottom and water column averaged DO were requested by NOAA and are provided in Attachment H-1. Table H-1-13 details the change (or delta) in DO values for the bottom layer, low flow condition between March and October. The lowest DO TMDL segments (A39-A60) experience a negligible change as a result of the proposed project. Some segments decrease by 0.03 mg/L and some segments increase by up to 0.02 mg/L. In this scenario, the maximum delta throughout the harbor is 0.1 mg/L within segment W2. While a statistical analysis was not performed on these results, the deltas fall within the range of precision of the instrumentation to measure DO.

Activities that disturb sediments (e.g., dredging, fill) may reduce DO depending on the volume and duration of sediment resuspension, and the oxygen demand of the sediment. Fine sediments high in organic matter have greater potential oxygen demand than sandy sediments. DO reduction generally is associated with near bottom waters adjacent to the disturbance and decrease towards the surface and with increasing distance. This effect is anticipated to be temporary and localized in nature. The effects of temporary DO reduction on EFH-managed species may be negligible during winter-spring when DO levels are naturally high. However, similar reductions may result in temporary adverse effects in summer when DO is naturally lower. The potential to impact managed fishery species would depend on existing conditions and project-specific factors such as location, construction schedule, and impact duration. Avoidance displacement associated with project-related DO reduction could be locally adverse if spawning movements and/or recruitment of nursery areas were affected.

Table 5. Mean and 10th percentile of dissolved oxygen levels for Charleston Harbor TMDL evaluation segments (Low Flow, March through October).

Segment	10th%-tile (mg/L)	Mean (mg/L)	Segment	10th%-tile (mg/L)	Mean (mg/L)	Segment	10th%-tile (mg/L)	Mean (mg/L)
A01	5.313	6.075	A50	0.987	2.392	C36	5.014	6.046
A02	5.309	6.028	A51	1.023	2.469	C37	4.997	6.048
A03	5.269	6.007	A52	0.861	2.327	C38	5.003	6.060
A04	5.271	5.997	A53	0.837	2.316	C39	5.015	6.075
A05	5.284	6.001	A54	0.812	2.312	C40	5.022	6.089
A06	5.239	5.970	A55	0.806	2.314	C41	5.032	6.107
A07	5.269	5.962	A56	0.792	2.325	C42	5.046	6.123
A08	5.242	5.918	A57	0.788	2.352	C43	5.053	6.136
A09	5.267	5.905	A58	0.799	2.398	C44	5.065	6.152
A10	5.238	5.867	A59	0.822	2.481	C45	5.075	6.166
A11	5.153	5.803	A60	0.925	2.711	C46	5.079	6.178
A12	5.112	5.770	A61	1.173	3.097	C47	5.085	6.192
A13	5.031	5.718	A62	2.123	3.940	C48	5.092	6.210
A14	4.996	5.695	C01	5.130	6.023	C49	5.100	6.226
A15	4.931	5.655	C02	5.115	6.018	C50	5.107	6.237
A16	4.871	5.610	C03	5.104	6.004	C51	5.111	6.247
A17	4.831	5.579	C04	5.066	5.977	C52	5.115	6.260
A18	4.757	5.541	C05	5.048	5.968	C53	5.123	6.274
A19	4.647	5.484	C06	5.015	5.950	C54	5.133	6.289
A20	4.570	5.429	C07	4.969	5.921	C55	5.144	6.303
A21	4.443	5.357	C08	4.939	5.905	C56	5.160	6.319
A23	4.261	5.255	C09	4.895	5.880	C57	5.181	6.340
A24	4.139	5.164	C10	4.814	5.822	C58	5.201	6.359

A25	4.058	5.098	C11	4.771	5.788	C59	5.217	6.376
A26	3.966	5.022	C12	4.754	5.775	C60	5.236	6.395
A27	3.857	4.917	C13	4.744	5.767	H01	4.980	5.841
A28	3.747	4.817	C14	4.756	5.780	H02	5.139	5.969
A29	3.654	4.719	C15	4.773	5.798	H03	5.053	5.904
A30	3.565	4.642	C16	4.802	5.825	H04	5.214	6.023
A31	3.487	4.570	C17	4.818	5.850	H05	5.126	5.964
A32	3.398	4.480	C18	4.846	5.873	H06	5.172	6.008
A33	3.300	4.385	C19	4.858	5.886	H07	5.162	6.024
A34	3.128	4.261	C20	4.861	5.894	H08	5.161	6.032
A35	2.895	4.118	C21	4.869	5.900	H09	5.198	6.043
A36	2.756	4.026	C22	4.876	5.907	W01	5.228	6.074
A37	2.433	3.772	C23	4.882	5.915	W02	5.234	6.090
A38	1.989	3.382	C24	4.894	5.925	W03	5.250	6.113
A39	1.730	3.094	C25	4.904	5.936	W04	5.263	6.129
A40	1.548	2.875	C26	4.909	5.944	W05	5.278	6.144
A41	1.409	2.679	C27	4.916	5.952	W06	5.289	6.159
A42	1.276	2.508	C28	4.928	5.963	W07	5.306	6.181
A43	1.152	2.390	C29	4.934	5.974	W08	5.305	6.191
A44	1.107	2.350	C30	4.946	5.988	W09	5.300	6.197
A45	1.071	2.360	C31	4.952	5.999	W10	5.292	6.201
A46	1.039	2.366	C32	4.962	6.009	W11	5.285	6.199
A47	1.019	2.373	C33	4.969	6.017	W12	5.273	6.195
A48	1.010	2.376	C34	4.977	6.025	W13	5.255	6.187
A49	0.988	2.383	C35	4.987	6.033	NA	4.776	5.559

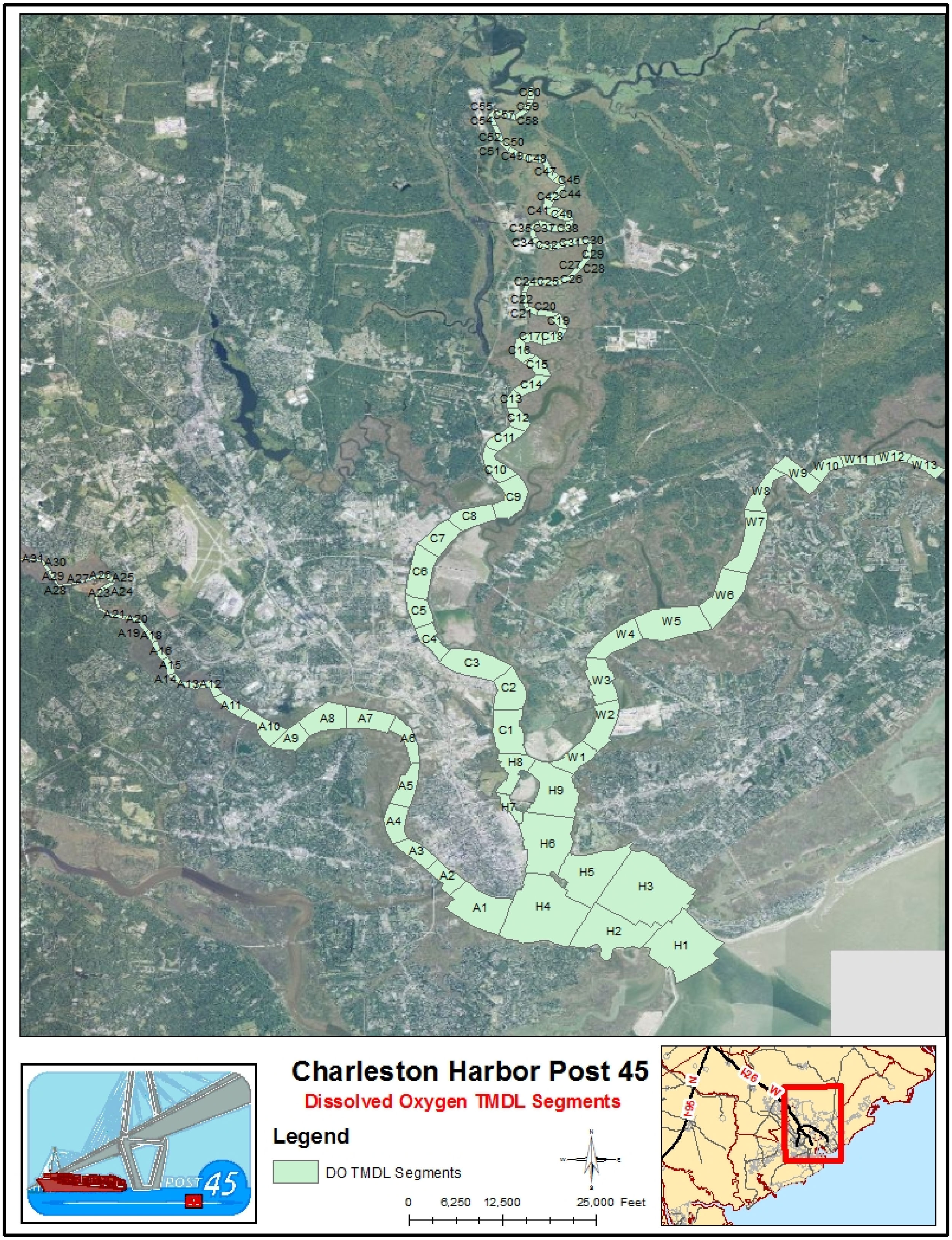


Figure 21. Charleston Harbor TMDL Segments Used for Dissolved Oxygen Evaluation

Intertidal and Subtidal Mudflats (Unconsolidated Bottom). Preliminary assessments of direct impacts to shallow sub-bottom habitat (between 0 and -2m MLLW) expected as a result of the proposed action are estimated to be 2.84 acres. These impacts occur primarily on the Daniel Island side of the new Navy Base Terminal and are a result of the proposed turning basin in that area. Considering the location of these impacts and the abundance of this habitat within the Charleston Harbor, the impact is not significant to warrant compensatory mitigation (Figure 22). This assessment includes impacts from construction as well as maintenance activities as well as permanent habitat modifications.

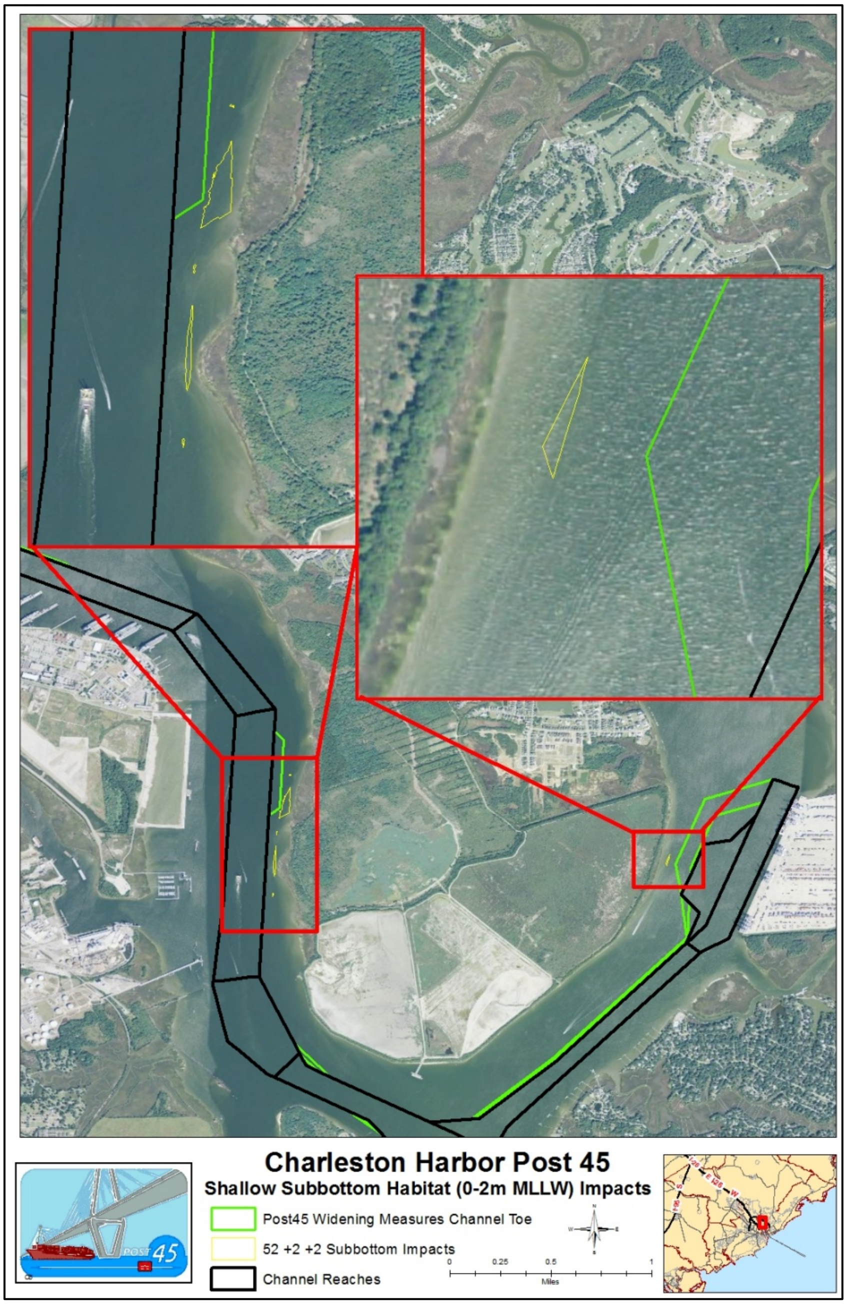


Figure 22. Shallow subbottom habitat impacts

Coastal Inlets. Coastal inlets are HAPC for shrimp species, summer flounder, and species of the snapper grouper complex (see Figure 17). The major coastal inlet associated with the project area is the Charleston Harbor inlet. The coastal inlet comprises the landward portion of the entrance channel, Mount Pleasant Reach, as well as shallower areas toward, and along Sullivan's Island and Morris Island. The entrance channel will be directly affected through the deepening of the federal channel, although the cross-section of the channel will not change. Other features in the inlet channel are not anticipated to change directly as a result of the proposed project, but the position of spits, sandbars, and other features associated with the inlet are constantly changing due to stochastic events.

Hardbottom. Hardbottoms, as well as most artificial reef Special Management Zones (SMZs), are HAPC for species of the snapper grouper complex (see offshore areas outlined in Figure 16). The proposed project may impact up to 28.6 acres of potential hardbottom within the footprint of the Federal Navigation Channel, but may also expose an undeterminable amount of hardbottom for potential, periodic colonization and periodic maintenance dredging. Impacts related to the side slopes of the channel have been avoided by the implementation of an avoidance and minimization measure of extending the same side slope down the new channel depth so that the channel toe moves inward. This measure reduces the channel dimensions to roughly 944' vs the previous 1000' (Figure 2). Details on this analysis can be found in the hardbottom impacts and Habitat Equivalency Analysis. USACE has determined that 33 acres (29.8 acres required by HEA) of hardbottom reef will be created as mitigation for these impacts (full description in Hardbottom and HEA Appendix, Appendix I), in addition to any new hardbottom that will be exposed in the channel following dredging. An additional reef will be created in the same manner as the mitigation reef, and 6 additional 33 acre reefs will be created along the entrance channel.

Additional Habitat Areas of Particular Concern. HAPC for various managed species groups are noted in the above text where relevant. Below are additional HPAC considered in this assessment:

- The Charleston Bump (at the north end of the Blake Plateau, seaward of the Florida-Hatteras Slope, see http://oceanexplorer.noaa.gov/explorations/03bump/welcome.html) is HAPC for coastal migratory pelagic species and species of the snapper grouper complex. These areas will not be affected by the proposed action.
- Seagrass habitats are HAPC for species of the snapper grouper complex, but since none have been identified in the project area, and none are in the project footprint, these will not likely be affected.
- The surf zone seaward of intertidal beaches where ebb and flow currents are created by a bottleneck area of intense currents is HAPC for bluefish. This zone will not be affected by the proposed project.
- State-designated nursery habitats are of particular importance to snapper grouper complex species (Figure 23).
- Finally, estuarine ebb and flows are critical to provide transport, refuge, and feeding/development areas for all life stages for black sea bass (a species of the snapper grouper complex). Ebb and flow are not anticipated to be affected due to the proposed action.

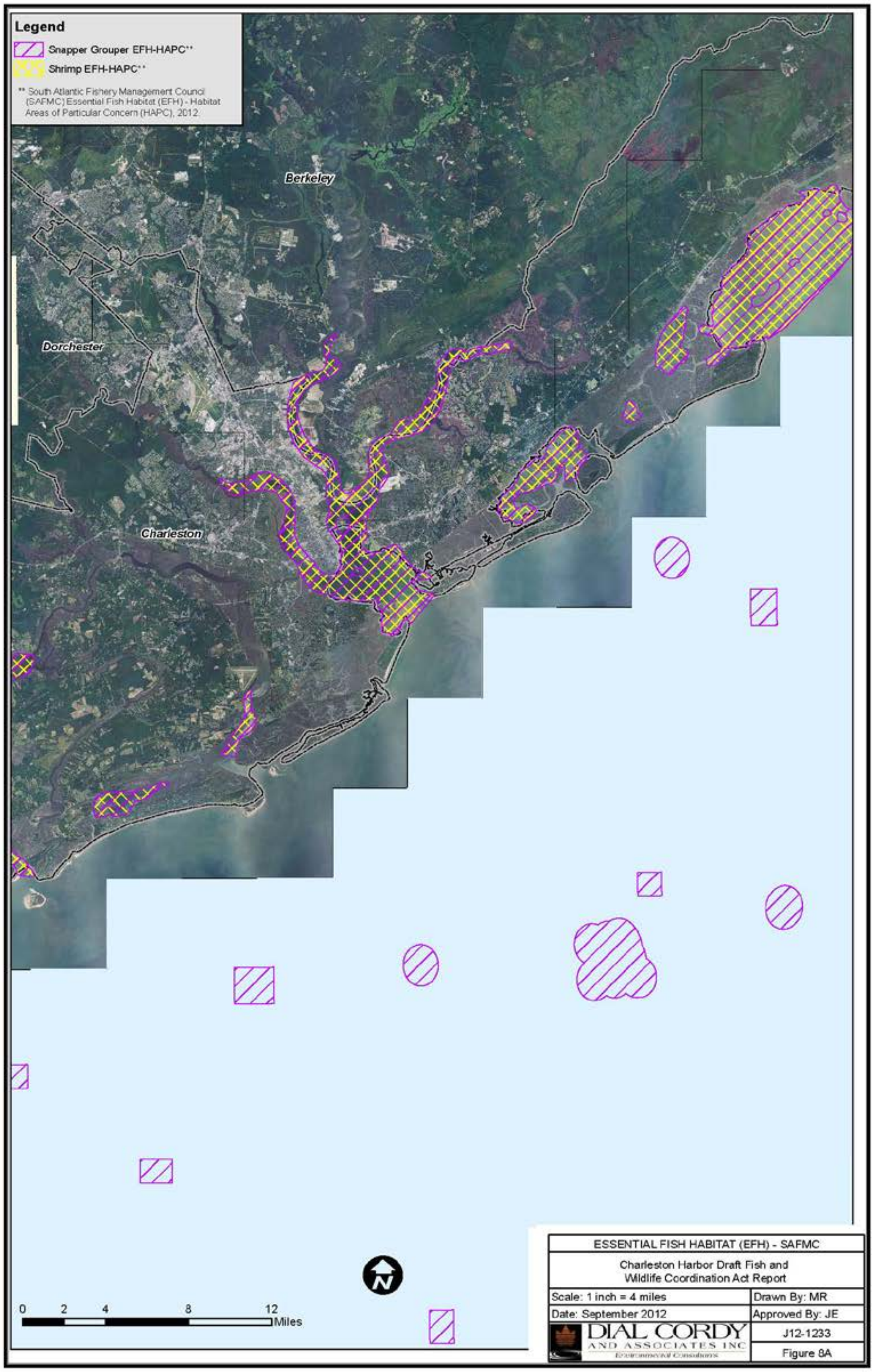


Figure 23. Habitat areas of particular concern for shrimp and snapper grouper complex species

7.0 POTENTIAL EFFECTS ON MANAGED SPECIES

7.1 General Effects

Effects of the proposed project include death and injury of fishes and forage during dredging operations and subsequent maintenance dredging operations. Direct removal of softbottom habitats will occur, but indirect impacts due to changes in water quality will affect the widest geographic effect in the project area. These effects have been modeled by USACE and results are detailed in the wetland assessment appendix (Appendix L of the EIS), and affect both the estuarine water column as well as some tidally influenced wetlands upstream in the Cooper and Ashley Rivers. Effects to specific groups of managed species associated with certain essential fish habitats are detailed below.

7.2 Penaeoid Shrimps

The life history of white shrimp is typical of other penaeoid shrimp (shrimps belong to eight distinct, yet similar, families). Effects to the species in and adjacent to Charleston Harbor due to the proposed project may be similar to those of other species; white shrimp are treated here as representative shrimp species in the project area.

Direct impacts to white shrimp may include death due to dredges, a temporary process that is likely to be repeated during episodes of maintenance dredging (approximately every 12 to 18 months) in future years. These impacts and the potential for entrainment are more likely at the mouth of Charleston Harbor as the post-larvae species migrate into the estuary. In South Carolina, penaeoid shrimp enter estuaries from February to September. Bearden (1961) reported that white shrimp ingress from June – September.

There may or may not be permanent, indirect effects on white shrimp due to anticipated, slight increases in water column salinity in some parts of the estuary. As described in Section 5.1 above, salinity is a critical factor in the movement of individuals through the estuary. Low salinities may force juveniles from nursery areas and even into the ocean prematurely. Low salinities also adversely affect shrimp during cold weather events. Given these two types of impacts, increases in salinity may actually mitigate against premature migration and physiological stress. However, it was also noted above that "low landings seem to be related to unusually dry summers resulting in higher than average salinity values." Hence, low river discharge resulting in higher salinities is also undesirable for the population. Hughes (1969) found that salinity decreases of 2-3ppt were sufficient to cause penaeoid shrimp to move downstream and that postlarvae showed an aversion to low salinity water. If the above are taken together, and given the very slight increases in salinity in some areas (anticipated by models run for the future-with-project condition), the proposed project's net indirect effects on white shrimp are likely neither adverse nor beneficial.

Permanent, indirect effects on white shrimp due to anticipated, slight increases in water column DO in some parts of the estuary have also been considered. Based on experimental data (Rosasa et al. 1999) indicating that white shrimp have a tolerance for DO levels as depressed as 2 mg/L (lower levels were not tested in this study), it is likely that slight decreases in water-column DO due to the proposed project would not adversely affect individuals.

7.3 Snapper grouper Complex Species

Effects to gray snapper in the project area may resemble those to other species in the snapper grouper complex. Direct effects of dredging and maintenance activities include death or injury to gray snapper utilizing hardbottoms or passing through the inlet. It is likely that this will principally involve less motile life-history stages such as larvae and juveniles within the estuary, but to a lesser degree, larger individuals associated with hardbottom areas offshore that will flee and be dislocated from disturbed sites.

Individuals of the local gray snapper population in the project footprint may also be temporarily dislodged during dredging. The proposed project may impact up to 28.6 acres of hardbottom habitat that is potentially used by gray snapper, but may also expose an undeterminable amount of hardbottom for potential colonization by sponges and corals between maintenance dredging events. Over 29 acres of hardbottom reef will be created as mitigation for these impacts.

Among indirect impacts are changes to water column salinity and oxygen that could affect fish behavior, migration, and physiology. Serrano et al. (2010) found that individuals (at approximately 20 cm) have a preference for habitats for salinities between 9 and 23 ppt. This may indicate that if water column salinities of a certain concentration move upstream in the estuary, fish may seek those habitats. Studies on a congener of gray snapper in the Gulf of Mexico indicated that high-value habitat comprises DO levels of at least 5 mg/L (Gallawaya et al. 1999). Data in Table 2 show areas where DO levels are below this threshold for a species that may or may not have tolerances similar to gray snapper. The proposed project does not result in reduced DO by more than 0.1 mg/L in any segment. The project would cause localized turbidity during construction; however, turbidity would be minimized using best management practices so that any impacts would be minor and temporary.

7.4 Coastal Migratory Pelagic Complex Species

Effects to king mackerel in the project area may resemble those of other coastal migratory pelagic complex species. Direct effects of dredging and maintenance activities include death or injury to mackerel offshore. It is likely that this will principally involve less motile life-history stages such as pelagic larvae and juveniles; it is less likely that larger individuals would be impacted, as they can flee construction areas/disturbed waters. This impact on behavior would be temporary.

Indirect impacts to the species (and others similar to it) may include effects to the prey base of king mackerel due to slight changes in estuary water column DO and salinity in certain parts of the estuary. For example, if anchovies and shrimp (common prey for king mackerel according to Perrotta 2014) populations were disrupted, this may affect king mackerel, which is largely dependent on prey (frequently schooling fishes) that spend at least part of their life history associated with estuaries. However, it appears that significant adverse impacts to shrimp and anchovies are not likely to occur. Moreover, the king mackerel is a generalist predator, and if such prey became slightly less numerous, it would likely utilize other prey.

7.5 Bluefish

Direct effects of dredging and maintenance activities include death or injury to bluefish offshore and in the inlet. Again, mortality due to contact with dredge equipment is more likely for larvae and smaller individuals than for larger individuals, which can efficiently move away from disturbances. These effects will be temporary. Other temporary construction and maintenance dredging effects include interference with feeding due to sediment resuspension; bluefish are visual feeders. Effects would be relatively minor as adult bluefish could seek forage where turbidity would not limit their movement.

Indirect effects on bluefish due to slight shifts in estuarine water column salinity in some areas are not likely. As stated above, minimum salinities listed for various stages were 26.2, 31, 35, and 33 ppt, for eggs, larvae, pelagic juveniles, and juveniles/older individuals, respectively (NMFS 1999). Water quality models predict a slight increase of salinities in some parts of the estuary, not a decrease, so the necessary minimum salinities will be maintained in the future-with-project condition.

NMFS (1999) indicated that individual bluefish have been captured in waters with DO levels as low as 4.5 mg/L. Data in Table 2 show areas where DO levels are below this level.

7.6 Summer Flounder

Direct effects of dredging and maintenance activities include death or injury to summer flounder offshore and in the estuary. Of the finfish species considered in this assessment, it may be least motile swimmer, and therefore, the most likely to suffer mortality from dredge equipment during construction and maintenance activities. This includes all life-history phases. These effects will be temporary in duration.

Indirect effects of slight salinity increases in some parts of the estuary may affect selection of habitats during early development. As indicated above, larvae enter lower salinity waters in upper reaches of estuary. Therefore, if the salinity changes occur in upper estuarine reaches, larvae may have to progress farther upstream to reach lower salinities. However, also as noted above, individuals tolerate a wide salinity range, and growth is apparently optimal at intermediate (≥ 10 ppt) salinities. Therefore, depending on the exact positions of the modeled, anticipated, slight changes in salinity in the mid estuary, growth rates could be increased, decreased, or have no net effect.

7.7 Black Sea Bass

Direct effects of dredging and maintenance activities include death or injury to black sea bass offshore (particularly on hardbottom and areas) and in the inlet. Again, mortality due to contact with dredge equipment is more likely for eggs, larvae, and smaller individuals than for larger individuals, which can efficiently move away from disturbances. These effects will be temporary. Other temporary construction and maintenance dredging effects include interference with feeding due to sediment resuspension. Effects would be relatively minor as black sea bass are motile, opportunistic feeders, and could seek forage where turbidity would not limit their movement, and switch to other prey if typical forage are less abundant due to any potential project effects.

Individuals of the local black sea bass population in the project footprint may also be temporarily dislodged during dredging. The proposed project may impact up to 28.7 acres of known and potential hardbottom potentially used by sea bass, but may also expose an undeterminable amount of hardbottom for potential colonization by sponges and corals between maintenance dredging events. Over 29.8 acres of hardbottom reef will be created as mitigation for these impacts.

7.8 Highly Migratory Species

Highly migratory species potentially using the project area include sharks, most of which use inshore/inlet areas as juveniles. It is not likely that many individuals of these species will be taken by dredge equipment due to their high motility, but foraging and other behaviors may be altered as a result of construction and subsequent maintenance activities. Indirect effects, i.e., alteration of behavior of individuals, may result if prey habitat is altered and prey populations decline in the project area. In such a case, they are likely to move to another area where suitable prey would be found.

8.0 NON-MANAGED, ASSOCIATED FISHES AND INVERTEBRATES

Associated species consists of living resources that occur in conjunction with the managed species discussed above. These living resources would include the primary prey species and other fauna that occupy similar habitats.

2.3.1 Invertebrates

Dredging associated with deepening would result in direct adverse effects on invertebrate species in the proposed project area. Initially, this will result in a significant but localized reduction in the abundance, diversity, and biomass of the immediate fauna. Species affected most are those that have limited capabilities or are incapable in avoiding the dredging activities. The fauna most affected would predominantly include invertebrates such as crustaceans, echinoderms, mollusks, polychaetes, and annelids. However, due to the relatively small area that will be impacted as viewed on a spatial scale, impacts to the benthic community will be minimal due to the relatively short period of recovery regarding infaunal communities following dredging activities (Culter and Mahadevan 1982; Saloman et al. 1982). Adjacent areas not impacted would most likely be the primary source of recruitment to the impacted area. Direct impacts to invertebrates are also anticipated by placement of material in the ODMDS. These habitats hold many invertebrate species that are prey for a variety of fishes, but are routinely impacted by maintenance dredging operations. Similar to the dredging impacts, these species are expected to recover within two years.

Zooplankton are primarily filter feeders and suspended inorganic particles can foul the fine structures associated with feeding appendages. Zooplankton that feed by ciliary action (e.g., echinoderm larvae) would also be susceptible to mechanical affects of suspended particles (Sullivan and Hancock 1977). Zooplankton mortality is assumed from the physical trauma associated with dredging activities (Reine and Clark 1998). Zooplankton may also be entrained by the dredge operations. Considering the high reproductive capacity of zooplankton and the relatively small area of dredge suction field and volume of water entrained compared to the overall volume of surrounding waters, it is highly unlikely that entrainment would result in any long term significant impacts to zooplankton. The overall impact on the zooplankton community should be minimal due to the limited extent and transient nature of the sediment plume.

2.3.2 Fishes

Associated fish species outside of those addressed in the scope of this EFH assessment may also be impacted. These fishes may play important roles in the various life stages of managed species, especially as prey species. The larvae of the managed fish species discussed in this EFH assessment are generally hatched from planktonic eggs and the larvae are also planktonic. The primary source of food for larvae is microzooplankton with a dietary overlap in many species and specialization (Sale 1991). Algae is most likely food for only the youngest larval stages of certain species, or for those larvae that are very small after hatching, and then only for a short time. The algae-eating larvae eventually switch to animal food while they are still small. At this time, varying life history stages of copepods become the dominant food and to a lesser extent cladocerans, tunicate and gastropod larvae, isopods, amphipods, and other crustacea.

Larval feeding efficiency depends on many factors such as light intensity, temperature, prey evasiveness, food density, larva experience, and olfaction (Gerking 1994). Larval fishes are visual feeders that depend on adequate light levels in the water column which reduces the reaction distance between larval fish and prey. Suspended sediment and dispersion due to dredging activities will temporarily increase turbidity levels in the proposed project area. This will reduce light levels within the water column which may have a short term negative effect regarding feeding efficiency. In addition, turbidity can affect light scattering which will impede fish predation (Benfield and Minello 1996). However, because the sediment plumes are transient and temporary, and the area to be impacted is relatively small when examined on a spatial scale, the overall impact to the larval fish population and consequently, the adult population should be minimal (Sale 1991). The majority of larval fish mortality will be attributed to the physical trauma associated with the dredging activities.

Similar to larval fishes, both juvenile and adult fishes are primarily visual feeders. Consequently, the visual effects of turbidity as described above will apply. Also, suspended sediment can impair feeding ability by clogging the gill rakers or the mucous layer of filter feeding species (Gerking 1994). However, because these fishes have the ability to migrate away from the dredging activities, the impact of the sediment plumes should be minimal. Although few adult fishes have been entrained by dredging operations (McGraw and Armstrong 1988; Reine and Clark 1998), most juvenile and adult fishes again have the ability to migrate away from the dredging activities. Consequently, dredging operations would have minimal effects on juvenile and adult fishes in the area. In addition, the reduction of benthic epifaunal and infaunal prey, and pelagic prey in the immediate area would have little effect on juvenile and adult fishes because they can migrate to adjacent areas that have not been impacted to feed.

9.0 IMPACT MINIMIZATION AND MITIGATION MEASURES

Incorporation of avoidance and minimization measures into the proposed action may eliminate or lessen the likelihood that EFH will be adversely affected. NMFS (2004) generally considers the following types of avoidance and minimization measures depending on potential impacts:

- Careful alternatives analysis,
- Design stipulations,

- BMPs,
- Avoidance of sensitive habitats (e.g., intertidal mudflats, shellfish beds),
- Time-of-year restrictions, and
- Monitoring.

The following specific avoidance and minimization measures were identified and are proposed for this project:

Dredging Volume and Duration: The USACE will avoid unnecessarily extending construction durations and limit total disposal volumes by not dredging past the depths needed to construct and maintain the project. Many areas do not require frequent maintenance dredging. Therefore environmental impacts can be minimized by limiting overdepth dredgeing (dredging to deeper depths in order to maintain the authorized depth between mainentance dreding) in the outer entrance channel to 1-foot of required overdepth and 2-feet of allowable overdepth instead of the typical 2-feet of required overdepth and 2-feet of allowable overdepth. The reduction of impacts include reduced new construction dredging quantities and potential decreased future maintenance dredging quantities

Hardbottom Habitat Impacts: To avoid direct impacts to hardbottom habitat in the entrance channel an avoidance measure was coordinated with the ICT. This method involves maintaining the existing side slopes and extends them downward rather than maintaining the existing bottom width and extending the side slopes outward. The measure would avoid all direct impacts to hardbottom habitat along the margins of the entrance channel. This measure has the additional benefit of reducing the quantity of dredged material. The only impact to the Navigation Channel would be the movement of the toe of the ledge inward by roughly 20 feet on either side. The overall channel would be 944' rather than 1000' (Figure 1), with no loss of width in the main shipping channel.

Biological Impacts from Rock Blasting: Geotechnical investigations involving rock strength analysis indicates the rock that requires removal to obtain the project depth can be removed with either a cutterhead dredge or a rock bucket clamshell dredge and will not require blasting. As a result of this analysis the District intends to avoid blasting as an option for rock removal, therefore eliminating any potential effects resulting from noise impacts to marine mammals and fish that blasting may cause.

PED phase channel widening reductions: During the Preliminary Engineering and Design (PED) phase, the District will use ship simulation results to optimize the widening and turning basin expansion measures to the size necessary to safely maneuver vessels. The optimization of those measures could reduce environmental impacts to DO, fish habitat, salinity intrusion, and shallow subtidal habitat, and the projected increase in channel shoaling.

No anchorage allowed within hardbottom habitat during construction: As a means to avoid or minimize effects of anchorage during dredging on hardbottom habitat, the design specifications will be written to require the contractor to avoid anchoring of equipment within adjacent hardbottom habitat. The approximate locations of these resources will be shown in the contract drawings. If the contractor is required to anchor outside the channel to utilize a cutterhead dredge, anchor placement shall be placed to avoid affecting any of the identified hardbottom habitat or any of the created hardbottom habitat reefs.

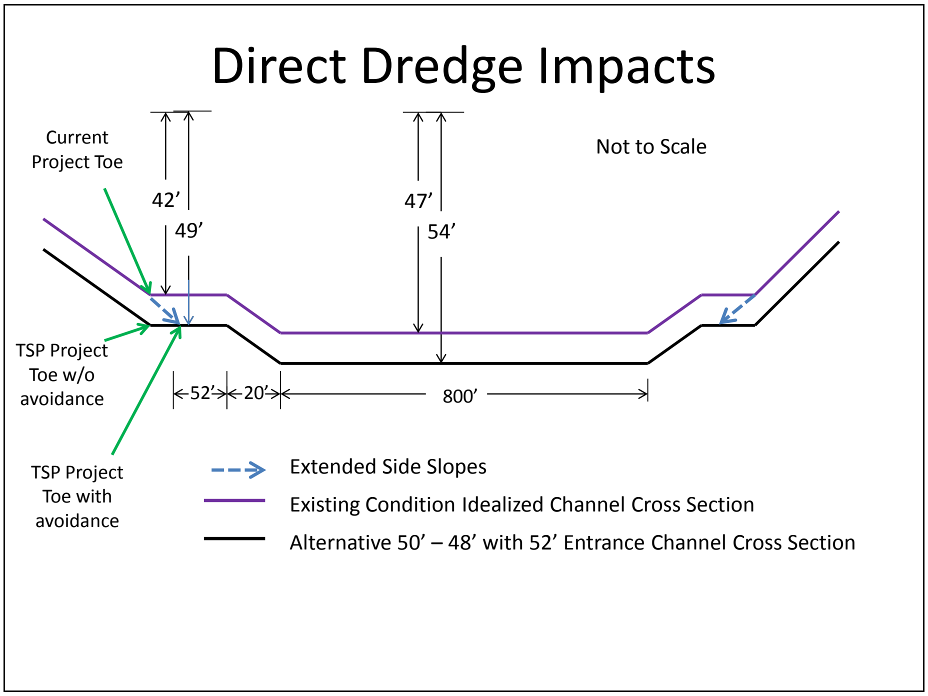


Figure 24. Avoidance of Hardbottom Habitat Impacts 1000' – 960' Reduction

New Construction. Fish may avoid and/or move (displacement) from areas as a result of physical disturbance from vessels, equipment, noise, sediment disturbance, and/or changes in water quality (e.g., turbidity, sedimentation). Avoidance and displacement disturbance during construction generally are temporary effects that do not adversely affect EFH. However, temporary displacement would be a concern if it were to substantially interfere with seasonal movement of managed fishery species to or from estuarine nursery and/or spawning areas. It is unlikely that the main navigational channel is used as nursery and/or spawning habitats by managed fisheries species due to relatively deep depth (>=45 feet) and hydrodynamics. Furthermore, sediment surveys indicate that many parts of the main navigation channel in the harbor is depositional (i.e., accumulates fine sediments and organic matter). These conditions provide less than optimal EFH to support foraging, spawning, and/or nursery functions. Consequently, managed fishery species likely use the channel on a transient basis if at all. Therefore, on a large scale, potential disturbance effects from construction activities in the channel would be limited and have minimal effect on EFH and managed fishery species.

SCDNR has identified fish spawning hotspots in Charleston Harbor. Two of these areas are sciaenid spawning areas and are adjacent to or within close proximity of the navigation channel. These two areas are at "the Grillage" and the base of the Ravenel Bridge. When practicable, seasonal "windows" for dredging will be observed by USACE contractors in order to ensure the availability of critical spawning and foraging locations and periods. For new work construction (as well as future O&M dredging), USACE will adhere to a seasonal window at two noted SCDNR identified sciaenid fish species spawning hot spots.

- The Grillage: From April through September, dredging will not occur within Mt. Pleasant, Rebellion Reach or in Ft Sumter Reach between the jetties.
- Ravenel Bridge: From April through September, dredging will not occur within Hog Island Reach within a distance of 1000 ft on either side of the Bridge.

Operations and Maintenance. Increased turbidity and decreased DO during dredging are temporary, localized effects that mobile fish and shrimp are capable of avoiding. Use of standard management practices to minimize turbidity, leaks, and spills would reduce the potential for adverse effects to EFH uses by managed fishery species. USACE will adhere to the seasonal windows indicated above for the Grillage and Ravenel Bridge spawning hotspots.

10.0 CONCLUSIONS

The following list summarizes potential effects of the proposed action on EFH and managed species as detailed in the sections above:

1. Direct mortality or injury of individual fishes (adults, subadults, juveniles, larvae, and/or eggs, depending on species, time of year, location, etc.) due to dredge equipment during construction and maintenance dredging (an effect temporary in duration).
2. Indirectly affecting foraging behavior of individuals through production of turbidity at construction/maintenance dredging sites (an effect temporary in duration)
3. Indirectly affecting movements of individuals around/away from dredging sites due to construction equipment and related disturbed benthic habitats (an effect temporary in duration).
4. Indirectly affecting foraging and refuge habitats by removal of benthic habitat (i.e., hardbottom) (an effect temporary in duration); mitigation areas will compensate for functional losses, and new hardbottom may be exposed due to dredging.
5. Directly, but slightly, affecting water column DO and salinity in certain parts of the estuary (a permanent effect)
6. Indirectly affecting some fishes and invertebrates (not currently identified), which may move a short distance upstream if they are intolerant of slight increases in salinity, or to other positions/microhabitats in the estuary if they are intolerant of slight shifts in DO. (a permanent effect)
7. Indirectly affecting plant species composition and/or relative percent coverage in certain riparian wetlands due to slight shifts in pore water salinity (a permanent effect). Wetland mitigation will be provided to compensate for functional losses of tidal freshwater wetlands.

Individually or in sum, the above are not anticipated to significantly adversely affect managed species or EFHs. Where possible, the above effects have been minimized via project design, and effects will be further mitigated by implementation of best management plans during construction and maintenance dredging. Where necessary impacts remain, USACE will provide compensatory mitigation for habitats where practicable.

11.0 REFERENCES

Able, K.W., and M.P. Fahay. 1998. The First Year in the Life of Estuarine Fishes in the Middle Atlantic Bight. Rutgers University Press. New Brunswick, NJ.

Allen, G.R. 1985. An annotated and illustrated catalogue of lutjanid species known to date. FAO species catalogue, snappers of the world. No. 125, 6:208.

Atlantic States Marine Fisheries Commission. 2009a. Managed Species Black Sea Bass, Habitat Fact Sheet, Life History and Habitat Needs. Washington, D.C. Accessed March 2009. Available online at www.asmfc.org.

Atlantic States Marine Fisheries Commission. 2009i. Managed Species Black Sea Bass, Species Profile. Washington, D.C. Accessed March 2009. Available online at www.asmfc.org.

Bearden, C.M. 1961. Notes on postlarvae of commercial shrimp (Penaeus) in South Carolina. Contributions from Bears Bluff Laborities No. 33:1-8.

Benfield, M.C. and T.J. Minello. 1996. Relative effects of turbidity and light intensity on reaction distance and feeding of an estuarine fish. Environmental Biology of Fishes 46:211-216.

Berry, F.H. 1959. Young jack crevalles (*Caranx* species) off the southeastern Atlantic coast of the United States. Fishery Bulletin 152(59):417-535. Berry, F.H. 1959. Young jack crevalles (*Caranx* species) off the southeastern Atlantic coast of the United States. Fishery Bulletin 152(59):417-535.

Bester, C. 2014. Gray Snapper. Website accessed 25 February 2014: http://www.flmnh.ufl.edu/fish/Gallery/Descript/GraySnapper/Graysnapper.html. Florida Museum of Natural History, University of Florida. Gainesville, FL.

Bortone, S.A. and J.L. Williams. 1986. Species profiles: life histories and environmental requirements of coastal fishes and invertebrates (south Florida) - gray, lane, mutton, and yellowtail snappers. U.S. Fish and Wildlife Service Biological Report 82(11.52). U.S. Army Corps of Engineers, TR EL-82-4:18.

Buckel, J.A., M.J. Fogarty, and D.O. Conover. 1999. Foraging habits of bluefish, *Pomatomus saltatrix*, on the U.S. east coast continental shelf. Fish. Bull. 97:758-775.

Clark, J.R. 1973. Bluefish. *In* A.L. Pacheco ed., Proceedings of a workshop on egg, larval, and juvenile stages of fish in Atlantic coast estuaries. p. 250-251. U.S. Dep. Commer., NOAA, NMFS, Mid-Atl. Coastal Fish. Cent., Tech. Publ. No. 1., as cited in NMFS 1999.

Cowardin, LM, Carter, V, Golet, F.C.and LaRoe, E.T. 1979. Classification of wetlands and deepwater habitats of the United States. US Fish and Wildlife Service FWS/OBS 79/31. 103pp.

Culter, J.K. and S. Mahadevan. 1982. Long-term effects of beach nourishment on the benthic fauna of Panama City Beach, Florida. U.S. Army Corps of Engineers Coastal Engineering Research Center Miscellaneous Report No. 82, 2:57.

Cummings, W.C., B.D. Brahy, and J.Y. Spires. 1966. Sound production, schooling, and feeding habits of the margate, *Haemulon album*, off north Bimini, Bahamas. Bulletin of Marine Science 16(3):626-640.

Darcy, G.H. 1983. Synopsis of biological data on the grunts *Haemulon aurolineatum* and *H. plumieri* (Pisces: Haemulidae). NOAA Technical Report NMFS Circular 448:39.

Dennis, G. D., K.J. Sulak, and D. C. Weaver. 2001. Nekton species inventory for the Timucuan Ecological and Historical Preserve and surrounding areas. Report to the National Park Service, Timucuan Preserve. Prepared by: USGS Florida Caribbean Research Center, Gainesville, FL. 77 pp.

Fahay, M.P., P.L. Berrien, D.L. Johnson, and W.W. Morse. 1999. Essential Fish Habitat Source Document: Bluefish (*Pomatomus saltatrix)* life history and habitat characteristics. NOAA Technical Memorandum, NMFS-NE-144:78.

Frazer, T.K., W.J. Lindberg, and G.R. Stanton. 1991. Predation on sand dollars by gray triggerfish, *Balistes capriscus*, in the northeastern Gulf of Mexico. Bulletin of Marine Science 48(1):159-164.

Gallawaya, B.J., J.G. Colea, R. Meyer, and P. Roscignob 1999. Delineation of Essential Habitat for Juvenile Red Snapper in the Northwestern Gulf of Mexico. Transactions of the American Fisheries Society 128(4):713-726.

Gerking, S.D. 1994. Feeding ecology of fish. Academic Press, San Diego, CA. 416 pp.

Goodwin, J.M. and J.H. Finucane. 1985. Reproductive biology of blue runner (*Caranx crysos*) from the eastern Gulf of Mexico. Northeast Gulf Science 7(2):139-146.

Goodwin, J.M. and A.G. Johnson. 1986. Age, growth, and mortality of blue runner (*Caranx crysos*) from the northern Gulf of Mexico. Northeast Gulf Science 8(2):107-114.

Graves, J.E., J.R. McDowell, A.M. Beardsley, and D.R. Scoles. 1992. Stock structure of the

bluefish (*Pomatomus saltatrix*) along the Mid-Atlantic coast. Fishery Bulletin 90:703-710.

Heemstra, P.C. and J.E. Randall. 1993. An annotated and illustrated catalogue of the grouper, rockcod, hind, coral grouper and lyretail species known to date. FAO species catalogue. Groupers of the world (Family Serranidae, Subfamily Epinephelinae). No. 125, 16:382.

Hughes, D.A. 1969. Responses to salinity changes as tidal transport mechanism of pink shrimp. Biological Bulletin 136: 43-53.

Johnson, A.G. and C.H. Saloman. 1984. Age, growth, and mortality of gray triggerfish (*Balistes capriscus)* from the northeastern Gulf of Mexico. Fishery Bulletin 82(3):485-492.

Jory, D.E. and E.S. Iverson. 1989. Species profiles: life histories and environmental requirements of coastal fishes and invertebrates (South Florida) - black, red, and Nassau groupers. U.S. Fish and Wildlife Service Biological Report 82(11.110). U.S. Army Corps of Engineers, TR EL-82-4:21.

Manooch, C.S. and C.A. Barans. 1982. Distribution, abundance, age, and growth of the tomtate, *Haemulon aurolineatum*, along the southeastern United States coast. Fishery Bulletin 80(1):1-19.

Manooch, C.S. and M. Haimovici. 1983. Foods of greater amberjack, *Seriola dumerili*, and almaco jack, *Seriola rivoliana* (Pisces: Carangidae), from the south Atlantic Bight. The Journal of the Elisha Mitchell Scientific Society 99(1):1-9.

Manooch, C.S. and J.C. Potts. 1997a. Age, growth, and mortality of greater amberjack from the southeastern United States. Fisheries Research 30:229-240.

Manooch, C.S. and J.C. Potts. 1997b. Age, growth, and mortality of greater amberjack, *Seriola dumerili*, from the U.S. Gulf of Mexico headboat fishery. Bulletin of Marine Science 61(3):671-683.

McFarland, W.N., E.B. Brothers, J.C. Ogden, M.J. Shulman, E.L. Bermingham, and N.M. Kotchian-Prentiss. 1985. Recruitment patterns in young French grunts, *Haemulon flavolineatum* (Family

McGraw, K.A. and D.A. Armstrong. 1988. Fish entrainment by dredges in Grays Harbor, Washington. In: C.A. Simenstad, editor. Effects of dredging on anadromous pacific coast fishes. Workshop Proceedings: University of Washington Sea Grant, FL. 113-131.

Mercer, L.P. 1989. Species profile: life histories and environmental requirements of coastal fishes and invertebrates (South Atlantic) - black sea bass. U.S. Fish and Wildlife Service Biological Report 82(11.99). U.S. Army Corps of Engineers, TR EL-82-4:16.

National Marine Fisheries Service (NMFS). 1999. Essential Fish Habitat Source Document:

Bluefish, *Pomatomus saltatrix*, Life History and Habitat Characteristics NOAA Technical Memorandum NMFS-NE-144. Northeast Fisheries Science Center, Woods Hole, Massachusetts. 64 pp.

National Marine Fisheries Service (NMFS). 2006. Final consolidated Atlantic highly migratory species fishery management plan. Office of Sustainable Fisheries, Highly Migratory Species Management Division, Silver Spring, MD. Available from: http://www.nmfs.noaa.gov/sfa/hms/hmsdocument_files/FMPs.htm. Accessed 25 October 2010.

National Marine Fisheries Service (NMFS). 2010a. National Oceanic and Atmospheric Administration. NMFS Essential Fish Habitat mapper. Available from: http://sharpfin.nmfs.noaa.gov/website/ EFH_Mapper/map.aspx. Accessed October 2010.

National Marine Fisheries Service (NMFS). 2010b. Summer flounder *(Paralichthys dentatus)* Essential Fish Habitat (EFH) for Summer flounder: Available from: http://www.nero.noaa.gov/hcd/summer flounder.htm. Accessed October 2010

National Oceanic and Atmospheric Administration (NOAA), Fisheries Service. 2009a. Office of Habitat Conservation, Habitat Protection Division South Atlantic, Black Sea Bass. Accessed March 2009. Available online at www.nmfs.noaa.gov/habitat/habitatprotection/efh/GIS_inven.htm.

Northeast Fisheries Science Center. 2009b. Status of Fishery Resources off the Northeastern US, Resource Evaluation and Assessment Division. Woods Hole, Massachusetts. Modified March 2009, Accessed April 2009. Available online at www.nefsc.noaa.gov/sos/spsyn/op/bluefish/.

Packer, D.B., S.J. Griesbach, P.L. Berrien, C.A. Zetlin, D.L. Johnson, and M.W. Morse. 1999. Essential Fish Habitat Source Document: Summer flounder, *Paralichthys dentatus*, life history and habitat characteristics. NOAA Technical Memorandum NMFS-NE-151. Northeast Fisheries Science Center, Woods Hole, MA.

Perrotta, T. 2014. King mackerel. Website visited 11 March 2014:

http://www.flmnh.ufl.edu/fish/Gallery/Descript/kingmackerel/kingmackerel.html. University of Florida, Florida Museum of Natural History. Gainesville, FL.

Peterson, C.H. and N.M. Peterson. 1979. The ecology of intertidal flats of North Carolina: A community profile. U.S. Fish and Wildlife Service, OBS-79/39, 73 p.

Reine, K.J. and D.G. Clark. 1998. Entrainment by hydraulic dredges -A review of potential impacts. U.S. Army Engineer Waterways Experiment Station, Reseach and Development Center, Vicksburg, MS, DOER Tech Notes Collection (TN DOER-E1).

Render, J.H. and C.A. Wilson. 1992. Sexuality of the sheepshead *Archosargus probatocephalus* (Teleostei: Sparidae) from the northern Gulf of Mexico. Copeia 1992:917-919.

Richards, W.J., K.C. Lindeman, J.L. Shultz, J.M. Leis, A. Ropke, M.E. Clarke, and B.H. Comyns. 1994. Preliminary guide to the identification of the early life history stages of lutjanid fishes of the western central Atlantic. NOAA Technical Memorandum NMFS-SEFSC-345:49.

Rosasa, C., E. Martinezb, G. Gaxiolaa, R. Britoc, A. Sáncheza, L.A Sotod. 1999. The effect of dissolved oxygen and salinity on oxygen consumption, ammonia excretion and osmotic pressure of *Penaeus setiferus* (Linnaeus) juveniles. Journal of Experimental Marine Biology and Ecology 234(1):41–57.

Sale, P.F. 1991. The ecology of fishes on coral reefs. Academic Press, Inc., San Diego, CA. 754 pp.

Saloman, C.H., S.P. Naughton, and J.L. Taylor. 1982. Benthic community response to dredging borrow pits, Panama City Beach, Florida. U.S. Army Corps of Engineers, Coastal Engineering Research Center, Fort Belvoir, VA, Miscellaneous Report 823:138.

Sedberry, G.R. 1985. Food and feeding of the tomtate, *Haemulon aurolineatum* (Pisces, Haemulidae), in the south Atlantic Bight. Fishery Bulletin 83(3):461-466.

Serrano, X., M. Grosell, J. E. Serafy. 2010. Salinity selection and preference of the grey snapper Lutjanus griseus: field and laboratory observations. Journal of Fish Biology 76(7):1592–1608.

Shaw, R.F. and D.L. Drullinger. 1990. Early-life history profiles, seasonal abundance, and distribution of four species of carangid larvae off Louisiana, 1982 and 1983. NOAA Technical Report NMFS Circular 89:37.

Shepherd, G. R. 2006. Status of fishery resources off the Northeastern US., bluefish (*Pomatomus saltatrix)*. Available from: http://www.nefsc.noaa.gov/sos/spsyn/op/ bluefish/archives/25_Bluefish_2006.pdf. Accessed October 2010.

Shepherd, G.R., and D.B. Packer. 2006. Essential fish habitat source document: bluefish, *Pomatomus saltatrix*, life history and habitat characteristics, 2nd Edition. NOAA Technical Memorandum, NMFS-NE-198:89.

Shepherd, G.R., J. Moser, D. Deuel, and Pam Carlson. 2006. The migration patterns of bluefish (Pomatomus saltatrix) along the Atlantic coast determined from tag recoveries. Fishery Bulletin, Vol. 104, No. 4.

South Atlantic Fishery Management Council (SAFMC). 1998a. Final Habitat Plan for the South Atlantic Region: Essential Fish Habitat Requirements for Fishery Management Plans of the South Atlantic Fishery Management Council: The Shrimp Fishery Management Plan, The Red Drum Fishery Management Plan, The Snapper Grouper Fishery Management Plan, The Coastal Migratory Pelagics Fishery Management Plan, The Golden Crab Fishery Management Plan, The Spiny Lobster Fishery Management Plan, The Coral, Coral Reefs, and Live/Hard Bottom Habitat Fishery Management Plan, The Sargassum Habitat Fishery Management Plan, and the Calico Scallop Fishery Management Plan. Charleston, SC, 457 pp.

South Atlantic Fishery Management Council (SAFMC). 1998b. Final Comprehensive Amendment Addressing Essential Fish Habitat in Fishery Management Plans of the South Atlantic Region: Amendment 3 to the Shrimp Fishery Management Plan, Amendment 1 to the Red Drum Fishery Management Plan, Amendment 10 to the Snapper Grouper Fishery Management Plan, Amendment 10 to the Coastal Migratory Pelagics Fishery management Plan, Amendment 1 to the Golden Crab Fishery Management Plan, Amendment 5 to the Spiny Lobster Fishery Management Plan, and Amendment 4 to the Coral, Coral Reefs, and Live/Hard Bottom habitat Fishery Management Plan (Including a Final EA/SEIS, RIR & SIA/FIS). Charleston, South Carolina. Prepared by South Atlantic Fishery Management Council. October 1998. Copyright 2009. Accessed March 2009. Available online at http://ocean.floridamarine.org/efh_coral/pdfs/Comp_Amend/EFHAmendSect4.0.pdf.

South Atlantic Fisheries Management Council. 2009. Regulations by Species, Black Sea Bass. Accessed March 2009. Available online at www.safmc.net/FishIDandRegs/FishGallery/BlackSeaBass/tabid/272/Default.aspx.

South Atlantic Region (SAR), NOAA. 2008a. National Marine Fisheries Service Habitat Conservation Division; Southeast Regional Office. St. Petersburg, Florida. Essential Fish Habitat: A Marine Fish Habitat Conservation Mandate for Federal Agencies. Revision Date August 2008. Accessed March 2009. Available online at http://sero.nmfs.noaa.gov/hcd/pdfs/efhdocs/sa_guide_2008.pdf.

South Atlantic Region (SAR), NOAA 2008b. National Marine Fisheries Service Habitat Conservation Division; Southeast Regional Office. Summary of EFH Requirements for Species Managed by the Mid-Atlantic Fishery Management Council Appendix 7. St. Petersburg, Florida. Essential Fish Habitat: A Marine Fish Habitat Conservation Mandate for Federal Agencies. Revision Date August 2008. Accessed March 2009. Available online at http://sero.nmfs.noaa.gov/hcd/pdfs/efhdocs/sa_guide_2008.pdf.

South Carolina Department of Natural Resources (SCDNR). 2013a. King mackerel recreational fishery in SC. Website http://www.dnr.sc.gov/marine/species/graphs/kingmackerelstatus.html.

South Carolina Department of Natural Resources (SCDNR). 2013b. King Mackerel (*Scomberomorus cavalla*) Website: http://www.dnr.sc.gov/marine/species/kingmackerel.html.

South Carolina Department of Natural Resources (SCDNR). 2013c. Summer flounder (*Paralichthys dentatus*) Website: http://www.dnr.sc.gov/marine/species/summerflounder.html.

South Carolina Department of Natural Resources (SCDNR). 2013d. Summer flounder recreational fishery in SC. Website: http://www.dnr.sc.gov/marine/species/graphs/summerflounderstatus.html.

Sullivan, B.K. and D. Hancock. 1977. Zooplankton and dredging: research perspectives from a critical review. Water Research Bulletin 13(3):461-468.

Thresher, R.E. 1984. Reproduction in Reef Fishes. T.F.H. Publications, Inc., Neptune City, NJ. 399 pp.

Vose, F.E. and W.G. Nelson. 1994. Gray triggerfish (*Balistes capriscus* Gmelin) feeding from artificial and natural substrate in shallow Atlantic waters of Florida. Bulletin of Marine Science 55(2-3):1223-1316.

Wenner, E. 2004. 2004. Penaeid Shrimp. South Carolina Department of Natural Resources Marine Resources Division. Charleston, SC.

Whitaker, J.D. 2012. Shrimp in SC. Website visited 23 February 2014: https://www.dnr.sc.gov/marine/pub/seascience/shrimp.html. South Carolina Department of Natural Resources Marine Resources Division. Charleston, SC.

Attachment H-1

Dissolved Oxygen Tables

Table H-1. 2022 Condition, Low Flow, Actual Loads, Bottom layer DO, July

Segment	10%	50%	90%	Mean	Segment	10%	50%	90%	Mean
A1	5.183	5.354	5.494	5.344	C2	5.039	5.209	5.307	5.188
A10	4.766	5.335	5.78	5.292	C20	4.731	4.936	5.19	4.952
A11	4.762	5.362	5.827	5.326	C21	4.749	4.946	5.195	4.965
A12	4.786	5.369	5.808	5.332	C22	4.762	4.959	5.204	4.973
A13	4.722	5.306	5.753	5.269	C23	4.763	4.958	5.204	4.979
A14	4.727	5.288	5.722	5.261	C24	4.792	4.977	5.214	4.994
A15	4.745	5.294	5.7	5.266	C25	4.812	4.982	5.233	5.011
A16	4.755	5.292	5.656	5.254	C26	4.826	5.002	5.253	5.026
A17	4.786	5.276	5.629	5.252	C27	4.835	5.013	5.261	5.033
A18	4.822	5.259	5.634	5.249	C28	4.833	5.018	5.262	5.038
A19	4.807	5.242	5.598	5.217	C29	4.839	5.022	5.278	5.043
A2	5.126	5.346	5.542	5.343	C3	5.017	5.151	5.291	5.156
A20	4.745	5.197	5.569	5.179	C30	4.855	5.04	5.293	5.062
A21	4.663	5.158	5.557	5.137	C31	4.862	5.058	5.308	5.075
A23	4.531	5.117	5.569	5.081	C32	4.871	5.065	5.314	5.083
A24	4.398	5.04	5.547	5.001	C33	4.881	5.083	5.323	5.09
A25	4.324	4.994	5.523	4.947	C34	4.884	5.09	5.33	5.096
A26	4.219	4.912	5.468	4.874	C35	4.887	5.099	5.333	5.103
A27	4.109	4.818	5.399	4.784	C36	4.934	5.143	5.349	5.14
A28	3.989	4.717	5.337	4.688	C37	4.872	5.093	5.321	5.095
A29	3.872	4.61	5.276	4.598	C38	4.848	5.11	5.326	5.094
A3	5.066	5.246	5.48	5.259	C39	4.851	5.127	5.33	5.104
A30	3.798	4.546	5.231	4.525	C4	4.977	5.115	5.27	5.12
A31	3.706	4.466	5.169	4.454	C40	4.878	5.13	5.335	5.112
A32	3.59	4.373	5.098	4.368	C41	4.901	5.147	5.347	5.128
A33	3.475	4.265	5.027	4.267	C42	4.92	5.153	5.353	5.138
A34	3.274	4.149	4.947	4.142	C43	4.93	5.166	5.357	5.15
A35	3.035	4.007	4.886	4.005	C44	4.941	5.178	5.362	5.162
A36	2.852	3.898	4.829	3.889	C45	4.963	5.188	5.374	5.177
A37	2.323	3.604	4.628	3.556	C46	4.969	5.197	5.386	5.187
A38	1.928	3.256	4.244	3.199	C47	4.975	5.197	5.397	5.196
A39	1.565	2.882	3.956	2.851	C48	4.986	5.21	5.424	5.21
A4	5.054	5.247	5.548	5.274	C49	4.998	5.22	5.444	5.224
A40	1.346	2.598	3.625	2.558	C5	4.961	5.101	5.26	5.11
A41	1.16	2.227	3.325	2.242	C50	5.004	5.231	5.461	5.232
A42	1.007	1.788	2.822	1.882	C51	5.01	5.24	5.48	5.242
A43	0.903	1.464	2.218	1.551	C52	5.012	5.251	5.496	5.251
A44	0.857	1.389	2.144	1.456	C53	5.018	5.26	5.512	5.261
A45	0.846	1.399	2.12	1.453	C54	5.027	5.27	5.528	5.272
A46	0.852	1.389	2.12	1.444	C55	5.037	5.276	5.539	5.281
A47	0.858	1.357	2.07	1.41	C56	5.044	5.284	5.555	5.293
A48	0.841	1.313	1.986	1.368	C57	5.057	5.3	5.571	5.31
A49	0.829	1.272	1.915	1.33	C58	5.067	5.318	5.586	5.325
A5	5.08	5.332	5.64	5.348	C59	5.08	5.33	5.603	5.337
A50	0.833	1.26	1.851	1.298	C6	4.926	5.072	5.236	5.077
A51	0.868	1.266	1.89	1.334	C60	5.098	5.343	5.611	5.35
A52	0.699	1.082	1.66	1.141	C7	4.888	5.035	5.204	5.043
A53	0.678	1.016	1.569	1.08	C8	4.855	5.017	5.18	5.019
A54	0.651	0.972	1.463	1.033	C9	4.774	4.947	5.129	4.951
A55	0.653	0.955	1.355	0.988	H1	4.785	5.064	5.298	5.039
A56	0.64	0.909	1.249	0.945	H2	4.979	5.204	5.411	5.193
A57	0.645	0.889	1.199	0.914	H3	4.884	5.134	5.363	5.115
A58	0.643	0.869	1.175	0.899	H4	5.094	5.267	5.407	5.255
A59	0.681	0.862	1.158	0.89	H5	4.994	5.21	5.388	5.193
A6	4.952	5.367	5.677	5.348	H6	5.075	5.257	5.382	5.239
A60	0.68	0.945	1.302	0.965	H7	5.101	5.272	5.371	5.254
A61	0	0.859	1.67	0.809	H8	5.112	5.263	5.364	5.251
A62	0.609	1.416	2.506	1.476	H9	5.14	5.306	5.409	5.284

A7	4.911	5.352	5.687	5.332	W1	5.184	5.343	5.464	5.331
A8	4.605	5.278	5.641	5.214	W10	5.364	5.658	5.818	5.626
A9	4.787	5.279	5.718	5.268	W11	5.351	5.661	5.829	5.63
C1	5.035	5.208	5.32	5.19	W12	5.331	5.641	5.827	5.613
C10	4.692	4.858	5.051	4.87	W13	5.28	5.63	5.811	5.587
C11	4.595	4.748	4.949	4.765	W2	5.201	5.362	5.5	5.356
C12	4.568	4.711	4.92	4.732	W3	5.243	5.41	5.589	5.417
C13	4.505	4.65	4.859	4.668	W4	5.285	5.447	5.626	5.456
C14	4.522	4.668	4.88	4.684	W5	5.32	5.493	5.65	5.488
C15	4.559	4.711	4.941	4.738	W6	5.334	5.528	5.668	5.514
C16	4.614	4.792	5.029	4.818	W7	5.377	5.59	5.735	5.571
C17	4.665	4.872	5.129	4.884	W8	5.376	5.616	5.765	5.593
C18	4.718	4.92	5.167	4.935	W9	5.351	5.619	5.78	5.593
C19	4.736	4.942	5.182	4.95					

Table H-2. 2022 Condition, Low Flow, Actual Loads, Bottom layer DO, August

Segment	10%	50%	90%	Mean	Segment	10%	50%	90%	Mean
A1	4.991	5.188	5.466	5.214	C2	4.798	4.98	5.254	5.005
A10	4.787	5.297	5.555	5.236	C20	4.586	4.882	5.202	4.884
A11	4.846	5.33	5.623	5.281	C21	4.602	4.897	5.215	4.898
A12	4.916	5.345	5.632	5.308	C22	4.62	4.907	5.222	4.907
A13	4.86	5.295	5.6	5.259	C23	4.617	4.918	5.232	4.913
A14	4.848	5.294	5.602	5.25	C24	4.635	4.943	5.233	4.928
A15	4.894	5.308	5.574	5.275	C25	4.655	4.952	5.243	4.945
A16	4.908	5.319	5.58	5.289	C26	4.679	4.955	5.251	4.963
A17	4.947	5.331	5.565	5.298	C27	4.688	4.966	5.253	4.971
A18	4.944	5.327	5.574	5.302	C28	4.699	4.974	5.266	4.978
A19	4.946	5.315	5.551	5.285	C29	4.688	4.977	5.257	4.982
A2	4.906	5.239	5.488	5.219	C3	4.832	5.022	5.264	5.036
A20	4.929	5.287	5.54	5.261	C30	4.714	4.993	5.285	5.004
A21	4.9	5.265	5.533	5.234	C31	4.746	4.998	5.287	5.017
A23	4.775	5.265	5.573	5.207	C32	4.756	5.004	5.29	5.026
A24	4.675	5.216	5.544	5.144	C33	4.771	5.003	5.299	5.033
A25	4.581	5.18	5.54	5.101	C34	4.789	5.008	5.315	5.04
A26	4.481	5.112	5.501	5.04	C35	4.804	5.013	5.322	5.047
A27	4.328	5.041	5.473	4.965	C36	4.856	5.047	5.349	5.082
A28	4.185	4.945	5.44	4.886	C37	4.801	5.013	5.32	5.042
A29	4.042	4.855	5.398	4.809	C38	4.794	5.016	5.331	5.043
A3	4.804	5.166	5.423	5.141	C39	4.81	5.027	5.352	5.057
A30	3.947	4.799	5.374	4.747	C4	4.772	5.004	5.23	5.003
A31	3.864	4.719	5.339	4.685	C40	4.83	5.028	5.372	5.067
A32	3.75	4.657	5.274	4.607	C41	4.851	5.046	5.407	5.092
A33	3.632	4.566	5.229	4.519	C42	4.859	5.068	5.426	5.105
A34	3.443	4.459	5.167	4.408	C43	4.888	5.073	5.441	5.119
A35	3.255	4.304	5.127	4.278	C44	4.895	5.086	5.466	5.135
A36	3.087	4.206	5.091	4.174	C45	4.913	5.098	5.476	5.152
A37	2.662	3.931	4.911	3.872	C46	4.929	5.109	5.48	5.164
A38	2.241	3.652	4.608	3.577	C47	4.941	5.125	5.499	5.177
A39	1.821	3.294	4.314	3.239	C48	4.945	5.146	5.526	5.194
A4	4.782	5.199	5.452	5.153	C49	4.964	5.16	5.538	5.21
A40	1.69	3.033	4.024	2.967	C5	4.771	5	5.219	4.996
A41	1.467	2.783	3.675	2.679	C50	4.973	5.175	5.546	5.221
A42	1.095	2.369	3.21	2.277	C51	4.976	5.19	5.553	5.233
A43	0.857	1.892	2.544	1.83	C52	4.979	5.208	5.563	5.245
A44	0.87	1.747	2.22	1.66	C53	4.989	5.224	5.573	5.257
A45	0.857	1.849	2.369	1.736	C54	4.995	5.243	5.588	5.27
A46	0.852	1.77	2.471	1.73	C55	5.006	5.258	5.601	5.282
A47	0.852	1.691	2.45	1.68	C56	5.013	5.273	5.615	5.296
A48	0.84	1.622	2.368	1.618	C57	5.027	5.296	5.639	5.317
A49	0.84	1.559	2.278	1.56	C58	5.039	5.313	5.656	5.335
A5	4.862	5.265	5.539	5.223	C59	5.06	5.329	5.672	5.35
A50	0.832	1.501	2.182	1.508	C6	4.728	4.981	5.192	4.966
A51	0.903	1.492	2.182	1.517	C60	5.083	5.346	5.691	5.367

A52	0.715	1.264	1.951	1.307	C7	4.7	4.959	5.158	4.937
A53	0.683	1.187	1.821	1.227	C8	4.691	4.934	5.142	4.918
A54	0.676	1.137	1.697	1.163	C9	4.593	4.873	5.096	4.856
A55	0.661	1.098	1.562	1.103	H1	4.559	4.919	5.292	4.926
A56	0.651	1.035	1.454	1.045	H2	4.777	5.064	5.394	5.074
A57	0.645	0.992	1.358	0.996	H3	4.662	4.991	5.349	5.001
A58	0.648	0.928	1.303	0.959	H4	4.9	5.104	5.404	5.131
A59	0.677	0.879	1.261	0.941	H5	4.801	5.058	5.379	5.075
A6	4.81	5.291	5.557	5.231	H6	4.918	5.086	5.386	5.117
A60	0.639	0.879	1.444	0.974	H7	4.959	5.078	5.37	5.129
A61	0.019	0.852	1.92	0.912	H8	4.957	5.072	5.361	5.125
A62	0.405	1.115	2.921	1.422	H9	4.975	5.12	5.405	5.158
A7	4.77	5.279	5.552	5.218	W1	5.003	5.165	5.432	5.196
A8	4.597	5.233	5.49	5.135	W10	5.153	5.345	5.559	5.35
A9	4.731	5.275	5.482	5.201	W11	5.144	5.33	5.552	5.341
C1	4.833	4.996	5.286	5.035	W12	5.111	5.3	5.528	5.312
C10	4.506	4.799	5.029	4.779	W13	5.056	5.27	5.509	5.278
C11	4.397	4.699	4.936	4.679	W2	5.017	5.189	5.437	5.214
C12	4.375	4.665	4.908	4.649	W3	5.069	5.246	5.47	5.265
C13	4.303	4.603	4.852	4.586	W4	5.113	5.277	5.492	5.298
C14	4.329	4.62	4.883	4.609	W5	5.153	5.296	5.508	5.321
C15	4.374	4.665	4.945	4.666	W6	5.165	5.314	5.512	5.33
C16	4.441	4.748	5.047	4.746	W7	5.183	5.352	5.544	5.362
C17	4.502	4.812	5.111	4.815	W8	5.175	5.352	5.552	5.359
C18	4.566	4.864	5.162	4.867	W9	5.141	5.338	5.541	5.338
C19	4.576	4.88	5.18	4.882					

Table H-3. 2022 Condition, Low Flow, Actual Loads, Bottom layer DO, September

Segment	10%	50%	90%	Mean	Segment	10%	50%	90%	Mean
A1	5.18	5.372	6.062	5.479	C2	4.948	5.139	6	5.282
A10	4.107	5.101	5.978	5.029	C20	4.754	5.065	6.021	5.215
A11	4.003	5.135	5.959	5.005	C21	4.765	5.077	6.045	5.235
A12	3.904	5.132	5.958	4.979	C22	4.774	5.084	6.068	5.248
A13	3.714	5.053	5.901	4.897	C23	4.787	5.09	6.066	5.257
A14	3.706	5.007	5.899	4.877	C24	4.8	5.116	6.087	5.278
A15	3.698	5	5.91	4.863	C25	4.821	5.145	6.109	5.303
A16	3.654	4.946	5.875	4.834	C26	4.829	5.172	6.144	5.326
A17	3.69	4.92	5.845	4.813	C27	4.841	5.179	6.159	5.338
A18	3.685	4.89	5.832	4.796	C28	4.856	5.194	6.164	5.353
A19	3.608	4.811	5.794	4.726	C29	4.854	5.214	6.177	5.367
A2	5.107	5.384	5.99	5.448	C3	4.964	5.145	5.981	5.273
A20	3.526	4.737	5.752	4.652	C30	4.878	5.246	6.207	5.393
A21	3.373	4.637	5.705	4.567	C31	4.898	5.269	6.249	5.413
A23	3.111	4.539	5.652	4.482	C32	4.909	5.28	6.286	5.426
A24	2.958	4.458	5.536	4.372	C33	4.915	5.289	6.303	5.439
A25	2.812	4.357	5.521	4.297	C34	4.923	5.294	6.336	5.449
A26	2.694	4.289	5.458	4.207	C35	4.922	5.302	6.335	5.459
A27	2.551	4.178	5.414	4.086	C36	4.97	5.33	6.347	5.486
A28	2.4	4.067	5.299	3.967	C37	4.914	5.307	6.391	5.469
A29	2.269	3.951	5.202	3.853	C38	4.922	5.314	6.435	5.487
A3	4.97	5.229	5.968	5.322	C39	4.942	5.319	6.449	5.505
A30	2.212	3.878	5.148	3.765	C4	4.924	5.098	5.95	5.23
A31	2.136	3.799	5.073	3.682	C40	4.967	5.324	6.46	5.52
A32	2.045	3.686	4.998	3.582	C41	4.999	5.337	6.491	5.545
A33	1.906	3.567	4.934	3.476	C42	5.009	5.342	6.503	5.559
A34	1.792	3.405	4.799	3.333	C43	5.025	5.366	6.521	5.573
A35	1.619	3.245	4.673	3.175	C44	5.043	5.393	6.54	5.589
A36	1.475	3.1	4.597	3.061	C45	5.055	5.408	6.56	5.606
A37	1.12	2.72	4.366	2.758	C46	5.061	5.431	6.576	5.62
A38	0.894	2.271	3.913	2.341	C47	5.062	5.446	6.583	5.634
A39	0.717	1.998	3.533	2.041	C48	5.082	5.466	6.597	5.656
A4	4.919	5.237	5.96	5.297	C49	5.084	5.497	6.6	5.673
A40	0.603	1.794	3.1	1.808	C5	4.901	5.092	5.953	5.219
A41	0.503	1.6	2.732	1.604	C50	5.084	5.509	6.6	5.684
A42	0.499	1.444	2.366	1.436	C51	5.094	5.532	6.592	5.697
A43	0.488	1.319	2.253	1.328	C52	5.099	5.542	6.596	5.712
A44	0.556	1.293	2.224	1.31	C53	5.106	5.558	6.608	5.726
A45	0.619	1.276	2.328	1.338	C54	5.112	5.573	6.631	5.742
A46	0.683	1.292	2.398	1.373	C55	5.127	5.587	6.65	5.757
A47	0.716	1.298	2.42	1.406	C56	5.148	5.603	6.666	5.774
A48	0.738	1.29	2.494	1.43	C57	5.173	5.622	6.681	5.797
A49	0.762	1.318	2.593	1.455	C58	5.194	5.641	6.691	5.818
A5	4.892	5.312	6.005	5.327	C59	5.215	5.66	6.705	5.836
A50	0.779	1.333	2.654	1.483	C6	4.847	5.062	5.934	5.187
A51	0.85	1.404	2.772	1.601	C60	5.244	5.682	6.731	5.856

A52	0.742	1.285	2.501	1.432	C7	4.817	5.029	5.922	5.158
A53	0.764	1.309	2.488	1.432	C8	4.783	5.007	5.908	5.137
A54	0.755	1.337	2.444	1.439	C9	4.705	4.952	5.875	5.085
A55	0.771	1.355	2.488	1.456	H1	4.875	5.222	5.752	5.26
A56	0.767	1.393	2.519	1.485	H2	5.054	5.313	5.944	5.387
A57	0.781	1.444	2.577	1.533	H3	4.979	5.263	5.873	5.329
A58	0.798	1.506	2.66	1.599	H4	5.126	5.344	6.005	5.43
A59	0.842	1.612	2.832	1.71	H5	5.053	5.319	5.949	5.392
A6	4.74	5.303	6.024	5.276	H6	5.095	5.329	5.981	5.419
A60	0.968	1.911	3.209	1.997	H7	5.096	5.305	6.02	5.41
A61	1.07	2.369	3.716	2.347	H8	5.084	5.283	6.024	5.394
A62	2.027	3.429	4.431	3.258	H9	5.138	5.346	6.05	5.441
A7	4.603	5.252	6.016	5.212	W1	5.184	5.351	6.094	5.465
A8	4.268	5.087	5.956	5.037	W10	5.298	5.505	6.398	5.655
A9	4.277	5.15	5.98	5.062	W11	5.281	5.497	6.392	5.65
C1	4.995	5.184	5.981	5.316	W12	5.234	5.458	6.38	5.624
C10	4.637	4.873	5.822	5.018	W13	5.156	5.445	6.367	5.594
C11	4.551	4.787	5.786	4.935	W2	5.196	5.349	6.121	5.476
C12	4.532	4.771	5.773	4.919	W3	5.22	5.379	6.156	5.521
C13	4.472	4.714	5.744	4.866	W4	5.242	5.408	6.2	5.552
C14	4.5	4.743	5.772	4.899	W5	5.261	5.433	6.252	5.579
C15	4.544	4.8	5.806	4.967	W6	5.28	5.446	6.303	5.601
C16	4.605	4.881	5.871	5.051	W7	5.312	5.487	6.351	5.64
C17	4.657	4.978	5.929	5.13	W8	5.312	5.495	6.369	5.648
C18	4.705	5.032	6.006	5.187	W9	5.295	5.482	6.373	5.64
C19	4.746	5.06	6.008	5.208					

Table H-4. 2022 Condition, Low Flow, Actual Loads, Water Column Average DO, July

Segment	10%	50%	90%	Mean	Segment	10%	50%	90%	Mean
A1	5.324	5.484	5.608	5.475	C2	5.184	5.352	5.447	5.342
A10	5.287	5.548	5.906	5.574	C20	4.843	5.01	5.216	5.022
A11	5.196	5.542	5.892	5.547	C21	4.845	5.012	5.22	5.027
A12	5.178	5.532	5.881	5.535	C22	4.85	5.017	5.224	5.032
A13	5.136	5.499	5.851	5.495	C23	4.852	5.029	5.233	5.038
A14	5.097	5.489	5.829	5.479	C24	4.856	5.031	5.239	5.046
A15	5.054	5.463	5.804	5.446	C25	4.86	5.034	5.251	5.055
A16	5.003	5.43	5.759	5.407	C26	4.867	5.04	5.265	5.062
A17	4.986	5.399	5.737	5.383	C27	4.872	5.048	5.272	5.068
A18	4.966	5.373	5.713	5.351	C28	4.881	5.066	5.284	5.076
A19	4.892	5.323	5.689	5.306	C29	4.884	5.073	5.295	5.084
A2	5.342	5.493	5.626	5.488	C3	5.117	5.273	5.399	5.264
A20	4.81	5.28	5.677	5.262	C30	4.895	5.085	5.311	5.094
A21	4.73	5.226	5.645	5.199	C31	4.901	5.101	5.321	5.103
A23	4.571	5.139	5.622	5.11	C32	4.914	5.112	5.327	5.111
A24	4.433	5.058	5.573	5.026	C33	4.918	5.117	5.333	5.118
A25	4.351	5.006	5.554	4.966	C34	4.922	5.123	5.34	5.124
A26	4.244	4.926	5.5	4.894	C35	4.932	5.13	5.344	5.132
A27	4.134	4.823	5.421	4.797	C36	4.955	5.158	5.358	5.158
A28	4.018	4.729	5.361	4.702	C37	4.935	5.146	5.342	5.139
A29	3.891	4.616	5.288	4.607	C38	4.936	5.148	5.344	5.141
A3	5.321	5.472	5.623	5.469	C39	4.948	5.155	5.346	5.151
A30	3.818	4.552	5.233	4.532	C4	5.072	5.232	5.364	5.226
A31	3.723	4.473	5.177	4.462	C40	4.953	5.166	5.351	5.157
A32	3.601	4.376	5.105	4.375	C41	4.958	5.178	5.362	5.166
A33	3.495	4.275	5.033	4.28	C42	4.97	5.188	5.364	5.177
A34	3.295	4.169	4.959	4.157	C43	4.979	5.196	5.368	5.184
A35	3.05	4.028	4.895	4.015	C44	4.989	5.203	5.382	5.193
A36	2.923	3.942	4.83	3.919	C45	4.999	5.211	5.392	5.203
A37	2.558	3.64	4.648	3.641	C46	5.007	5.214	5.398	5.211
A38	1.973	3.201	4.288	3.202	C47	5.014	5.218	5.409	5.22
A39	1.599	2.804	3.978	2.849	C48	5.02	5.231	5.431	5.231
A4	5.319	5.482	5.67	5.488	C49	5.019	5.241	5.449	5.241
A40	1.407	2.554	3.619	2.562	C5	5.057	5.214	5.357	5.212
A41	1.222	2.283	3.25	2.28	C50	5.024	5.248	5.466	5.249
A42	1.102	2.034	2.888	2.007	C51	5.022	5.258	5.487	5.256
A43	1.001	1.772	2.558	1.774	C52	5.023	5.269	5.504	5.265
A44	0.927	1.603	2.359	1.625	C53	5.031	5.273	5.522	5.274
A45	0.892	1.488	2.249	1.54	C54	5.04	5.282	5.539	5.285
A46	0.864	1.418	2.158	1.474	C55	5.047	5.291	5.554	5.295
A47	0.868	1.374	2.079	1.425	C56	5.053	5.301	5.567	5.307
A48	0.856	1.324	1.99	1.379	C57	5.065	5.321	5.584	5.322
A49	0.851	1.295	1.92	1.341	C58	5.079	5.331	5.597	5.337
A5	5.326	5.512	5.743	5.526	C59	5.093	5.344	5.61	5.349
A50	0.847	1.267	1.856	1.309	C6	5.028	5.188	5.339	5.185
A51	0.874	1.27	1.905	1.341	C60	5.112	5.361	5.621	5.363

A52	0.716	1.093	1.667	1.152	C7	4.979	5.147	5.311	5.145
A53	0.689	1.022	1.582	1.091	C8	4.943	5.129	5.299	5.12
A54	0.672	0.985	1.496	1.044	C9	4.888	5.086	5.26	5.079
A55	0.663	0.965	1.382	1	H1	4.86	5.161	5.38	5.128
A56	0.653	0.922	1.281	0.962	H2	5.067	5.293	5.48	5.277
A57	0.655	0.905	1.227	0.937	H3	4.962	5.219	5.423	5.194
A58	0.667	0.908	1.205	0.932	H4	5.18	5.367	5.484	5.347
A59	0.703	0.925	1.217	0.952	H5	5.066	5.29	5.441	5.261
A6	5.305	5.503	5.776	5.528	H6	5.158	5.328	5.441	5.309
A60	0.798	1.045	1.477	1.101	H7	5.16	5.334	5.434	5.315
A61	1.039	1.355	1.967	1.43	H8	5.176	5.338	5.436	5.32
A62	1.92	2.372	3.128	2.447	H9	5.201	5.362	5.467	5.348
A7	5.322	5.527	5.829	5.559	W1	5.247	5.409	5.515	5.393
A8	5.274	5.519	5.831	5.547	W10	5.378	5.677	5.832	5.648
A9	5.313	5.542	5.894	5.574	W11	5.365	5.688	5.851	5.652
C1	5.174	5.343	5.432	5.325	W12	5.353	5.697	5.864	5.652
C10	4.812	5.002	5.182	5	W13	5.332	5.688	5.863	5.647
C11	4.767	4.938	5.112	4.947	W2	5.268	5.429	5.549	5.418
C12	4.752	4.909	5.092	4.921	W3	5.295	5.457	5.605	5.454
C13	4.74	4.89	5.082	4.904	W4	5.324	5.485	5.638	5.482
C14	4.754	4.898	5.09	4.91	W5	5.348	5.52	5.662	5.511
C15	4.76	4.904	5.115	4.926	W6	5.373	5.56	5.696	5.545
C16	4.79	4.929	5.142	4.956	W7	5.391	5.601	5.747	5.588
C17	4.802	4.963	5.175	4.98	W8	5.398	5.637	5.784	5.614
C18	4.824	4.99	5.199	5.004	W9	5.388	5.663	5.805	5.633
C19	4.835	5.006	5.212	5.016					

Table H-5. 2022 Condition, Low Flow, Actual Loads, Water Column Average DO, August

Segment	10%	50%	90%	Mean	Segment	10%	50%	90%	Mean
A1	5.17	5.296	5.571	5.341	C2	4.978	5.129	5.379	5.16
A10	5.212	5.514	5.771	5.501	C20	4.711	4.952	5.235	4.958
A11	5.198	5.508	5.757	5.496	C21	4.716	4.96	5.242	4.963
A12	5.237	5.516	5.764	5.508	C22	4.72	4.967	5.247	4.97
A13	5.209	5.504	5.741	5.487	C23	4.719	4.971	5.258	4.977
A14	5.194	5.5	5.73	5.482	C24	4.724	4.978	5.27	4.986
A15	5.165	5.476	5.714	5.466	C25	4.738	4.986	5.277	4.995
A16	5.145	5.454	5.698	5.446	C26	4.743	4.993	5.284	5.003
A17	5.149	5.447	5.683	5.432	C27	4.75	4.997	5.293	5.009
A18	5.122	5.435	5.655	5.41	C28	4.762	5	5.3	5.019
A19	5.104	5.406	5.629	5.376	C29	4.773	5.005	5.304	5.029
A2	5.168	5.319	5.589	5.357	C3	4.968	5.125	5.355	5.146
A20	5.07	5.369	5.622	5.344	C30	4.787	5.017	5.312	5.041
A21	4.97	5.327	5.619	5.3	C31	4.796	5.023	5.325	5.05
A23	4.8	5.288	5.603	5.234	C32	4.811	5.029	5.333	5.059
A24	4.689	5.237	5.577	5.166	C33	4.82	5.034	5.344	5.066
A25	4.589	5.194	5.555	5.117	C34	4.829	5.041	5.353	5.074
A26	4.486	5.14	5.528	5.059	C35	4.847	5.046	5.363	5.082
A27	4.34	5.05	5.494	4.978	C36	4.879	5.075	5.38	5.108
A28	4.195	4.952	5.459	4.899	C37	4.862	5.05	5.371	5.092
A29	4.053	4.864	5.412	4.819	C38	4.869	5.056	5.383	5.097
A3	5.135	5.305	5.571	5.335	C39	4.883	5.065	5.407	5.11
A30	3.954	4.803	5.379	4.753	C4	4.921	5.105	5.326	5.113
A31	3.868	4.725	5.346	4.692	C40	4.901	5.072	5.419	5.119
A32	3.756	4.663	5.287	4.615	C41	4.909	5.08	5.448	5.132
A33	3.644	4.575	5.23	4.531	C42	4.924	5.09	5.467	5.145
A34	3.456	4.472	5.171	4.421	C43	4.93	5.101	5.475	5.155
A35	3.261	4.333	5.12	4.291	C44	4.941	5.116	5.482	5.167
A36	3.114	4.259	5.101	4.204	C45	4.956	5.123	5.498	5.18
A37	2.742	4.015	4.917	3.951	C46	4.961	5.134	5.505	5.19
A38	2.234	3.619	4.622	3.564	C47	4.96	5.141	5.518	5.201
A39	1.817	3.292	4.329	3.236	C48	4.961	5.162	5.54	5.216
A4	5.132	5.319	5.585	5.351	C49	4.982	5.181	5.559	5.23
A40	1.607	3.009	4.037	2.968	C5	4.908	5.102	5.312	5.101
A41	1.397	2.78	3.678	2.7	C50	4.989	5.187	5.563	5.239
A42	1.202	2.536	3.306	2.42	C51	4.987	5.202	5.564	5.248
A43	1.031	2.264	2.944	2.149	C52	4.993	5.217	5.581	5.258
A44	0.941	2.086	2.697	1.968	C53	5.001	5.235	5.597	5.27
A45	0.9	1.949	2.638	1.867	C54	5.011	5.253	5.604	5.283
A46	0.868	1.793	2.579	1.771	C55	5.023	5.267	5.618	5.295
A47	0.858	1.696	2.481	1.697	C56	5.033	5.284	5.627	5.309
A48	0.845	1.626	2.374	1.628	C57	5.039	5.305	5.648	5.328
A49	0.845	1.565	2.286	1.57	C58	5.057	5.32	5.664	5.345
A5	5.163	5.361	5.632	5.387	C59	5.074	5.336	5.676	5.361
A50	0.837	1.506	2.189	1.517	C6	4.872	5.088	5.293	5.078

A51	0.911	1.501	2.188	1.524	C60	5.096	5.359	5.695	5.378
A52	0.722	1.271	1.962	1.317	C7	4.825	5.053	5.259	5.042
A53	0.69	1.202	1.825	1.237	C8	4.792	5.028	5.237	5.02
A54	0.688	1.149	1.703	1.173	C9	4.73	4.991	5.206	4.984
A55	0.673	1.104	1.576	1.114	H1	4.632	5.02	5.355	5.013
A56	0.661	1.046	1.47	1.06	H2	4.87	5.144	5.458	5.155
A57	0.665	1.015	1.384	1.019	H3	4.736	5.083	5.402	5.078
A58	0.676	0.977	1.322	0.995	H4	5.013	5.194	5.475	5.222
A59	0.706	0.963	1.327	0.994	H5	4.856	5.136	5.435	5.142
A6	5.137	5.392	5.661	5.396	H6	4.989	5.155	5.432	5.185
A60	0.78	1.015	1.49	1.103	H7	5.033	5.143	5.421	5.191
A61	0.95	1.254	2.039	1.392	H8	5.04	5.138	5.427	5.195
A62	1.692	2.179	3.222	2.334	H9	5.051	5.178	5.457	5.22
A7	5.171	5.419	5.687	5.428	W1	5.086	5.214	5.482	5.257
A8	5.156	5.441	5.699	5.435	W10	5.176	5.371	5.576	5.373
A9	5.209	5.491	5.742	5.482	W11	5.169	5.357	5.572	5.363
C1	5.006	5.127	5.402	5.172	W12	5.159	5.343	5.566	5.352
C10	4.652	4.913	5.149	4.91	W13	5.135	5.326	5.551	5.337
C11	4.622	4.869	5.102	4.862	W2	5.105	5.235	5.486	5.274
C12	4.596	4.842	5.081	4.839	W3	5.134	5.273	5.5	5.302
C13	4.587	4.825	5.076	4.825	W4	5.162	5.289	5.511	5.323
C14	4.601	4.835	5.089	4.835	W5	5.189	5.313	5.533	5.343
C15	4.61	4.85	5.117	4.854	W6	5.195	5.34	5.544	5.361
C16	4.636	4.886	5.149	4.885	W7	5.199	5.37	5.568	5.38
C17	4.657	4.905	5.177	4.912	W8	5.194	5.373	5.574	5.381
C18	4.683	4.928	5.194	4.937	W9	5.18	5.373	5.57	5.377
C19	4.7	4.945	5.218	4.951					

Table H-6. 2022 Condition, Low Flow, Actual Loads, Water Column Average DO, September

Segment	10%	50%	90%	Mean	Segment	10%	50%	90%	Mean
A1	5.296	5.502	6.142	5.593	C2	5.084	5.28	6.077	5.404
A10	4.662	5.418	6.132	5.356	C20	4.835	5.121	6.118	5.289
A11	4.48	5.345	6.102	5.264	C21	4.846	5.138	6.127	5.3
A12	4.336	5.281	6.071	5.205	C22	4.852	5.139	6.131	5.309
A13	4.233	5.197	6.053	5.133	C23	4.861	5.149	6.142	5.321
A14	4.196	5.159	6.038	5.099	C24	4.873	5.165	6.139	5.334
A15	4.055	5.113	6	5.043	C25	4.877	5.184	6.141	5.35
A16	3.955	5.039	5.956	4.983	C26	4.876	5.199	6.148	5.362
A17	3.881	4.978	5.938	4.94	C27	4.878	5.208	6.17	5.372
A18	3.796	4.94	5.92	4.887	C28	4.886	5.229	6.197	5.388
A19	3.681	4.865	5.871	4.81	C29	4.9	5.246	6.229	5.404
A2	5.268	5.476	6.111	5.567	C3	5.063	5.26	6.048	5.375
A20	3.555	4.776	5.842	4.734	C30	4.918	5.268	6.252	5.422
A21	3.382	4.68	5.758	4.641	C31	4.929	5.286	6.281	5.437
A23	3.142	4.576	5.659	4.511	C32	4.941	5.296	6.309	5.45
A24	2.955	4.482	5.57	4.397	C33	4.947	5.302	6.33	5.461
A25	2.832	4.409	5.544	4.316	C34	4.959	5.312	6.349	5.472
A26	2.707	4.31	5.487	4.223	C35	4.965	5.316	6.369	5.482
A27	2.558	4.198	5.414	4.097	C36	4.987	5.337	6.384	5.505
A28	2.414	4.083	5.315	3.978	C37	4.987	5.324	6.411	5.501
A29	2.277	3.96	5.222	3.862	C38	4.996	5.329	6.443	5.515
A3	5.215	5.442	6.108	5.524	C39	5.004	5.338	6.454	5.531
A30	2.221	3.886	5.152	3.773	C4	5.008	5.22	6.021	5.335
A31	2.145	3.804	5.079	3.69	C40	5.01	5.346	6.472	5.546
A32	2.054	3.695	4.989	3.589	C41	5.03	5.355	6.502	5.565
A33	1.956	3.602	4.889	3.484	C42	5.041	5.381	6.52	5.581
A34	1.827	3.41	4.781	3.343	C43	5.057	5.4	6.532	5.594
A35	1.648	3.233	4.655	3.181	C44	5.066	5.417	6.555	5.609
A36	1.555	3.107	4.59	3.075	C45	5.078	5.441	6.573	5.624
A37	1.275	2.769	4.339	2.791	C46	5.087	5.455	6.589	5.637
A38	0.927	2.298	3.946	2.354	C47	5.086	5.465	6.591	5.651
A39	0.761	2.018	3.508	2.054	C48	5.098	5.486	6.603	5.67
A4	5.178	5.46	6.1	5.512	C49	5.104	5.503	6.611	5.686
A40	0.629	1.812	3.086	1.831	C5	4.985	5.204	6.018	5.32
A41	0.574	1.644	2.695	1.635	C50	5.101	5.519	6.619	5.698
A42	0.555	1.472	2.397	1.477	C51	5.104	5.54	6.611	5.708
A43	0.57	1.364	2.284	1.377	C52	5.108	5.553	6.611	5.722
A44	0.598	1.323	2.271	1.348	C53	5.119	5.569	6.619	5.736
A45	0.651	1.295	2.355	1.365	C54	5.123	5.583	6.637	5.752
A46	0.694	1.317	2.404	1.389	C55	5.133	5.602	6.657	5.767
A47	0.721	1.304	2.441	1.416	C56	5.155	5.611	6.672	5.784
A48	0.743	1.302	2.508	1.439	C57	5.18	5.63	6.695	5.806
A49	0.767	1.326	2.599	1.464	C58	5.209	5.65	6.706	5.826
A5	5.14	5.47	6.129	5.513	C59	5.224	5.673	6.714	5.845
A50	0.789	1.342	2.657	1.492	C6	4.948	5.178	6.008	5.294

A51	0.854	1.408	2.765	1.606	C60	5.25	5.692	6.736	5.866
A52	0.756	1.306	2.506	1.442	C7	4.894	5.132	5.991	5.257
A53	0.771	1.324	2.492	1.441	C8	4.864	5.111	5.981	5.237
A54	0.768	1.349	2.449	1.449	C9	4.823	5.08	5.97	5.212
A55	0.78	1.377	2.494	1.467	H1	4.985	5.31	5.821	5.349
A56	0.777	1.417	2.526	1.498	H2	5.153	5.41	6.009	5.474
A57	0.799	1.455	2.59	1.549	H3	5.065	5.355	5.917	5.404
A58	0.831	1.528	2.676	1.622	H4	5.205	5.424	6.061	5.518
A59	0.879	1.643	2.857	1.745	H5	5.121	5.388	6.002	5.454
A6	5.058	5.452	6.133	5.468	H6	5.163	5.393	6.048	5.477
A60	1.065	1.954	3.225	2.06	H7	5.144	5.368	6.066	5.463
A61	1.475	2.523	3.733	2.572	H8	5.136	5.357	6.072	5.455
A62	2.586	3.653	4.462	3.627	H9	5.193	5.401	6.098	5.497
A7	5.019	5.458	6.141	5.47	W1	5.241	5.418	6.132	5.525
A8	4.888	5.418	6.137	5.415	W10	5.318	5.534	6.408	5.676
A9	4.781	5.437	6.154	5.408	W11	5.305	5.526	6.409	5.672
C1	5.114	5.315	6.069	5.427	W12	5.286	5.523	6.409	5.666
C10	4.761	4.995	5.935	5.149	W13	5.261	5.517	6.409	5.653
C11	4.733	4.974	5.931	5.117	W2	5.249	5.412	6.162	5.535
C12	4.722	4.962	5.924	5.108	W3	5.268	5.423	6.186	5.558
C13	4.709	4.946	5.918	5.103	W4	5.276	5.444	6.217	5.578
C14	4.729	4.964	5.934	5.123	W5	5.285	5.469	6.261	5.601
C15	4.737	4.991	5.955	5.15	W6	5.304	5.497	6.314	5.626
C16	4.77	5.029	5.991	5.188	W7	5.331	5.516	6.36	5.655
C17	4.792	5.074	6.033	5.225	W8	5.329	5.524	6.381	5.666
C18	4.816	5.102	6.061	5.256	W9	5.327	5.533	6.399	5.672
C19	4.826	5.114	6.1	5.276					

Table H-7. TSP (50-48), 2022 Condition, Low Flow, Actual Loads, Bottom Layer DO, July

Segment	10%	50%	90%	Mean	Segment	10%	50%	90%	Mean
A1	5.122	5.297	5.448	5.29	C2	4.941	5.115	5.208	5.093
A10	4.788	5.341	5.75	5.294	C20	4.716	4.933	5.184	4.943
A11	4.771	5.373	5.799	5.322	C21	4.73	4.94	5.19	4.957
A12	4.791	5.364	5.789	5.33	C22	4.743	4.95	5.196	4.964
A13	4.736	5.308	5.742	5.268	C23	4.75	4.949	5.201	4.97
A14	4.751	5.293	5.714	5.262	C24	4.78	4.965	5.214	4.985
A15	4.773	5.302	5.692	5.266	C25	4.802	4.97	5.228	5.001
A16	4.761	5.287	5.657	5.253	C26	4.817	4.992	5.251	5.017
A17	4.791	5.275	5.632	5.249	C27	4.824	4.998	5.258	5.024
A18	4.82	5.259	5.631	5.245	C28	4.829	5.006	5.254	5.029
A19	4.797	5.239	5.584	5.214	C29	4.829	5.016	5.272	5.034
A2	5.073	5.295	5.488	5.29	C3	4.924	5.058	5.202	5.063
A20	4.742	5.195	5.561	5.177	C30	4.846	5.034	5.292	5.053
A21	4.657	5.153	5.557	5.132	C31	4.853	5.042	5.304	5.065
A23	4.528	5.109	5.575	5.078	C32	4.861	5.052	5.304	5.074
A24	4.4	5.038	5.535	4.997	C33	4.868	5.065	5.315	5.079
A25	4.323	4.991	5.513	4.944	C34	4.877	5.07	5.322	5.086
A26	4.218	4.906	5.46	4.871	C35	4.877	5.084	5.328	5.092
A27	4.107	4.812	5.4	4.783	C36	4.918	5.131	5.344	5.13
A28	3.993	4.712	5.334	4.688	C37	4.857	5.072	5.32	5.083
A29	3.873	4.614	5.272	4.598	C38	4.82	5.081	5.321	5.077
A3	5.036	5.22	5.471	5.236	C39	4.824	5.118	5.323	5.088
A30	3.809	4.546	5.227	4.526	C4	4.89	5.024	5.186	5.035
A31	3.721	4.465	5.171	4.456	C40	4.838	5.127	5.326	5.096
A32	3.606	4.364	5.099	4.37	C41	4.866	5.14	5.346	5.114
A33	3.469	4.267	5.031	4.269	C42	4.889	5.149	5.351	5.126
A34	3.255	4.153	4.947	4.146	C43	4.907	5.158	5.356	5.141
A35	3.026	4.01	4.888	4.009	C44	4.927	5.174	5.361	5.157
A36	2.823	3.911	4.829	3.895	C45	4.945	5.187	5.374	5.173
A37	2.359	3.619	4.636	3.567	C46	4.95	5.198	5.39	5.184
A38	2.002	3.239	4.257	3.221	C47	4.967	5.204	5.402	5.195
A39	1.639	2.876	3.967	2.885	C48	4.981	5.212	5.425	5.21
A4	5.029	5.235	5.537	5.262	C49	4.989	5.231	5.445	5.224
A40	1.377	2.612	3.634	2.594	C5	4.884	5.017	5.183	5.028
A41	1.169	2.276	3.323	2.259	C50	4.999	5.233	5.46	5.233
A42	0.975	1.844	2.867	1.895	C51	5.005	5.241	5.481	5.243
A43	0.922	1.496	2.311	1.578	C52	5.01	5.255	5.498	5.253
A44	0.864	1.401	2.139	1.46	C53	5.013	5.263	5.515	5.262
A45	0.856	1.432	2.123	1.465	C54	5.019	5.272	5.529	5.273
A46	0.855	1.405	2.138	1.458	C55	5.03	5.277	5.539	5.283
A47	0.862	1.375	2.081	1.424	C56	5.039	5.287	5.555	5.295
A48	0.846	1.327	2.004	1.379	C57	5.054	5.305	5.573	5.311
A49	0.833	1.291	1.932	1.34	C58	5.061	5.318	5.591	5.327

A5	5.071	5.322	5.617	5.332	C59	5.076	5.329	5.603	5.339
A50	0.835	1.271	1.858	1.306	C6	4.852	4.989	5.167	5.002
A51	0.871	1.271	1.9	1.34	C60	5.093	5.345	5.61	5.351
A52	0.701	1.085	1.662	1.146	C7	4.811	4.952	5.125	4.964
A53	0.682	1.021	1.581	1.085	C8	4.796	4.939	5.115	4.953
A54	0.655	0.974	1.47	1.037	C9	4.734	4.893	5.074	4.903
A55	0.655	0.958	1.359	0.992	H1	4.75	5.036	5.253	5.004
A56	0.643	0.916	1.253	0.949	H2	4.949	5.159	5.345	5.146
A57	0.647	0.891	1.206	0.917	H3	4.844	5.087	5.3	5.067
A58	0.646	0.87	1.178	0.902	H4	5.034	5.211	5.342	5.194
A59	0.685	0.864	1.16	0.892	H5	4.936	5.153	5.312	5.132
A6	4.956	5.349	5.646	5.333	H6	5.004	5.188	5.304	5.166
A60	0.679	0.95	1.304	0.968	H7	5.024	5.187	5.291	5.172
A61	0	0.869	1.608	0.803	H8	5.026	5.177	5.281	5.166
A62	0.612	1.415	2.489	1.469	H9	5.054	5.217	5.322	5.198
A7	4.941	5.342	5.662	5.321	W1	5.078	5.24	5.352	5.225
A8	4.622	5.269	5.619	5.207	W10	5.311	5.568	5.716	5.543
A9	4.784	5.284	5.708	5.265	W11	5.305	5.577	5.73	5.55
C1	4.941	5.114	5.224	5.098	W12	5.274	5.567	5.727	5.534
C10	4.66	4.82	5.015	4.834	W13	5.218	5.558	5.716	5.511
C11	4.57	4.721	4.928	4.74	W2	5.083	5.244	5.36	5.229
C12	4.551	4.693	4.903	4.713	W3	5.135	5.302	5.476	5.31
C13	4.487	4.631	4.84	4.65	W4	5.18	5.346	5.522	5.35
C14	4.508	4.651	4.866	4.67	W5	5.214	5.384	5.542	5.382
C15	4.544	4.699	4.927	4.725	W6	5.241	5.423	5.558	5.412
C16	4.604	4.784	5.018	4.806	W7	5.295	5.489	5.631	5.473
C17	4.652	4.861	5.12	4.874	W8	5.303	5.519	5.665	5.5
C18	4.708	4.911	5.155	4.925	W9	5.287	5.526	5.676	5.505
C19	4.72	4.932	5.177	4.94					

Table H-8. TSP (50-48), 2022 Condition, Low Flow, Actual Loads, Bottom Layer DO, August

Segment	10%	50%	90%	Mean	Segment	10%	50%	90%	Mean
A1	4.931	5.133	5.412	5.159	C2	4.702	4.882	5.155	4.907
A10	4.8	5.293	5.549	5.234	C20	4.575	4.874	5.185	4.871
A11	4.85	5.313	5.611	5.272	C21	4.586	4.885	5.207	4.884
A12	4.926	5.329	5.626	5.3	C22	4.604	4.896	5.213	4.894
A13	4.865	5.288	5.599	5.254	C23	4.603	4.91	5.215	4.9
A14	4.855	5.278	5.593	5.244	C24	4.623	4.926	5.226	4.915
A15	4.899	5.307	5.566	5.267	C25	4.641	4.939	5.235	4.931
A16	4.907	5.318	5.57	5.279	C26	4.655	4.941	5.236	4.949
A17	4.92	5.32	5.55	5.287	C27	4.68	4.953	5.239	4.957
A18	4.969	5.327	5.571	5.296	C28	4.684	4.958	5.253	4.965
A19	4.947	5.308	5.547	5.277	C29	4.69	4.96	5.246	4.969
A2	4.843	5.158	5.45	5.158	C3	4.739	4.928	5.165	4.941
A20	4.913	5.276	5.543	5.251	C30	4.712	4.984	5.265	4.991
A21	4.887	5.255	5.535	5.226	C31	4.732	4.992	5.27	5.004
A23	4.757	5.263	5.57	5.2	C32	4.742	4.994	5.274	5.014
A24	4.667	5.215	5.548	5.137	C33	4.756	4.995	5.278	5.02
A25	4.575	5.175	5.537	5.095	C34	4.772	4.998	5.293	5.026
A26	4.458	5.11	5.497	5.033	C35	4.785	5.003	5.305	5.032
A27	4.329	5.038	5.471	4.961	C36	4.834	5.041	5.325	5.067
A28	4.192	4.947	5.436	4.883	C37	4.783	4.999	5.305	5.024
A29	4.058	4.855	5.394	4.807	C38	4.751	5.003	5.291	5.018
A3	4.769	5.132	5.397	5.113	C39	4.782	5.013	5.313	5.032
A30	3.952	4.788	5.37	4.745	C4	4.687	4.915	5.141	4.914
A31	3.869	4.725	5.339	4.684	C40	4.804	5.013	5.346	5.044
A32	3.762	4.651	5.277	4.607	C41	4.831	5.033	5.384	5.07
A33	3.645	4.559	5.227	4.52	C42	4.84	5.054	5.411	5.088
A34	3.452	4.452	5.171	4.409	C43	4.86	5.068	5.426	5.106
A35	3.261	4.3	5.127	4.279	C44	4.885	5.081	5.456	5.125
A36	3.106	4.205	5.093	4.178	C45	4.898	5.096	5.471	5.143
A37	2.676	3.93	4.921	3.881	C46	4.914	5.107	5.477	5.156
A38	2.294	3.654	4.618	3.593	C47	4.923	5.12	5.498	5.171
A39	1.904	3.309	4.328	3.267	C48	4.939	5.141	5.52	5.19
A4	4.766	5.173	5.442	5.134	C49	4.957	5.16	5.531	5.207
A40	1.742	3.031	4.032	2.995	C5	4.688	4.915	5.133	4.911
A41	1.552	2.786	3.707	2.709	C50	4.968	5.175	5.542	5.218
A42	1.212	2.373	3.234	2.301	C51	4.972	5.189	5.546	5.231
A43	0.856	1.925	2.595	1.847	C52	4.973	5.209	5.56	5.243
A44	0.895	1.745	2.238	1.646	C53	4.985	5.23	5.57	5.255
A45	0.873	1.841	2.347	1.731	C54	4.995	5.244	5.587	5.268
A46	0.873	1.781	2.437	1.742	C55	5.002	5.255	5.602	5.28
A47	0.857	1.703	2.467	1.697	C56	5.008	5.27	5.616	5.295
A48	0.848	1.625	2.387	1.634	C57	5.02	5.296	5.637	5.315
A49	0.842	1.564	2.293	1.575	C58	5.034	5.312	5.657	5.333
A5	4.841	5.242	5.515	5.202	C59	5.052	5.328	5.668	5.348
A50	0.844	1.501	2.205	1.521	C6	4.656	4.902	5.11	4.888
A51	0.912	1.493	2.205	1.527	C60	5.072	5.349	5.689	5.366
A52	0.719	1.271	1.959	1.316	C7	4.619	4.876	5.066	4.853
A53	0.688	1.194	1.815	1.234	C8	4.63	4.872	5.065	4.847
A54	0.678	1.146	1.706	1.169	C9	4.557	4.824	5.029	4.803
A55	0.666	1.106	1.571	1.108	H1	4.538	4.878	5.236	4.889
A56	0.653	1.041	1.459	1.049	H2	4.742	5.01	5.343	5.025
A57	0.647	0.994	1.366	0.999	H3	4.637	4.933	5.291	4.951
A58	0.651	0.932	1.302	0.961	H4	4.84	5.033	5.347	5.068
A59	0.681	0.878	1.248	0.941	H5	4.762	4.995	5.305	5.013
A6	4.808	5.274	5.534	5.214	H6	4.84	5	5.311	5.04
A60	0.646	0.878	1.437	0.972	H7	4.873	4.989	5.291	5.044
A61	0.035	0.883	1.929	0.95	H8	4.872	4.983	5.277	5.037
A62	0.422	1.117	2.855	1.422	H9	4.885	5.021	5.321	5.07
A7	4.78	5.27	5.532	5.208	W1	4.883	5.052	5.336	5.09
A8	4.654	5.227	5.467	5.13	W10	5.096	5.28	5.483	5.284
A9	4.743	5.268	5.481	5.197	W11	5.089	5.271	5.48	5.277
C1	4.738	4.896	5.189	4.941	W12	5.06	5.242	5.458	5.251
C10	4.477	4.755	4.978	4.738	W13	5.009	5.223	5.44	5.221

C11	4.378	4.674	4.902	4.648	W2	4.894	5.064	5.321	5.09
C12	4.361	4.643	4.88	4.625	W3	4.958	5.145	5.372	5.161
C13	4.29	4.58	4.824	4.563	W4	5.008	5.182	5.396	5.198
C14	4.316	4.6	4.856	4.589	W5	5.046	5.202	5.411	5.225
C15	4.361	4.647	4.932	4.648	W6	5.076	5.226	5.43	5.242
C16	4.431	4.73	5.029	4.729	W7	5.097	5.268	5.465	5.28
C17	4.491	4.792	5.095	4.8	W8	5.097	5.273	5.477	5.284
C18	4.548	4.848	5.146	4.852	W9	5.075	5.267	5.465	5.267
C19	4.567	4.871	5.157	4.868					

Table H-9. TSP (50-48), 2022 Condition, Low Flow, Actual Loads, Bottom Layer DO, September

Segment	10%	50%	90%	Mean	Segment	10%	50%	90%	Mean
A1	5.124	5.328	6.025	5.428	C2	4.86	5.051	5.896	5.19
A10	4.132	5.102	5.986	5.033	C20	4.734	5.052	5.988	5.2
A11	3.998	5.117	5.997	5.008	C21	4.75	5.069	6.024	5.22
A12	3.905	5.142	5.963	4.981	C22	4.76	5.078	6.029	5.232
A13	3.72	5.04	5.922	4.897	C23	4.769	5.076	6.04	5.243
A14	3.742	5.018	5.891	4.88	C24	4.79	5.101	6.058	5.263
A15	3.723	5.005	5.903	4.866	C25	4.812	5.128	6.075	5.288
A16	3.684	4.952	5.882	4.831	C26	4.817	5.154	6.106	5.311
A17	3.697	4.905	5.871	4.812	C27	4.823	5.165	6.133	5.323
A18	3.692	4.885	5.843	4.791	C28	4.837	5.178	6.141	5.337
A19	3.611	4.788	5.809	4.724	C29	4.841	5.204	6.145	5.352
A2	5.066	5.349	5.962	5.413	C3	4.886	5.065	5.877	5.184
A20	3.53	4.738	5.761	4.649	C30	4.865	5.232	6.19	5.381
A21	3.373	4.634	5.704	4.564	C31	4.876	5.258	6.243	5.4
A23	3.106	4.499	5.657	4.477	C32	4.89	5.273	6.265	5.414
A24	2.958	4.46	5.53	4.368	C33	4.901	5.284	6.275	5.426
A25	2.8	4.354	5.505	4.294	C34	4.903	5.292	6.296	5.436
A26	2.693	4.281	5.463	4.205	C35	4.907	5.297	6.303	5.447
A27	2.543	4.182	5.405	4.086	C36	4.944	5.329	6.317	5.474
A28	2.409	4.07	5.291	3.968	C37	4.891	5.309	6.362	5.455
A29	2.262	3.954	5.207	3.855	C38	4.89	5.311	6.405	5.473
A3	4.934	5.217	5.948	5.302	C39	4.911	5.315	6.446	5.493
A30	2.215	3.886	5.149	3.768	C4	4.848	5.028	5.859	5.149
A31	2.138	3.796	5.068	3.686	C40	4.945	5.321	6.453	5.509
A32	2.046	3.69	5.001	3.587	C41	4.983	5.338	6.479	5.535
A33	1.92	3.582	4.938	3.48	C42	4.993	5.347	6.498	5.552
A34	1.811	3.418	4.805	3.339	C43	5.012	5.366	6.514	5.567
A35	1.617	3.246	4.682	3.182	C44	5.031	5.39	6.53	5.584
A36	1.471	3.115	4.606	3.069	C45	5.044	5.409	6.556	5.602
A37	1.132	2.739	4.376	2.77	C46	5.056	5.431	6.566	5.617
A38	0.896	2.296	3.938	2.357	C47	5.058	5.446	6.575	5.632
A39	0.72	2.024	3.556	2.056	C48	5.077	5.468	6.586	5.654
A4	4.891	5.23	5.948	5.283	C49	5.085	5.5	6.597	5.672
A40	0.602	1.811	3.113	1.823	C5	4.83	5.022	5.869	5.142
A41	0.507	1.61	2.76	1.618	C50	5.078	5.511	6.599	5.683
A42	0.501	1.453	2.381	1.45	C51	5.091	5.531	6.586	5.696
A43	0.488	1.337	2.255	1.339	C52	5.098	5.54	6.592	5.711
A44	0.558	1.298	2.231	1.318	C53	5.102	5.554	6.604	5.725
A45	0.617	1.285	2.331	1.344	C54	5.11	5.57	6.625	5.741
A46	0.684	1.306	2.398	1.378	C55	5.118	5.585	6.643	5.755

A47	0.716	1.324	2.416	1.41	C56	5.148	5.6	6.663	5.773
A48	0.736	1.309	2.494	1.433	C57	5.173	5.621	6.683	5.796
A49	0.766	1.321	2.585	1.457	C58	5.193	5.641	6.691	5.816
A5	4.868	5.303	5.997	5.313	C59	5.208	5.662	6.704	5.834
A50	0.782	1.34	2.652	1.484	C6	4.788	4.999	5.858	5.116
A51	0.852	1.407	2.778	1.602	C60	5.23	5.684	6.726	5.855
A52	0.744	1.285	2.499	1.433	C7	4.739	4.96	5.833	5.081
A53	0.765	1.306	2.485	1.433	C8	4.728	4.954	5.837	5.073
A54	0.757	1.338	2.443	1.441	C9	4.67	4.91	5.817	5.039
A55	0.772	1.358	2.488	1.457	H1	4.836	5.179	5.701	5.218
A56	0.769	1.393	2.518	1.486	H2	5.014	5.261	5.887	5.335
A57	0.784	1.445	2.577	1.534	H3	4.931	5.22	5.814	5.276
A58	0.802	1.506	2.659	1.6	H4	5.068	5.285	5.94	5.366
A59	0.845	1.612	2.829	1.71	H5	4.982	5.256	5.876	5.329
A6	4.728	5.291	6.022	5.266	H6	5.022	5.263	5.903	5.344
A60	0.968	1.913	3.208	1.997	H7	5.018	5.226	5.933	5.328
A61	1.073	2.367	3.714	2.351	H8	5.004	5.206	5.929	5.311
A62	2.031	3.429	4.43	3.257	H9	5.044	5.262	5.954	5.357
A7	4.593	5.238	6.017	5.209	W1	5.08	5.254	5.996	5.363
A8	4.268	5.077	5.942	5.036	W10	5.224	5.428	6.309	5.578
A9	4.275	5.15	5.977	5.06	W11	5.211	5.426	6.311	5.574
C1	4.914	5.095	5.881	5.227	W12	5.161	5.382	6.302	5.549
C10	4.611	4.844	5.777	4.982	W13	5.084	5.37	6.285	5.519
C11	4.529	4.77	5.744	4.909	W2	5.083	5.238	5.996	5.356
C12	4.516	4.756	5.739	4.898	W3	5.117	5.283	6.055	5.42
C13	4.454	4.696	5.706	4.845	W4	5.145	5.317	6.089	5.453
C14	4.487	4.727	5.738	4.88	W5	5.17	5.344	6.144	5.483
C15	4.528	4.787	5.773	4.949	W6	5.192	5.364	6.196	5.51
C16	4.592	4.87	5.842	5.035	W7	5.229	5.409	6.251	5.553
C17	4.641	4.968	5.904	5.115	W8	5.23	5.419	6.272	5.565
C18	4.693	5.021	5.983	5.172	W9	5.221	5.405	6.288	5.56
C19	4.727	5.039	5.985	5.193	NA	3.985	4.317	4.902	4.372

Table H-10. TSP (50-48), 2022 Condition, Low Flow, Actual Loads, Water Column Averaged DO, July

Segment	10%	50%	90%	Mean	Segment	10%	50%	90%	Mean
A1	5.266	5.431	5.553	5.422	C2	5.095	5.263	5.347	5.25
A10	5.282	5.55	5.895	5.568	C20	4.833	5.006	5.211	5.014
A11	5.197	5.538	5.88	5.543	C21	4.834	5.007	5.213	5.019
A12	5.182	5.53	5.87	5.532	C22	4.839	5.017	5.222	5.025
A13	5.138	5.489	5.839	5.493	C23	4.838	5.021	5.231	5.031
A14	5.099	5.49	5.816	5.477	C24	4.846	5.026	5.236	5.039
A15	5.042	5.464	5.797	5.443	C25	4.853	5.027	5.254	5.048
A16	4.999	5.429	5.758	5.404	C26	4.859	5.034	5.266	5.055
A17	4.987	5.398	5.735	5.379	C27	4.863	5.052	5.274	5.061
A18	4.951	5.368	5.71	5.347	C28	4.871	5.061	5.28	5.07
A19	4.878	5.321	5.677	5.301	C29	4.878	5.068	5.294	5.077
A2	5.295	5.442	5.584	5.441	C3	5.033	5.178	5.309	5.175
A20	4.807	5.279	5.673	5.258	C30	4.884	5.074	5.311	5.088
A21	4.726	5.221	5.652	5.195	C31	4.896	5.091	5.318	5.096
A23	4.576	5.137	5.619	5.106	C32	4.907	5.101	5.324	5.105
A24	4.424	5.056	5.574	5.022	C33	4.911	5.11	5.328	5.111
A25	4.341	5	5.544	4.963	C34	4.92	5.111	5.332	5.118
A26	4.241	4.918	5.489	4.892	C35	4.926	5.118	5.336	5.126
A27	4.128	4.818	5.415	4.795	C36	4.946	5.154	5.352	5.152
A28	4.013	4.723	5.36	4.701	C37	4.929	5.137	5.335	5.133
A29	3.891	4.618	5.286	4.608	C38	4.932	5.145	5.342	5.135
A3	5.28	5.429	5.586	5.431	C39	4.94	5.151	5.344	5.145
A30	3.827	4.549	5.23	4.533	C4	4.992	5.141	5.278	5.141
A31	3.734	4.47	5.177	4.463	C40	4.95	5.162	5.349	5.152
A32	3.616	4.369	5.108	4.377	C41	4.955	5.173	5.359	5.162
A33	3.485	4.277	5.034	4.283	C42	4.964	5.186	5.364	5.173
A34	3.285	4.171	4.962	4.161	C43	4.975	5.196	5.369	5.182
A35	3.065	4.026	4.898	4.02	C44	4.983	5.205	5.385	5.192
A36	2.898	3.935	4.837	3.925	C45	4.991	5.212	5.392	5.202
A37	2.566	3.664	4.656	3.651	C46	5	5.214	5.397	5.21
A38	2.013	3.218	4.298	3.221	C47	5.008	5.219	5.41	5.22
A39	1.667	2.808	3.995	2.875	C48	5.013	5.23	5.433	5.232
A4	5.286	5.45	5.641	5.456	C49	5.018	5.242	5.456	5.243
A40	1.472	2.559	3.652	2.591	C5	4.98	5.129	5.274	5.13
A41	1.267	2.309	3.268	2.308	C50	5.024	5.252	5.469	5.251
A42	1.106	2.051	2.896	2.032	C51	5.017	5.26	5.487	5.257
A43	1.014	1.806	2.547	1.797	C52	5.021	5.272	5.508	5.266
A44	0.932	1.631	2.358	1.641	C53	5.028	5.277	5.528	5.276
A45	0.906	1.516	2.261	1.557	C54	5.035	5.286	5.543	5.287
A46	0.878	1.437	2.183	1.489	C55	5.04	5.293	5.555	5.297
A47	0.871	1.385	2.102	1.438	C56	5.053	5.303	5.568	5.308
A48	0.861	1.34	2.008	1.39	C57	5.066	5.32	5.585	5.324
A49	0.851	1.302	1.936	1.351	C58	5.076	5.337	5.598	5.338
A5	5.301	5.483	5.712	5.496	C59	5.092	5.35	5.611	5.35
A50	0.854	1.277	1.864	1.317	C6	4.953	5.109	5.262	5.109
A51	0.876	1.276	1.907	1.347	C60	5.117	5.363	5.621	5.364
A52	0.717	1.096	1.68	1.157	C7	4.915	5.068	5.225	5.07
A53	0.692	1.028	1.594	1.096	C8	4.886	5.056	5.225	5.056
A54	0.672	0.989	1.498	1.048	C9	4.853	5.032	5.207	5.03
A55	0.664	0.967	1.388	1.004	H1	4.848	5.129	5.329	5.094
A56	0.655	0.927	1.285	0.965	H2	5.036	5.25	5.423	5.235
A57	0.657	0.907	1.229	0.94	H3	4.928	5.173	5.357	5.148
A58	0.669	0.91	1.208	0.934	H4	5.133	5.307	5.423	5.291
A59	0.705	0.926	1.223	0.954	H5	5.015	5.224	5.369	5.201
A6	5.288	5.484	5.744	5.505	H6	5.083	5.253	5.362	5.233
A60	0.798	1.047	1.478	1.103	H7	5.08	5.254	5.358	5.235
A61	1.038	1.355	1.964	1.428	H8	5.089	5.254	5.353	5.235
A62	1.919	2.371	3.121	2.444	H9	5.116	5.277	5.379	5.261
A7	5.305	5.508	5.802	5.538	W1	5.156	5.311	5.415	5.295
A8	5.263	5.506	5.814	5.531	W10	5.324	5.594	5.726	5.565
A9	5.305	5.538	5.879	5.565	W11	5.317	5.603	5.748	5.571

C1	5.086	5.252	5.345	5.235	W12	5.308	5.606	5.761	5.574
C10	4.782	4.962	5.133	4.962	W13	5.289	5.614	5.761	5.571
C11	4.746	4.906	5.086	4.919	W2	5.163	5.322	5.435	5.31
C12	4.733	4.884	5.071	4.898	W3	5.193	5.353	5.493	5.35
C13	4.722	4.869	5.06	4.884	W4	5.222	5.377	5.53	5.376
C14	4.74	4.878	5.072	4.893	W5	5.246	5.413	5.55	5.405
C15	4.746	4.886	5.098	4.911	W6	5.275	5.452	5.586	5.442
C16	4.777	4.916	5.132	4.943	W7	5.311	5.504	5.645	5.491
C17	4.788	4.956	5.164	4.97	W8	5.324	5.544	5.683	5.522
C18	4.812	4.977	5.19	4.994	W9	5.327	5.574	5.706	5.546
C19	4.822	4.998	5.205	5.007					

Table H-11. TSP (50-48), 2022 Condition, Low Flow, Actual Loads, Water Column Averaged DO, August

Segment	10%	50%	90%	Mean	Segment	10%	50%	90%	Mean
A1	5.114	5.239	5.52	5.287	C2	4.883	5.033	5.284	5.065
A10	5.208	5.5	5.752	5.491	C20	4.7	4.938	5.219	4.946
A11	5.191	5.497	5.745	5.488	C21	4.703	4.944	5.236	4.951
A12	5.239	5.512	5.746	5.5	C22	4.704	4.952	5.241	4.958
A13	5.21	5.493	5.731	5.479	C23	4.712	4.957	5.246	4.965
A14	5.189	5.494	5.716	5.475	C24	4.715	4.969	5.257	4.974
A15	5.158	5.469	5.706	5.458	C25	4.728	4.975	5.266	4.984
A16	5.136	5.449	5.683	5.437	C26	4.734	4.979	5.279	4.992
A17	5.128	5.438	5.661	5.424	C27	4.741	4.985	5.285	4.998
A18	5.111	5.426	5.651	5.402	C28	4.752	4.991	5.292	5.009
A19	5.1	5.392	5.618	5.368	C29	4.762	4.999	5.296	5.018
A2	5.126	5.264	5.544	5.307	C3	4.879	5.033	5.259	5.055
A20	5.052	5.362	5.616	5.337	C30	4.777	5.01	5.305	5.031
A21	4.952	5.321	5.615	5.293	C31	4.786	5.021	5.311	5.04
A23	4.796	5.285	5.6	5.228	C32	4.795	5.025	5.329	5.049
A24	4.682	5.24	5.575	5.159	C33	4.798	5.028	5.332	5.056
A25	4.585	5.189	5.555	5.111	C34	4.816	5.031	5.344	5.064
A26	4.479	5.127	5.527	5.053	C35	4.833	5.036	5.352	5.072
A27	4.337	5.045	5.494	4.974	C36	4.869	5.068	5.371	5.099
A28	4.2	4.954	5.461	4.895	C37	4.851	5.044	5.356	5.083
A29	4.069	4.862	5.405	4.816	C38	4.859	5.044	5.356	5.086
A3	5.093	5.26	5.532	5.295	C39	4.876	5.057	5.388	5.1
A30	3.959	4.789	5.375	4.752	C4	4.838	5.017	5.232	5.024
A31	3.873	4.73	5.349	4.691	C40	4.888	5.065	5.403	5.11
A32	3.767	4.65	5.291	4.615	C41	4.903	5.074	5.43	5.123
A33	3.653	4.571	5.226	4.531	C42	4.918	5.085	5.45	5.138
A34	3.464	4.466	5.174	4.422	C43	4.923	5.095	5.465	5.149
A35	3.267	4.331	5.124	4.292	C44	4.932	5.11	5.481	5.162
A36	3.13	4.256	5.103	4.206	C45	4.94	5.123	5.492	5.175
A37	2.743	4.027	4.923	3.958	C46	4.952	5.129	5.496	5.186
A38	2.283	3.639	4.633	3.579	C47	4.952	5.14	5.509	5.199
A39	1.845	3.303	4.345	3.256	C48	4.962	5.159	5.545	5.214
A4	5.098	5.288	5.555	5.317	C49	4.973	5.175	5.557	5.228
A40	1.661	3.02	4.041	2.99	C5	4.827	5.017	5.223	5.016
A41	1.465	2.785	3.7	2.724	C50	4.986	5.187	5.561	5.238
A42	1.24	2.556	3.319	2.446	C51	4.985	5.2	5.565	5.246
A43	1.092	2.285	2.984	2.173	C52	4.993	5.217	5.586	5.257
A44	0.957	2.081	2.697	1.982	C53	4.999	5.235	5.591	5.269
A45	0.902	1.96	2.653	1.884	C54	5.007	5.253	5.603	5.282
A46	0.888	1.815	2.605	1.79	C55	5.018	5.269	5.618	5.294
A47	0.868	1.716	2.522	1.716	C56	5.025	5.283	5.628	5.308
A48	0.853	1.63	2.395	1.645	C57	5.039	5.304	5.648	5.327
A49	0.847	1.574	2.304	1.585	C58	5.053	5.32	5.665	5.344
A5	5.136	5.327	5.598	5.356	C59	5.071	5.336	5.675	5.359
A50	0.85	1.514	2.217	1.531	C6	4.8	5.007	5.208	4.998
A51	0.919	1.503	2.213	1.534	C60	5.095	5.358	5.696	5.377
A52	0.726	1.276	1.973	1.326	C7	4.754	4.98	5.173	4.963
A53	0.696	1.205	1.819	1.244	C8	4.735	4.967	5.157	4.952
A54	0.689	1.154	1.713	1.179	C9	4.697	4.935	5.145	4.931
A55	0.679	1.111	1.588	1.119	H1	4.614	4.984	5.302	4.977
A56	0.663	1.057	1.475	1.064	H2	4.838	5.095	5.403	5.111
A57	0.667	1.016	1.398	1.021	H3	4.707	5.033	5.345	5.03
A58	0.68	0.976	1.327	0.996	H4	4.962	5.13	5.416	5.163
A59	0.708	0.964	1.314	0.994	H5	4.817	5.064	5.363	5.08

A6	5.121	5.364	5.636	5.372	H6	4.919	5.067	5.365	5.107
A60	0.782	1.017	1.49	1.101	H7	4.951	5.056	5.346	5.108
A61	0.952	1.251	2.039	1.389	H8	4.958	5.05	5.341	5.108
A62	1.694	2.174	3.214	2.332	H9	4.961	5.087	5.375	5.132
A7	5.16	5.401	5.663	5.408	W1	4.99	5.11	5.388	5.159
A8	5.147	5.428	5.679	5.42	W10	5.115	5.305	5.499	5.306
A9	5.203	5.48	5.726	5.47	W11	5.107	5.296	5.495	5.299
C1	4.909	5.035	5.312	5.081	W12	5.101	5.285	5.493	5.29
C10	4.628	4.874	5.101	4.868	W13	5.077	5.278	5.475	5.277
C11	4.596	4.839	5.061	4.829	W2	4.997	5.125	5.385	5.168
C12	4.58	4.819	5.051	4.812	W3	5.031	5.169	5.404	5.202
C13	4.574	4.802	5.048	4.8	W4	5.056	5.194	5.415	5.224
C14	4.587	4.812	5.062	4.813	W5	5.087	5.213	5.435	5.247
C15	4.597	4.835	5.081	4.834	W6	5.107	5.248	5.45	5.272
C16	4.625	4.866	5.119	4.868	W7	5.116	5.285	5.484	5.298
C17	4.638	4.89	5.159	4.897	W8	5.119	5.297	5.495	5.305
C18	4.669	4.916	5.184	4.923	W9	5.115	5.302	5.492	5.306
C19	4.685	4.929	5.198	4.938					

Table H-12. TSP (50-48), 2022 Condition, Low Flow, Actual Loads, Water Column Averaged DO, September

Segment	10%	50%	90%	Mean	Segment	10%	50%	90%	Mean
A1	5.25	5.445	6.095	5.543	C2	5.003	5.195	5.98	5.316
A10	4.65	5.403	6.136	5.345	C20	4.82	5.115	6.09	5.276
A11	4.471	5.34	6.111	5.256	C21	4.831	5.123	6.102	5.287
A12	4.329	5.277	6.085	5.199	C22	4.839	5.134	6.101	5.297
A13	4.246	5.208	6.06	5.127	C23	4.85	5.142	6.114	5.309
A14	4.193	5.169	6.033	5.093	C24	4.857	5.16	6.11	5.322
A15	4.059	5.112	6.01	5.037	C25	4.865	5.184	6.113	5.338
A16	3.928	5.038	5.977	4.977	C26	4.868	5.19	6.112	5.35
A17	3.882	4.975	5.945	4.935	C27	4.868	5.204	6.138	5.361
A18	3.779	4.929	5.913	4.881	C28	4.875	5.225	6.175	5.377
A19	3.687	4.86	5.866	4.805	C29	4.889	5.241	6.2	5.393
A2	5.228	5.436	6.071	5.525	C3	4.983	5.182	5.952	5.291
A20	3.556	4.769	5.835	4.729	C30	4.906	5.258	6.23	5.413
A21	3.391	4.679	5.765	4.637	C31	4.92	5.275	6.26	5.428
A23	3.143	4.573	5.664	4.507	C32	4.931	5.287	6.289	5.441
A24	2.953	4.473	5.557	4.394	C33	4.939	5.298	6.311	5.452
A25	2.824	4.406	5.538	4.314	C34	4.949	5.307	6.334	5.463
A26	2.701	4.308	5.491	4.221	C35	4.957	5.311	6.354	5.474
A27	2.559	4.201	5.406	4.097	C36	4.974	5.337	6.37	5.496
A28	2.411	4.088	5.309	3.979	C37	4.971	5.323	6.391	5.493
A29	2.271	3.96	5.225	3.864	C38	4.976	5.325	6.422	5.507
A3	5.181	5.412	6.069	5.488	C39	4.986	5.334	6.451	5.524
A30	2.223	3.89	5.156	3.776	C4	4.94	5.143	5.931	5.255
A31	2.147	3.804	5.076	3.694	C40	5	5.342	6.465	5.54
A32	2.054	3.697	4.986	3.593	C41	5.019	5.354	6.499	5.56
A33	1.958	3.614	4.891	3.489	C42	5.034	5.378	6.52	5.577
A34	1.834	3.432	4.786	3.349	C43	5.049	5.4	6.526	5.591
A35	1.642	3.244	4.664	3.188	C44	5.066	5.417	6.556	5.607
A36	1.544	3.116	4.594	3.083	C45	5.079	5.442	6.567	5.622
A37	1.273	2.774	4.35	2.802	C46	5.083	5.455	6.58	5.636
A38	0.93	2.324	3.959	2.368	C47	5.088	5.468	6.585	5.65
A39	0.763	2.028	3.525	2.069	C48	5.095	5.492	6.597	5.669
A4	5.141	5.428	6.072	5.481	C49	5.103	5.506	6.605	5.686
A40	0.638	1.828	3.098	1.845	C5	4.922	5.134	5.931	5.244
A41	0.573	1.659	2.709	1.648	C50	5.101	5.523	6.612	5.697
A42	0.556	1.483	2.407	1.49	C51	5.099	5.54	6.605	5.707
A43	0.572	1.39	2.293	1.387	C52	5.111	5.552	6.605	5.721
A44	0.599	1.332	2.269	1.356	C53	5.119	5.567	6.616	5.735
A45	0.652	1.302	2.357	1.371	C54	5.122	5.583	6.632	5.751
A46	0.694	1.323	2.404	1.393	C55	5.135	5.597	6.646	5.765
A47	0.721	1.33	2.437	1.419	C56	5.152	5.609	6.665	5.782
A48	0.742	1.318	2.509	1.441	C57	5.182	5.629	6.69	5.805
A49	0.772	1.334	2.59	1.466	C58	5.209	5.649	6.702	5.825
A5	5.109	5.441	6.099	5.484	C59	5.222	5.669	6.712	5.843
A50	0.793	1.353	2.655	1.494	C6	4.889	5.109	5.925	5.223
A51	0.855	1.41	2.77	1.607	C60	5.242	5.69	6.731	5.864
A52	0.76	1.308	2.503	1.443	C7	4.839	5.071	5.912	5.185
A53	0.774	1.324	2.489	1.443	C8	4.814	5.058	5.912	5.177
A54	0.768	1.35	2.448	1.45	C9	4.794	5.041	5.913	5.166
A55	0.783	1.379	2.494	1.468	H1	4.959	5.265	5.781	5.309
A56	0.779	1.416	2.525	1.499	H2	5.111	5.36	5.958	5.428
A57	0.801	1.455	2.589	1.55	H3	5.02	5.299	5.855	5.354
A58	0.83	1.528	2.672	1.622	H4	5.154	5.366	5.992	5.459
A59	0.881	1.643	2.854	1.745	H5	5.053	5.319	5.929	5.392

A6	5.033	5.432	6.118	5.448	H6	5.087	5.315	5.964	5.401
A60	1.063	1.954	3.223	2.059	H7	5.064	5.288	5.975	5.383
A61	1.474	2.521	3.731	2.571	H8	5.055	5.276	5.977	5.371
A62	2.584	3.65	4.461	3.626	H9	5.104	5.322	5.998	5.412
A7	4.998	5.435	6.13	5.452	W1	5.146	5.325	6.027	5.43
A8	4.867	5.407	6.141	5.4	W10	5.242	5.459	6.324	5.599
A9	4.772	5.424	6.151	5.394	W11	5.234	5.455	6.329	5.597
C1	5.028	5.23	5.969	5.339	W12	5.219	5.446	6.331	5.591
C10	4.735	4.969	5.885	5.113	W13	5.189	5.443	6.33	5.579
C11	4.708	4.951	5.878	5.089	W2	5.153	5.313	6.056	5.431
C12	4.701	4.939	5.883	5.085	W3	5.171	5.328	6.085	5.46
C13	4.693	4.928	5.881	5.081	W4	5.184	5.347	6.11	5.48
C14	4.712	4.947	5.897	5.103	W5	5.194	5.375	6.153	5.505
C15	4.723	4.979	5.92	5.133	W6	5.216	5.407	6.212	5.535
C16	4.756	5.017	5.962	5.172	W7	5.242	5.433	6.263	5.568
C17	4.774	5.059	6.009	5.211	W8	5.249	5.442	6.286	5.584
C18	4.803	5.093	6.037	5.242	W9	5.252	5.457	6.311	5.593
C19	4.808	5.107	6.072	5.264					

Table H-13. Delta between 2022 without project and TSP (50-48), 2022 Condition, Low Flow, Actual Loads, Bottom Layer DO, March through October

Segment	10%	50%	90%	Mean	Segment	10%	50%	90%	Mean
A1	0.052	0.044	0.010	0.038	C20	0.010	0.009	0.009	0.011
A10	-0.002	0.009	-0.004	0.004	C21	0.013	0.014	0.008	0.011
A11	0.006	0.011	-0.004	0.006	C22	0.014	0.014	0.009	0.011
A12	-0.004	0.006	-0.004	0.004	C23	0.011	0.008	0.011	0.010
A13	-0.013	0.012	0.001	0.003	C24	0.012	0.010	0.013	0.011
A14	-0.008	0.006	0.007	0.003	C25	0.013	0.009	0.014	0.011
A15	-0.009	0.007	0.011	0.004	C26	0.009	0.016	0.014	0.010
A16	-0.003	0.011	0.006	0.005	C27	0.012	0.011	0.015	0.011
A17	0.006	0.010	0.008	0.004	C28	0.007	0.007	0.021	0.011
A18	0.001	0.009	0.005	0.004	C29	0.006	0.011	0.017	0.010
A19	0.012	0.004	-0.001	0.005	C3	0.079	0.076	0.051	0.074
A2	0.054	0.031	-0.034	0.023	C30	0.008	0.011	0.016	0.010
A20	0.008	0.007	0.006	0.005	C31	0.011	0.016	0.017	0.010
A21	0.009	0.004	-0.001	0.005	C32	0.011	0.018	0.016	0.010
A23	0.006	0.008	-0.010	0.004	C33	0.012	0.022	0.014	0.010
A24	0.001	0.002	-0.010	0.003	C34	0.010	0.017	0.014	0.010
A25	-0.001	0.006	-0.012	0.002	C35	0.014	0.018	0.017	0.011
A26	-0.008	0.002	0.003	0.002	C36	0.014	0.012	0.021	0.010
A27	-0.012	0.003	-0.007	0.000	C37	0.015	0.015	0.028	0.012
A28	-0.002	0.005	-0.005	-0.001	C38	0.019	0.014	0.024	0.014
A29	-0.003	-0.002	-0.007	-0.002	C39	0.023	0.007	0.024	0.013
A3	0.025	0.011	-0.014	0.013	C4	0.075	0.074	0.046	0.068
A30	-0.012	-0.001	-0.006	-0.003	C40	0.023	0.007	0.014	0.013
A31	-0.008	-0.001	0.000	-0.004	C41	0.022	0.006	0.021	0.012
A32	-0.014	0.002	0.000	-0.005	C42	0.014	0.006	0.017	0.011
A33	-0.007	-0.002	0.000	-0.005	C43	0.014	0.002	0.009	0.008
A34	-0.015	-0.004	-0.009	-0.007	C44	0.013	0.001	0.013	0.007
A35	-0.014	-0.010	0.001	-0.008	C45	0.010	0.004	0.008	0.006
A36	-0.010	-0.012	-0.010	-0.009	C46	0.007	0.002	0.008	0.005
A37	-0.016	-0.015	-0.009	-0.014	C47	0.005	0.008	0.012	0.004
A38	-0.036	-0.021	-0.011	-0.021	C48	0.002	0.007	0.009	0.004
A39	-0.041	-0.030	-0.012	-0.024	C49	0.004	-0.002	0.012	0.003
A4	0.016	0.016	-0.012	0.009	C5	0.071	0.068	0.048	0.065
A40	-0.051	-0.027	-0.005	-0.024	C50	0.001	0.000	0.011	0.003
A41	-0.022	-0.020	-0.003	-0.020	C51	-0.001	0.002	0.011	0.002
A42	-0.018	-0.023	-0.005	-0.018	C52	0.000	0.001	0.011	0.002
A43	0.007	-0.023	-0.001	-0.012	C53	0.003	0.000	0.011	0.002
A44	0.016	-0.009	0.000	0.003	C54	0.003	0.001	0.015	0.002
A45	-0.014	0.003	0.001	-0.004	C55	0.001	0.004	0.014	0.003
A46	-0.013	-0.014	0.003	-0.008	C56	0.002	0.003	0.008	0.002
A47	-0.010	-0.012	0.002	-0.008	C57	0.001	0.004	0.000	0.002
A48	-0.007	-0.013	0.004	-0.008	C58	-0.001	0.003	0.006	0.002
A49	-0.006	-0.020	0.003	-0.007	C59	0.000	0.001	0.005	0.002
A5	0.011	0.017	-0.007	0.011	C6	0.067	0.062	0.045	0.059
A50	-0.004	-0.010	0.002	-0.006	C60	0.001	0.000	0.006	0.002
A51	-0.005	-0.011	0.004	-0.003	C7	0.069	0.068	0.048	0.063
A52	-0.002	-0.009	0.001	-0.004	C8	0.054	0.057	0.037	0.053
A53	-0.002	-0.009	0.005	-0.003	C9	0.032	0.037	0.039	0.038
A54	-0.003	-0.004	0.002	-0.002	H1	0.036	0.025	0.020	0.029
A55	-0.003	-0.003	0.001	-0.002	H2	0.042	0.033	0.026	0.038
A56	-0.003	-0.003	0.001	-0.002	H3	0.043	0.032	0.026	0.039
A57	-0.006	0.000	0.000	-0.001	H4	0.058	0.050	0.030	0.049
A58	-0.006	0.001	0.001	-0.001	H5	0.056	0.042	0.035	0.050
A59	-0.003	-0.002	0.001	0.000	H6	0.073	0.057	0.044	0.060

A6	-0.003	0.014	-0.005	0.009	H7	0.083	0.063	0.049	0.066
A60	-0.005	0.001	0.003	0.000	H8	0.084	0.072	0.048	0.069
A61	-0.040	-0.005	0.001	-0.005	H9	0.084	0.064	0.051	0.070
A62	-0.013	0.008	0.000	0.002	W1	0.097	0.078	0.062	0.085
A7	-0.005	0.016	-0.003	0.007	W10	0.070	0.084	0.095	0.083
A8	0.003	0.009	0.008	0.005	W11	0.066	0.083	0.096	0.082
A9	-0.007	0.009	0.007	0.005	W12	0.064	0.093	0.095	0.082
C1	0.087	0.081	0.046	0.074	W13	0.063	0.087	0.095	0.081
C10	0.025	0.029	0.023	0.029	W2	0.108	0.094	0.073	0.101
C11	0.020	0.020	0.020	0.021	W3	0.094	0.094	0.078	0.089
C12	0.014	0.017	0.016	0.016	W4	0.096	0.089	0.082	0.089
C13	0.011	0.018	0.013	0.016	W5	0.090	0.094	0.086	0.089
C14	0.010	0.013	0.012	0.014	W6	0.085	0.084	0.087	0.088
C15	0.010	0.015	0.015	0.013	W7	0.084	0.083	0.090	0.087
C16	0.009	0.015	0.013	0.013	W8	0.076	0.084	0.092	0.086
C17	0.012	0.012	0.012	0.011	W9	0.076	0.087	0.095	0.084
C18	0.009	0.013	0.012	0.011	Max Delta	0.100	0.500	0.900	0.076
C19	0.012	0.010	0.014	0.011	Average Delta	0.002	0.011	0.014	0.003
C2	0.083	0.079	0.050	0.076					

Table H-14. Delta between 2022 without project and TSP (50-48), 2022 Condition, Low Flow, Actual Loads, Water Column Averaged DO, March through October

Segment	10%	50%	90%	Mean	Segment	10%	50%	90%	Mean
A1	0.048	0.037	0.017	0.040	C20	0.008	0.008	0.005	0.009
A10	0.006	0.011	0.010	0.010	C21	0.009	0.010	0.005	0.009
A11	0.002	0.010	0.004	0.008	C22	0.009	0.007	0.005	0.009
A12	0.003	0.010	0.006	0.006	C23	0.007	0.013	0.000	0.009
A13	-0.002	0.009	0.008	0.006	C24	0.009	0.006	0.010	0.008
A14	-0.002	0.008	0.008	0.006	C25	0.011	0.013	0.009	0.008
A15	0.006	0.008	0.001	0.006	C26	0.007	0.005	0.012	0.008
A16	0.007	0.006	0.002	0.006	C27	0.010	0.015	0.009	0.008
A17	0.003	0.005	0.004	0.005	C28	0.009	0.010	0.014	0.007
A18	-0.003	0.009	-0.004	0.005	C29	0.007	0.008	0.011	0.007
A19	0.016	0.004	0.005	0.006	C3	0.080	0.068	0.051	0.070
A2	0.048	0.033	0.007	0.032	C30	0.008	0.009	0.008	0.008
A20	0.008	0.010	0.004	0.005	C31	0.006	0.012	0.010	0.007
A21	0.003	0.009	0.005	0.005	C32	0.004	0.013	0.005	0.007
A23	0.000	0.007	-0.006	0.004	C33	0.006	0.011	0.003	0.006
A24	0.000	0.002	-0.004	0.003	C34	0.007	0.008	0.010	0.007
A25	0.000	0.004	-0.002	0.002	C35	0.005	0.003	0.015	0.007
A26	-0.004	0.007	-0.007	0.001	C36	0.004	0.006	0.020	0.007
A27	-0.008	0.004	-0.004	0.001	C37	0.007	-0.005	0.011	0.007
A28	-0.001	0.001	-0.006	-0.001	C38	0.009	0.003	0.016	0.007
A29	-0.004	-0.006	-0.007	-0.002	C39	0.011	0.005	0.015	0.006
A3	0.037	0.028	0.010	0.027	C4	0.075	0.062	0.048	0.068
A30	-0.011	-0.001	-0.004	-0.003	C40	0.010	0.001	0.016	0.006
A31	-0.012	0.000	0.000	-0.004	C41	0.010	-0.001	0.015	0.006
A32	-0.011	0.000	-0.003	-0.004	C42	0.007	0.001	0.011	0.005
A33	-0.013	-0.004	0.000	-0.005	C43	0.004	0.001	0.008	0.004
A34	-0.014	-0.006	-0.019	-0.006	C44	0.005	0.002	0.006	0.004
A35	-0.009	-0.007	-0.004	-0.007	C45	0.002	0.000	0.012	0.003
A36	-0.011	-0.008	0.005	-0.009	C46	0.005	0.001	0.011	0.003
A37	-0.010	-0.013	-0.004	-0.012	C47	0.004	0.001	0.011	0.003
A38	-0.028	-0.017	-0.009	-0.018	C48	0.001	-0.003	0.007	0.003
A39	-0.026	-0.021	-0.012	-0.021	C49	0.001	-0.007	0.009	0.002
A4	0.033	0.031	0.012	0.024	C5	0.072	0.058	0.045	0.064
A40	-0.034	-0.023	-0.005	-0.021	C50	0.001	-0.002	0.005	0.002
A41	-0.036	-0.021	-0.010	-0.021	C51	0.000	0.000	0.013	0.002
A42	-0.026	-0.027	-0.012	-0.019	C52	0.001	-0.003	0.010	0.002
A43	-0.015	-0.020	0.000	-0.016	C53	0.001	0.001	0.008	0.002
A44	-0.014	-0.014	0.000	-0.010	C54	0.003	0.000	0.006	0.002
A45	-0.015	-0.016	0.001	-0.012	C55	0.004	-0.001	0.011	0.002
A46	-0.016	-0.018	0.002	-0.011	C56	0.000	0.004	0.009	0.002
A47	-0.012	-0.013	0.003	-0.009	C57	0.002	0.001	0.002	0.002
A48	-0.005	-0.014	0.005	-0.009	C58	-0.002	0.002	0.004	0.002
A49	-0.007	-0.018	0.003	-0.006	C59	-0.002	0.002	0.005	0.002
A5	0.030	0.027	0.009	0.023	C6	0.064	0.056	0.044	0.060
A50	-0.005	-0.009	0.002	-0.005	C60	0.001	-0.001	0.004	0.002
A51	-0.008	-0.010	0.006	-0.003	C7	0.066	0.059	0.043	0.060
A52	-0.005	-0.007	0.001	-0.004	C8	0.055	0.041	0.048	0.051
A53	-0.004	-0.009	0.001	-0.003	C9	0.039	0.031	0.043	0.039
A54	-0.003	-0.002	0.001	-0.002	H1	0.025	0.021	0.018	0.028
A55	-0.005	-0.005	0.000	-0.002	H2	0.042	0.027	0.024	0.034
A56	-0.004	-0.003	0.003	-0.001	H3	0.039	0.032	0.030	0.037
A57	-0.005	-0.002	0.001	-0.002	H4	0.059	0.038	0.034	0.046
A58	-0.002	-0.001	0.003	-0.001	H5	0.063	0.043	0.037	0.049
A59	-0.003	-0.001	0.001	0.000	H6	0.080	0.047	0.046	0.062

A6	0.019	0.025	0.008	0.017	H7	0.079	0.058	0.050	0.065
A60	-0.002	0.000	0.001	0.001	H8	0.084	0.068	0.052	0.068
A61	-0.001	0.005	0.001	0.002	H9	0.086	0.055	0.055	0.070
A62	0.002	0.006	0.001	0.002	W1	0.094	0.073	0.063	0.079
A7	0.021	0.021	0.007	0.017	W10	0.069	0.084	0.091	0.083
A8	0.014	0.019	0.007	0.013	W11	0.073	0.085	0.093	0.082
A9	0.015	0.015	0.007	0.011	W12	0.068	0.086	0.094	0.081
C1	0.082	0.081	0.049	0.072	W13	0.061	0.090	0.094	0.081
C10	0.027	0.026	0.027	0.030	W2	0.095	0.084	0.074	0.088
C11	0.019	0.018	0.023	0.023	W3	0.092	0.084	0.077	0.086
C12	0.016	0.014	0.019	0.019	W4	0.092	0.086	0.082	0.088
C13	0.015	0.019	0.018	0.017	W5	0.093	0.085	0.084	0.089
C14	0.013	0.016	0.015	0.016	W6	0.092	0.086	0.085	0.089
C15	0.010	0.011	0.019	0.014	W7	0.086	0.082	0.091	0.087
C16	0.013	0.014	0.015	0.013	W8	0.077	0.085	0.089	0.085
C17	0.009	0.011	0.009	0.011	W9	0.077	0.084	0.093	0.084
C18	0.010	0.008	0.008	0.011	Max Delta	0.095	0.090	0.094	0.089
C19	0.010	0.011	0.006	0.010	Average Delta	0.018	0.017	0.017	0.018
C2	0.086	0.076	0.052	0.073					

Attachment H-2

Managed Species Habitat Affiliations

Common Name	Scientific Name	Managing Agency	Life Stage in Project Area *	Habitat Associations	Nursery/ Spawning Habitats	Sensitive Life Stage Use of Estuary	Primary Prey
Atlantic Menhaden	*Brevoortia tyrannus*	SAFMC	E,L,P,J,S	Pelagic-water column; migratory	Nursery: Estuary Spawn: Offshore	Nursery (spring-summer, may overwinter	Plankton
Bluefish	*Pomatomus saltatrix*	MAFMC	J,A	Pelagic-water column; migratory	Nursery: Estuary, Inshore Spawn: Offshore	Nursery (spring-summer)	Opportunistic feeders on fish (e.g., Menhaden and herring), squid, lobster
Red Drum	*Sciaenops ocellatus*	SAFMC	E,L,S,A	Tidal creeks, aquatic vegetation, mangrove areas, oyster reefs, unconsolidated sediment, beaches; migratory	Nursery (summer-fall) Spawn (late summer-fall)	Opportunistic feeders on fish, invertebrates, small crabs, and shrimp	[Veries depending on availability/ abundance]
Spot	*Leiostomus xanthurus*	ASMFC	S,A	Tidal creeks, unconsolidated sediment; migratory	Nursery: Estuary Spawn: Offshore	Nursery (spring-fall, may overwinter)	Benthic invertebrates such as worms and crustaceans
Spotted Seatrout	*Cynoscion nebulosus*	ASMFC	E,L,S,A	Tidal marsh creeks, oyster beds, shallow grass beds, open water; generally non-migratory	Nursery: Estuary Spawn: Estuary, Inshore	Nursery (year-round); Spawn (spring-summer)	Shrimp and small fish

Common Name	Scientific Name	Managing Agency	Life Stage in Project Area *	Habitat Associations	Nursery/ Spawning Habitats	Sensitive Life Stage Use of Estuary	Primary Prey
Weakfish	*Cynoscion regalis*	SAFMC (FMP by ASMFC)	E,L,S,A	Sand areas; migratory	Nursery: Estuary Spawn: Estuary, Inshore	Nursery (spring-fall); Spawn (spring-summer)	Shrimp and small schooling fish such as herring and anchovy
Highly Migratory Species - Atlantic Sharks							
Atlantic Sharpnose Shark	*Rhizopriondodon terraenovae*	NMFS	J,A	Pelagic-water column; migratory	Nursery: Estuary, Inshore	Nursery (spring-fall)	Opportunistic feeders on fish (e.g., menhaden, eels, silversides, wrasses, jacks), shrimp, crabs, and mollusks.
Bonnethead Shark	*Sphyrna tiburo*	NMFS	J	Pelagic-water column; migratory	Nursery: Estuary, Inshore	Nursery warm months	Opportunistic feeders on crustaceans (e.g., shrimp), mollusks, and fish.
Lemon Shark	*Nagaprion brevirostris*	NMFS	J,A	Reefs, bays, sounds, river mouths	Nusery: estuary, inshore	Nursery Warm months	Fish, crustaceans, mollusks
Coastal Migratory Pelagics							
Cobia	*Rachycentron canadum*	SAFMC	L,P,J,A	Pelatic-water column, manmade structures, over reefs, mangroves; migratory	Nursery: Inshore Spawn: Offshore	Transient	Opportunistic feeders on small fish, crabs, shrimp and squid

Common Name	Scientific Name	Managing Agency	Life Stage in Project Area *	Habitat Associations	Nursery/ Spawning Habitats	Sensitive Life Stage Use of Estuary	Primary Prey
Spanish Mackerel	*Scomberomorous maculatus*	SAFMC	L,P,J,A	Pelagic-water column, over rock; migratory	Nursery: Inshore Spawn: Offshore	Nursery (spring-fall)	Pelagic schooling fish such as anchovies
Shad and River Herring							
Blueback Herring	*Alosa aestivalis*	n/a	E,L,P,J,S	Eggs-demersal on substrate; juveniles-submerged vegetation; adults-water column; migratory	Nursery: River-Estuary Spawn: River	Transient	Plankton
Hickory Shad	*Alosa mediocris*	n/a	E,L,P,J,S	Pelagic-water column; migratory	Nursery: Estuary, Inshore Spawn: River	Nursery (spring-summer)	Opportunistic feeders on small fish, squid, small crabs, and pelagic crustaceans
South Atlantic Snapper - Grouper Complex							
Atlantic Spadefish	*Chaetodipterus faber*	SAFMC	E,L,J,A	Manmade structures, oyster reefs, livebottom; migratory	Nursery: Estuary, Inshore Spawn: Inshore, Offshore	Nursery (spring-summer, may overwinter)	Benthic invertebrates including crustaceans, mollusks, annelids, sponges, and cnidarians; plankton

Common Name	Scientific Name	Managing Agency	Life Stage in Project Area *	Habitat Associations	Nursery/ Spawning Habitats	Sensitive Life Stage Use of Estuary	Primary Prey
Bank Sea Bass	*Centropristis ocyurus*	SAFMC	P,J,S	Hardbottom	Nursery: Inshore Spawn: Offshore	Unknown	Benthic invertebrates (e.g., crustaceans), squid, and small fish.
Black Sea Bass	*Centropristis striata*	SAFMC	P,J,S	Manmade structures, oyster reefs, marsh edges, submerged vegetation; migratory	Nursery: Estuary, Inshore Spawn: Offshore	Nursery (spring-summer)	Benthic invertebrates (crustaceans, mollusks, and worms) and fish
Crevalle Jack	*Caranx hippos*	SAFMC	P,J,S	Pelagic-water column; migratory	Nursery: Estuary, Inshore Spawn: Offshore	Nursery (spring-summer)	Opportunistic feeders on fish, shrimp and invertebrates
Dog Snapper	*Lutjanus jocu*	SAFMC	P,J,S	Rocky or coral reefs; offshore movement with age	Nursery: Estuary Spawn: Offshore	Nursery (spring-summer)	Opportunistic feeders on fish and benthic invertebrates, incl shrimps, crabs, gastropods and cephalopods

Common Name	Scientific Name	Managing Agency	Life Stage in Project Area *	Habitat Associations	Nursery/ Spawning Habitats	Sensitive Life Stage Use of Estuary	Primary Prey
Gray Snapper	*Lutjanus griseus*	SAFMC	P,J,A	Rocky areas, reefs, unconsolidated sediment; offshore movement with age	Nursery: Estuary, lower reaches of rivers Spawn: Offshore	Nursery (summer-fall)	Opportunistic feeders on small fish, shrimps, crabs, gastropods, and cephalopods
Lane Snapper	*Lutjanus synagris*	SAFMC	P,J,S	vegetated flats, reefs, over mud bottom; offshore movement with age	Nursery	Nursery (spring-summer)	Opportunistic feeders on small fish, shrimps, crabs, gastropods, and cephalopods
Rock Sea Bass	*Centropristis philadelphica*	SAFMC	P,J,S	Hardbottom, rocks, jetties, unconsolidated sediment; offshore movement with age	Nursery: Inshore Spawning: Offshore	Nursery (summer-fall)	Opportunistic feeders on small fish, crustaceans, and shellfish
Sheepshead	*Archosargus probatocephalus*	SAFMC	P,J,S	Rocky areas, reefs, pilings; limited seasonal movements	Nursery: Estuary, Inshore Spawn: Offshore	Nursery (spring-summer)	Benthic invertebrates, including crabs, crustaceans, and mollusks
Shrimp							
Brown Shrimp	*Farfantepenaeus aztecus*	SAFMC	P,J,S,A	Marsh grass-water interface, mud-sandy substrate; migratory	Nursery: Estuary Spawn: Offshore	Nursery (spring-summer; may overwinter)	Invertebrates, decaying plant matter, organic debris

Common Name	**Scientific Name**	**Managing Agency**	**Life Stage in Project Area ***	**Habitat Associations**	**Nursery/ Spawning Habitats**	**Sensitive Life Stage Use of Estuary**	**Primary Prey**
White Shrimp	*Litopenaeus setiferus*	SAFMC	P,J,S	Marsh grass-water interface, mud-sandy substrate; migratory	Nursery: Estuary Spawn: Offshore	Nursery (spring-summer; may overwinter)	Invertebrates, decaying plant matter, organic debris
Pink Shrimp	*Farfantepenaeus duorarum*	SAFMC	P,J,S	Marsh grass-water interface, mud-sandy substrate; migratory	Nursery: Estuary Spawn: Offshore	Nursery (spring-summer; may overwinter)	Invertebrates, decaying plant matter, organic debris

*Life Stages: P- ; J-Juvenile; S-Spawning; A-Adult