UNITED STATES DEPARTMENT OF COMMERCE
National Oceanic and Atmospheric Administration
PROGRAM PLANNING AND INTEGRATION
Silver Spring, Maryland 20910

APR 23 2012

To All Interested Government Agencies and Public Groups:

Under the National Environmental Policy Act, an environmental review has been performed on the following action.

TITLE: Finding of No Significant Impact and Environmental Assessment for The Noisette Creek Golf Course Wetland Restoration in North Charleston, South Carolina

LOCATION: Former Navy Golf Course adjacent to Noisette Creek, North Charleston, South Carolina

SUMMARY: The purpose of this project is to restore and improve 11.7 acres of tidal marsh habitat adjacent to Noisette Creek through the reestablishment of tidal hydrology. The Project will is being constructed as compensation for the injury to, loss of, destruction of, and lost use of natural resources resulting from the accidental discharge of oil from the M/V EVERREACH in the vicinity of Charleston, South Carolina on or about September 30, 2002.

RESPONSIBLE OFFICIAL: Brian T. Pawlak
Acting Director, Office of Habitat Conservation
National Oceanic and Atmospheric Administration
National Marine Fisheries Service
1315 East-West Highway
Silver Spring, MD 20910

The environmental review process led us to conclude that this action will not have a significant effect on the human environment. Therefore, an environmental impact statement will not be prepared. A copy of the finding of no significant impact (FONSI) including the supporting environmental assessment (EA) is enclosed for your information.

Although NOAA is not soliciting comments on this EA or FONSI, we will consider any comments submitted that would assist us in preparing future NEPA documents. Please submit any written comments to the responsible official named above.

Sincerely,

Patricia A. Montanio
NOAA NEPA Coordinator

Enclosure

FINAL

RESTORATION PLAN AND ENVIRONMENTAL ASSESSMENT FOR THE 2002 M/V EVER REACH OIL SPILL CHARLESTON, SOUTH CAROLINA

May 2012

Prepared by:
South Carolina Department of Natural Resources
South Carolina Department of Health and Environmental Control
National Oceanic and Atmospheric Administration
and
United States Fish and Wildlife Service
acting on behalf of the
United States Department of the Interior

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1.0 INTRODUCTION

This Final Restoration Plan and Environmental Assessment (Final RP/EA) has been developed by the South Carolina Department of Natural Resources (SCDNR), the South Carolina Department of Health and Environmental Control (SCDHEC), the National Oceanic and Atmospheric Administration (NOAA) of the United States Department of Commerce, and the United States Fish and Wildlife Service (USFWS), acting for the United States Department of the Interior (collectively, “the Trustees") to address the injury to, loss of, destruction of, and lost use of natural resources resulting from the accidental discharge of oil from the M/V EVERREACH in the vicinity of Charleston, South Carolina on or about September 30, 2002 (hereafter, the “oil spill” or the “Spill”). This document summarizes the Trustees’ assessment of the natural resource injuries caused by the spill (both ecological and recreational services losses) and describes the restoration actions that the Trustees have selected for use to compensate for the assessed ecological injuries. The purpose of restoration under this plan is to make the public whole by providing for restoration or replacement of resources and services that will compensate for the interim ecological resource and service losses attributable to the Spill.

The monetary value of the recreational services has been assessed but restoration planning for those losses is more appropriately undertaken after recovery of those funds and is, therefore, being deferred to a later time.

This Final RP/EA:

- Describes the September 30, 2002, M/V EVERREACH oil spill and the Trustees’ assessment of the natural resource injuries and losses from that spill,

- Identifies the restoration objectives for the natural resources or services that were injured or lost,

- Identifies and evaluates a reasonable number of restoration alternatives that are consistent with the restoration objectives for the ecological injuries,

- Identifies the restoration actions that the Trustees have selected for use to compensate for the ecological injuries that occurred,

- Identifies the scale of the restoration project needed to compensate for the injuries and losses that occurred,

- Describes the monitoring that will be used to determine the success of the project,

- Serves in part to document compliance with Trustee responsibilities under the National Environmental Policy Act (NEPA), 42 U.S.C. § 4321 *et seq.*, applicable to restoration planning.

In developing this plan, the Trustees have acted in accordance with the natural resource damage assessment regulations applicable to oil spills issued under the Oil Pollution Act of 1990 (OPA).

These regulations are set forth at 15 C.F.R. Part 990 (hereafter, "NRDA regulations"). In accordance with these regulations, the methods selected by the Trustees to assess resource losses and scale restoration are technically reliable and valid, and have been judged to be cost-effective for this incident.

The restoration alternatives considered and the restoration action selected in this plan were identified and evaluated based on the technical expertise and restoration experience of the Trustees and other consulted scientists. The restoration action selected for implementation encompasses all the actions appropriate to the design, construction, monitoring, and evaluation of restoration performance.

1.1 Authority

This Final RP/EA was prepared jointly by the Trustees[1] pursuant to their respective authority and responsibilities as designated Trustees for natural resources injured as a result of the spill under the Federal Water Pollution Control Act, 33 U.S.C. §1251 *et seq*., the Oil Pollution Act (OPA), 33 U.S.C. § 2701 *et seq.,* and other applicable federal laws, including Subpart G of the National Oil and Hazardous Substances Pollution Contingency Plan, 40 C.F.R. Part 300.600 et seq. SCDNR and SCDHEC also have such authority under the South Carolina Pollution Control Act, S.C. Code Ann 48-1-10 et seq. (Supp. 2002), or other applicable state laws.

Section 1002(a) of OPA provides that each party responsible for a vessel or facility from which oil is discharged, or which poses a substantial threat of a discharge of oil, into or upon the navigable waters of the United States or adjoining shorelines, is liable for natural resource damages resulting from such actual or threatened discharges of oil (33 U.S.C. §2702(a)). OPA Section 1006(d)(1) defines the measure of natural resource damages as the cost of restoring, rehabilitating, replacing or acquiring the equivalent of the injured natural resources, compensation for the diminution in value of those natural resources pending restoration, and the reasonable costs of assessing such damages (33 U.S.C. §2706(d)(1)). Sums recovered for the first two components of damages are required to be spent to restore, rehabilitate, replace or acquire the equivalent of the injured resources, in accordance with a restoration plan developed by the Trustees (33 U.S.C. §2706(f)).

1.2 Trustee Determinations Supporting Development of this Restoration Plan, 15 C.F.R. 990.40-.45 (Subpart D)

The Trustees' decision to conduct a natural resource damage assessment for this oil spill is based on and supported by certain determinations made by the Trustees pursuant to the NRDA regulations, i.e., the Determination of Jurisdiction to Pursue Restoration pursuant to 15 C.F.R. 990.41 and the Determination to Conduct Restoration Planning pursuant to15 C.F.R. 990.42. These determinations and the bases of these determinations were set forth and described in a Notice of Intent to Conduct Restoration Planning published by the Trustees on November 25, 2003, in *The Post and Courier*, a newspaper of large general circulation in and around the spill area. A copy of that Notice is included in this Final RP/EA, in Appendix A.

[1] The Office of the Governor of South Carolina (SCOG) is also a designated natural resource Trustee for the State of South Carolina under OPA. In accordance with a November 2003 Memorandum of Agreement among the Trustees applicable to this Spill, the SCOG did not directly participate in the development of the Draft RP/EA but has approved this Final RP/EA. *[NOTE: text if SCOG approves; approval is pending]*

1.3 Coordination with Responsible Party

Under OPA and state laws, the party responsible for a vessel or facility from which oil is discharged ("responsible party" or "RP") is liable for the injuries to natural resources that result from the discharge. The OPA regulations require the Trustees to invite RPs to participate in the damage assessment process. Although the RPs may contribute to the process in many ways, authority to make determinations regarding injury and restoration rests solely with the trustees.

Evergreen International, S.A., the owner and/or operator of the M/V EVERREACH, was officially designated as the RP for this oil spill. The Trustees officially invited the RP to cooperatively participate in the NRDA process in a letter dated December 11, 2002, and the RP officially confirmed its interest in doing so via a formal reply.

Input from the RP has been sought and considered by the Trustees in assessing the resource injuries and losses caused by this spill and in the development of this Final RP/EA. The RP has provided a substantial amount of data and other information that the Trustees considered in assessing the nature and extent of the spill's impacts on ecological resources and also provided technical comments on data, methodologies, draft analyses and draft estimates of injuries or losses as developed by the Trustees. The Trustees and the RP never reached technical agreement on many issues associated with the Trustees' injury analyses and estimates and the Trustees proceeded with plans to prepare and release the Draft RP/EA based on their positions on these issues. The Trustees shared a copy of the Draft RP/EA with the RP in advance of its completion and public release. The RP responded with formal technical comments on the injury assessment described therein. The RP has, however, since agreed to perform the restoration actions selected in this Final DARP/EA as part of a settlement of its natural resource damages liability for this Spill. In light of that pending settlement, the RP agreed the Trustees need not prepare formal responses to those comments. These comments are included in the Administrative Record relating to this Final RP/EA.

Overall, this coordination and cooperation between the Trustees and the RP helped avoid duplicate assessment studies, allowed increased information sharing and joint utilization of experts, has made the process more cost-effective, and led to the identification of appropriate, restoration-based compensation for the public natural resource damages claim arising from the Spill.

1.4 Public Participation

Section 1006(c)(5) of OPA requires the Trustees to involve the public in the restoration planning process (33 U.S.C. 2706(c)(5)). The NRDA regulations interpret this provision as requiring, at a minimum, that Trustees provide the public with the opportunity to comment on a draft restoration plan, and that any public comments received be considered prior to adopting a final plan (15 C.F.R. Section 990.55(c)). The Trustees believe that public involvement and input is essential to an effective restoration planning process. Affording opportunity for public comment is also consistent with all applicable state and federal laws and regulations, including NEPA and its implementing regulations at 40 C.F.R. Parts 1500-1508.

The Notice of Intent to Conduct Restoration Planning published in *The Post and Courier* on November 25, 2003, provided an early opportunity for the public to submit restoration ideas or alternatives for consideration by the Trustees in the development of a restoration plan for this spill (see Appendix A). That Notice identified the spill event and the Trustees involved[2], provided general information on the natural resource injuries and losses for which compensation might be required, and invited input from the public on the restoration alternatives that should be considered in developing this restoration plan. The Trustees also investigated possible restoration options through direct discussions with representatives of various state, county and local governments and institutions, private organizations and RP representatives. The Trustees used information from these discussions in developing this Final RP/EA and in identifying the restoration action selected herein.

The Draft RP/EA was released for public review and comment for a period of 30 days on July 24, 2009. Notice of the availability of the Draft RP/EA and of the period for public review and comment was published in the *The Post and Courier* on July 24, 2009. Public review of the Draft DARP/EA was the means by which the Trustees sought direct public input on the restoration plan they were proposing be used to compensate for the ecological injuries and losses caused by the Spill. The Trustees received no comments on the Draft DARP/EA during the time it was available for public review.

1.5 NEPA Compliance

Actions undertaken by Trustees to restore natural resources or services under OPA and other federal laws are subject to the National Environmental Policy Act (NEPA), 42 U.S.C. § 4321 *et seq.*, and the regulations guiding its implementation at 40 C.F.R. Part 1500. NEPA and its implementing regulations outline the responsibilities of federal agencies under NEPA, including the preparation of environmental documentation. In general, federal agencies contemplating implementation of a major federal action must produce an environmental impact statement (EIS) if the action is expected to have significant impacts on the quality of the human environment. When it is uncertain whether a contemplated action is likely to have significant impacts, federal agencies prepare an environmental assessment (EA) to evaluate the need for an EIS. If the EA demonstrates that the proposed action will not significantly impact the quality of the human environment, the agency issues a Finding of No Significant Impact (FONSI), which satisfies the requirements of NEPA, and no EIS is required. For a proposed restoration plan, if a FONSI determination is made, the Trustees may then issue a final restoration plan describing the selected restoration action(s).

In accordance with NEPA and its implementing regulations, this Final RP/EA summarizes the current environmental setting, describes the purpose and need for restoration, identifies alternative restoration actions considered for the ecological injuries, assesses their applicability and potential environmental consequences, and summarizes the opportunity afforded for public participation in the process of making the restoration plan decisions. This information was used to make the threshold determination as to whether preparation of an EIS was required prior to selecting the final ecological restoration action.

[2] This Notice identified the U.S. Navy as a Trustee participating in the assessment process for this spill. On December 16, 2003, after the publication of this Notice, the U.S. Navy notified the other Trustees it was ending its participation in that process after determining harm to its trust interests was limited and that compensation for those losses would be covered by the ongoing assessment actions of the other Trustees.

Based on the EA integrated into this document and the analyses described in Section 6.0, the federal Trustees – NOAA and USFWS – concluded that the ecological restoration action identified herein does not meet the threshold requiring an EIS and, accordingly, issued a Finding of No Significant Impact.

1.6 Administrative Record

Acting in accordance with 15 C.F.R. 990.45, the Trustees established an Administrative Record (AR) documenting records relied upon by the Trustees in proceeding with the NRDA for the Spill. These records collectively comprise those supporting this Final RP/EA. The AR is available for public review at the address given below. It is also available for use in future administrative or judicial review of Trustee actions, to the extent such review is provided by Federal or State law.

Documents within the AR can be viewed at:

USFWS
Division of Ecological Services,
176 Croghan Spur Road,
Charleston, S.C.

Appointments to review the AR may be arranged by contacting that office , by phone at 843-727-4707, ext. 218. Access to and copying of these records is subject to all applicable laws and policies including, but not limited to, laws and policies relating to copying fees and the reproduction or use of any material that is copyrighted.

2.0 PURPOSE AND NEED FOR RESTORATION

The purpose and need for restoration derives from the natural resources injuries and losses that resulted from the discharge of oil from the M/V EVERREACH into the Charleston Harbor, South Carolina, including from activities associated with clean-up. The need to pursue restoration is based upon OPA, which establishes the RP's liability for the resource injuries and losses caused by the Spill. The purpose of restoration under OPA and its implementing regulations is to restore, replace, rehabilitate or acquire equivalent natural resources or services, including where necessary to compensate for interim resource losses. Such restoration is defined in accordance with a restoration plan developed by designated natural resource trustees.

This section generally describes the Spill, including the resources and resource uses affected by the incident, and provides information on the physical, biological and cultural/human use environments that were affected by the Spill and that may be affected by the restoration actions identified in this Final RP/EA.

2.1 Description of the Spill Incident

On or about September 30, 2002, #6 fuel oil was accidentally discharged into the waters of the Cooper River and Charleston Harbor, in South Carolina, from the containership M/V EVERREACH. The amount of oil discharged is not precisely known, but has been estimated at approximately 12,500 gallons. The principal distribution of oil was concentrated along the western shore of the Cooper River between the Interstate 526 Bridge and the Cooper River Bridge, in the vicinity of the North Charleston Terminal and the Old Navy Base piers and docks, however, other shoreline areas were also exposed to oil in varying degrees. These other areas included tidal creeks and backwater areas in the vicinity of James Island, Fort Johnson, Shutes Folly, Crab Bank, Morris Island, Folly Beach and Sullivan's Island. In all, released oil was found over approximately 30 linear miles of shoreline comprised of a variety of types, including tidal flats, fringing marshes, intertidal oyster reefs, sandy beaches and man-made structures (i.e., docks, piers, bulkheads), and their associated sediments. The distribution of oil is generally depicted in Figure 2.1. The oil spill also resulted in the oiling of a number of shorebirds, a shellfish bed closure, and a temporary disruption to recreational shrimp baiting in area waters. Response actions were coordinated and carried out by the RP, the United States Coast Guard, and SCDHEC, with participation and assistance from other agencies. The response effort included actions to minimize the spread of oil and its potential effects, to remove oil from the environment (particularly from shoreline structures and habitats) and to protect the public from possible risks associated with resource uses during the spill event. Response actions could not prevent natural resource injuries and losses from occurring and did not restore or compensate for the injuries and losses that occurred.

Figure 2.1 Shoreline Oiling as a Result of the Spill.

2.2 Affected Environment: The Cooper River, Charleston Harbor, and Surrounding Areas

This subsection presents information on the physical, biological and cultural/human use environments in the area affected by the spill and that may be affected by restoration actions considered in this Final RP/EA. It includes information on the overall environmental setting in which the spill occurred as well as on the specific environments affected or potentially affected by the spill and that have been targeted for restoration activities. The physical environment includes the surface waters of Charleston Harbor, the Cooper River, the Ashley River, and the Wando River. The biological environment includes a wide variety of fish, shellfish, wetland vegetation, birds and other organisms, including endangered or threatened species.

2.2.1 The Physical Environment[3]

The Charleston Harbor Estuary

The Charleston Harbor Estuary (Estuary) is located within the Charleston Harbor Watershed, in the central portion of South Carolina's coastline and is formed by the confluence of the Ashley, Cooper, and Wando rivers. It is a highly dynamic Estuary, influenced by the salinity gradient that extends from the seawater at its mouth to freshwater upriver, and the tidal energy that mixes the fresh and saltwater. These dynamics in the Estuary provide habitat for marine, estuarine, and freshwater organisms.

The Estuary lies entirely within the South Carolina Coastal Plain and consists of sedimentary deposits of sand, gravel, clay, marl, and limestone resting on metamorphic and igneous rocks. Overlying these deposits are marine and riverine sediments and a thin veneer of sand, clay, and shell comprising Pleistocene and Recent formations. The watershed is composed of 63% uplands, 19% open water, 11% freshwater wetlands, 6.5% estuarine marsh, and less than 0.5% estuarine tidal creeks. Upland land use patterns within the watershed are 61.6% forested, 11% urban, 9.3% forested wetlands, 7.7% non-forested wetlands, 6.3% scrub/shrub/disturbed, 3.8% agricultural and grasslands, and 0.3% barren. Federal, state, county, and municipal governments own 302,122 acres (122,267 hectares) of the forested watershed lands. Farmers, corporations, and private individuals own the remaining 638,820 acres (258,527 hectares) or 68% of the total forested lands within the watershed. The forests are composed of approximately 45% loblolly, slash, and short- and long-leaf pines, and 20% oak/hickory hardwoods. Annual precipitation is 49 inches per year (124.9 cm). The wide variety of habitats present in the Estuary support a diverse array of flora and fauna, including more than 80 species of plants, over 250 species of birds, 67 species of mammals, over 570 species of invertebrates and finfish, and at least 580 species of plankton.

The average depth of the Estuary basin is 12 feet (3.7 m) at mean low water (MLW), but navigation channels have been deepened to 40 feet (12.2 m) MLW. The mean tidal range is 5.2 feet (1.6 m), and spring tides average 6.2 feet (1.9 m). Water temperatures range from 38°F to 87°F (3.5^o to 30.7^o C), and average 67°F (19.4^o C). Salinities range from 0 to 35.6 parts per thousand. Similarly, dissolved oxygen levels range from 0 to 17.1 milligrams per liter, averaging 7.3 mg/l over the entire Estuary.

The physical environment of the Estuary also includes many amenities supporting the use of natural resources for recreation by humans, including facilities such as boat ramps, marinas and public beaches. Natural resources in the Estuary environment that are popular with the public include Folly Beach, shellfish beds in and adjacent to the Folly River, and areas of Charleston Harbor popular for shrimp baiting in the fall season.

The Cooper River

The Cooper River watershed is extremely complex due to the Santee-Cooper Hydroelectric Project and the subsequent re-diversion of the river in 1985. The lower component of the basin extends 50 miles (81 km) from the Pinopolis Dam to the mouth of the Cooper River on the north side of the Charleston City peninsula where it flows into Charleston Harbor. This section of the river drains almost 1400 square miles (3,625 km^2) of midlands and lowlands, including fresh and brackish

[3] The description in this section is adapted from the Charleston Harbor Project Report (SCDHEC 2000**).**

wetlands. The West Branch Cooper River is 17 miles (26.5 km) long and flows from the Tail Race Canal at Moncks Corner to its junction with the East Branch. This reach is a meandering natural channel bordered by extensive tidal marshes, old rice fields, and levees in varying states of disrepair. The area contains volumes of poorly defined overbank storage and immeasurable flows because of broken levees between the channel and old rice fields. The East Branch Cooper River is 7.6 miles (12.3 km) long and flows from its headwaters in Hell Hole Bay to its junction with the West Branch, commonly referred to as the "Tee". The East Branch is a tidal slough throughout its 7.5 miles (12 km) length. The river then flows 17.7 miles (28.5 km) to its junction with the Charleston Harbor basin on the north side of the Charleston peninsula.

The Ashley River
The Ashley River flows approximately 31 miles (50 km) from its headwaters in Cypress Swamp in Berkeley County to its junction with the Intracoastal Waterway on the south side of the Charleston City Peninsula, where it empties into Charleston Harbor's lower basin. The Ashley River basin drains a 216-square-mile (900 km^2) area of marsh and lowlands, spread out over Dorchester, Berkeley, and Charleston counties. Depths of the natural channel in the river range from 5.9 to 36 feet (1.8 to 11.0 m) and are influenced by tidal action throughout the river's entire length. Essentially a tidal slough, the tidal ranges of the Ashley River amplify progressively upstream. The extent of saltwater intrusion on the river varies greatly with the hydrologic condition of the basin. During extremely dry periods, with little freshwater draining from Cypress Swamp, saltwater extends throughout most of the Ashley River. During periods of heavy precipitation, saltwater can be limited to the lower part of the river below Drayton Hall. The banks of the river are dominated by *Spartina* marshes.

The Wando River
The Wando River is a tidal river that flows approximately 24 miles (38 km) from its headwaters in I'on Swamp in Charleston County to its junction with the Cooper River on the north side of the Charleston City Peninsula. The river drains 120 square miles (310 km^2) of marsh and lowlands, and its depth ranges from 5 feet to 42 feet (1.5 to 12.8 m). The Wando is influenced by tidal action throughout its entire length, and estuarine waters extend into the creeks that form its upper limits. Like the Ashley River, the tide ranges are amplified as they progress upstream. The Wando River has the best water quality of the three rivers. Above the Wando Terminal, the water quality is suitable for harvesting clams, mussels, and oysters for human consumption. The banks of the River are dominated by extensive *Spartina* and *Juncus* marshes.

2.2.2 Biological Environments[4]

Tidal currents provide a highly diverse habitat for the plants and animals common to the Charleston Harbor Estuary. Marsh vegetation is extensive in the Estuary due to the gently sloping coastal plain and the tidal range. The estimated acreage of the marshes in this area exceeds 52,000 acres (21,000 ha) of which 28,500 acres (11,500 ha) consist of brackish and salt marsh, 18,500 acres (7,500 ha) consist of freshwater marsh, and approximately 5,000 acres (2,000 ha) lie within impoundments. A diverse assemblage of plant species typically found throughout the Southeast United States is found

[4] The description in this section is also adapted from the Charleston Harbor Project Report (SCDHEC 2000**).**

within the Estuary, with the distribution determined by salinity and the duration of inundation. The tidal marshes of the Ashley and Wando rivers reflect a strong marine influence, with salt and brackish water marshes existing throughout almost all of their length. The Cooper River marshes exhibit a wide range of vegetation, changing markedly from salt to brackish to freshwater species. The flow rate and salinity of the Cooper has been significantly altered by the diversion of the Santee into the Cooper and the 1985 re-diversion project.

The shallow marsh habitats of the Charleston Harbor Estuary provide seasonal year-round habitats for a diverse assemblage of adult and juvenile finfish and crustaceans. The highly productive marshes provide abundant food resources for early life history stages of a variety of species. The shallow-water marsh also serves as a refuge for many creatures by providing a diversity of habitat and by excluding predators from the upper reaches of the Estuary. These advantages result in reduced competition, lower mortality, and faster growth rates for many species. Many of these species are commercially or recreationally valuable. The Estuary contributes approximately 20% and 8% of the state's shrimp and crab landings, respectively. Spot, Atlantic croaker, red drum, spotted seatrout, flounder, and catfish inhabit the estuary and are recreationally important. The Estuary also supports numerous ecologically important species such as bay anchovy and grass shrimps, which serve as food for economically and recreationally important species. The young of several species of finfish that are spawned in the lower estuary or ocean enter the shallows of the Estuary as juveniles and stay until they reach larger sizes or until lower winter temperatures drive them seaward.

The spatial distribution of the fishery species living in the bottom of the Charleston Harbor Estuary is similar to that of other estuaries along the mid-Atlantic, southeast and Gulf coasts of the United States. Numerically dominant species include mollusks, polychaetes, oligochaetes, nematodes, and amphipods. Among the three river systems, average diversity values are lower in the Cooper River than in the Ashley and Wando rivers. The lower diversity in the Cooper River may reflect adverse effects from the greater number of industrial and port facilities in this system as compared to the other two river systems.

Studies show that some of the physical and biological changes seen within the Charleston Harbor Estuary are not typical for an estuarine system with reduced freshwater inflow. In any estuary, the mixing zone is an important nursery area for new recruits. Many species utilize the shallows of these areas independent of salinity and also use tidal stream transport to initially colonize the upper estuary. Increased freshwater inflow rates displace the freshwater line seaward, compress the freshwater boundary horizontally and vertically, and prevent flood-tide displacement into the recruitment areas. Conversely, a decreased freshwater inflow rate, as occurs with rediversion, should enhance the recruitment process, There are suggestions, however, that reductions in freshwater flow rates from diversions result in reduction in the overall size of the estuarine nursery habitat and disrupt spawning and nursery cycles. Evidence suggests that a reduction of freshwater inflow by as little as 30-40% can destroy the dynamic equilibrium of an estuary within three to seven years and may increase the impacts of pollutants by four to twelve times.

Rather than the losses and destruction reported in other estuaries, the Charleston Harbor Estuary has seen an increase in use by many more species as a nursery area, especially in the main channels of the rivers but what this represents is uncertain. It is possible that coincidental environmental conditions (drought or cold winters) may have eliminated, masked or postponed negative effects from the rediversion, or that the continued regulation of the flow, as opposed to absolute elimination, has contributed to an improved end result. It is also possible that changes are occurring on a larger time scale and that current results represent a transitional phase in this process, or that the Estuary is returning to its pre-1942 hydrographic/biologic character.

2.2.3 The Cultural/Human Use Environment[5]

The greater Charleston area is better known as the Trident Region and is comprised of portions of Berkeley, Charleston, and Dorchester counties. The area includes twenty-five incorporated communities ranging in size from Jamestown in Berkeley County, with a population of approximately 84, to the City of Charleston with about 104,000 residents. The total population of the three counties doubled between 1960 and 1990 and is expected to increase to 619,500 by the year 2015. Administratively, their respective county councils and the combined Berkeley-Charleston-Dorchester Council of Governments (COG) serve the counties. Charleston County is the state's most urban county with 88% of its residents living in an urban setting (as defined by the U. S. Census). Similarly, Berkeley and Dorchester counties are significantly more urban than rural, with respectively 65.1% and 67.4% of their populations classified as urban.

Tourism, the Port of Charleston, health care, and several large industrial employers heavily influence the economy. Charleston Harbor's port facilities, composed of an extensive network of modern shore side facilities, represent the largest economic resource associated with the Charleston Harbor Estuary. Most of the $10.7 billion in 1997 sales revenues attributed to South Carolina's ports came through Charleston. During the State Ports Authority's 1999 fiscal year, which ended in June, 13.3 million tons of cargo moved through the port aboard 2,457 ships and barges. The Port of Charleston is the number one container port on the southeast and gulf coasts and is second only to the combined ports of New York and New Jersey on the entire eastern seaboard. Until 1994, the U.S. Navy maintained its third largest homeport on the Cooper and Wando rivers. These facilities consisted of a naval shipyard and weapons station and served more than 70 surface vessels and submarines. Charleston International Airport provides commercial and military air service for the region and currently serves over 1.5 million passengers annually. Six private airports located throughout the region can accommodate both corporate and private aircraft. Approximately 100 motor carriers and three railroads serve the Trident Region and, along with Interstates I-26, I-95, and I-526, provide access to residential, private, government, and commercial concerns. Six colleges and universities are located within the region with a combined annual enrollment of almost 27,000 students.

Although there are no major industries located on the harbor, the basin is surrounded by urban development and receives secondarily treated effluent from two sewage treatment facilities on Plum Island and in Mount Pleasant. The number of permitted point sources of pollution in the Charleston Harbor estuary decreased from 115 in 1969 to 67 in 1996. The volume of these discharges decreased from 328 to 205 cubic feet per second (9.3 to 5.8 m^3/s) during the same time period. Other sources of pollution affecting the harbor include nonpoint source runoff from the city and other urban areas, marina facilities near the mouth of the Ashley River, and runoff and discharges from forested and agricultural lands. Several diked, dredged material disposal areas are located in the harbor area, with the largest being Drum Island. The water quality of the harbor's tidal saltwater is rated as suitable for fishing and boating, but not for swimming, and the harvesting of oysters, mussels and clams is prohibited. However, reviews of data collected by SCDHEC reveal that the water quality within the basin often meets higher standards for dissolved oxygen and fecal coliform than the ratings indicate.

[5] [5]The description in this section is also adapted from the Charleston Harbor Project Report (SCDHEC 2000).

Among the three river systems that form the Charleston Harbor Estuary, the Cooper River has the greatest number and density of industrial and port facilities. The majority is located on the western shore and includes the former U. S. Navy port facilities; commercial facilities associated with the State Ports Authority and numerous private companies. In all, there are 22 industrial and municipal permitted point dischargers into the Cooper River with a combined flow of 127 ft^3/s (3.6 m^3/s). To accommodate shipping traffic, a 40 feet (12.2 m) deep navigation channel is maintained in the lower Cooper River and extends 20 miles (32 km) upstream from the mouth of the river. The eastern shore of the Cooper River is relatively undeveloped, although there are several diked dredged material disposal sites along the length of the maintained channel. The water quality rating of the lower basin is rated as suitable for fishing and crabbing, but not for swimming or the harvesting of clams, oysters or mussels. Water quality often meets higher standards than the rating for oxygen and fecal coliform.

The Charleston Harbor area also contains some of the most significant historic and archeological sites in the United States. Cultural resources include historic buildings, structures and sites, unique commercial and residential areas, unique natural and scenic resources, archeological sites, and educational, religious, and entertainment areas or institutions. In some areas preservation programs are effective in maintaining these resources. In other areas these resources are being lost or neglected primarily because of our limited knowledge. There is a continuing need for surveys to identify the cultural resources, their locations and significance.

3.0 INJURY DETERMINATION AND QUANTIFICATION

3.1 Overview of Injury Assessment Process

The goal of the injury assessment process is to determine the nature, degree, and extent of any injuries to natural resources and services caused by a particular event, such as an oil spill.

Injury is defined in the NRDA regulations as "an observable or measurable adverse change in a natural resource or impairment of a natural resource service. Injury may occur directly or indirectly to a natural resource and/or service" (15 C.F.R. Section 990.30). "*Services*" are defined as "the functions performed by a natural resource for the benefit of another natural resource and/or the public" (15 C.F.R. Section 990.30).

The injury assessment process has two components: injury determination and injury quantification. *Injury determination* requires that trustees demonstrate that the discharged oil has caused an adverse effect on a resource or the services it provides. If trustees determine a resource has been injured or its services lost, the injury or losses are then quantified.

Injury quantification involves determining the severity, extent and duration of the adverse effects on a resource or its services caused by the spill. Resource injuries may be quantified directly and/or by the reduction in resource services caused by the oil. Adverse change in a natural resource or service is defined by the difference between its pre-spill 'baseline' and its post-spill conditions. 'Baseline' refers to the condition or level of services the resource would have maintained, in the absence of the effects caused by the oil spill. Once the magnitude of injury is defined, trustees then estimate the time required for the resource and/or its services to recover, i.e., to return to its baseline condition. While both the magnitude of injury and recovery time have to be considered when quantifying resources injuries and losses, the biological processes that determine recovery from an oil spill are complex. The knowledge and data needed to precisely estimate recovery times are rarely available.

Some resources or services may be affected to such a limited extent that they cannot be meaningfully quantified or quantified at a reasonable cost. Injuries/services losses of this nature, however, are usually related to other components of the ecosystem and, because of these interrelationships, these injuries/service losses are often implicitly captured in other analyses or benefit from the recovery or restoration of other resources. This allows development of more appropriate and cost-effective options for restoring injured resources or services in the affected ecosystem in the context of a restoration-based approach to defining compensation for resource injuries and losses. (15 C.F.R Section 990.54). The restoration-based approach is favored because it helps achieve restoration of resources and services, thereby compensating for injuries/losses of public resources, more directly and more quickly.

In choosing injury assessment procedures under the NRDA regulations, trustees consider the relevance and adequacy of the information a procedure will generate and its potential role in restoration-scaling (15 C.F.R. 990.27(c)). The NRDA regulations identify a variety of methods that may be used for scaling compensatory restoration actions, however, injury assessment and restoration scaling procedures are often interrelated; the assessment procedure used can influence the approach used in restoration-scaling (see Section 4.1 for further discussion of restoration-scaling approaches)

3.1.1 Injury Evaluation and Selection Criteria

Trustees consider a number of factors in deciding which potential injuries to include in an assessment. As described in the NRDA regulations at 15 C.F.R. Section 990.51(f), these include:

1. The natural resources and services of concern;
2. The procedures available to evaluate and quantify injury, and associated time and cost requirements;
3. The evidence indicating exposure;
4. The pathway from the incident to the natural resource and/or service of concern;
5. The adverse change or impairment that constitutes injury;
6. The evidence indicating injury
7. The mechanism by which injury occurred;
8. The potential degree, and spatial and temporal extent of the injury;
9. The potential natural recovery period; and
10. The kinds of primary and/or compensatory restoration actions that are feasible.

The resources and services investigated for potential injury or service losses for the EVERREACH oil spill are listed in Table 3.1. There were six categories of ecological resources and four categories of resource uses (recreational). These categories were identified using evidence or information obtained during the response or as part of the Trustees' pre-assessment activities, with input from local, state and federal officials, the RP's representatives, and academic or other persons with knowledge about the affected environment, as appropriate.

Ecological	**Recreational Uses**
Birds	Recreation Shrimp baiting
Aquatic Fauna	Recreational Shellfishing
Salt Marsh (Vegetated Shoreline)	Recreational Boating
Non-vegetated Shorelines	Beach Use
Oyster Reef	
Man-made Structures	

Table 3.1 EVERREACH Spill - Resources/Services Investigated for Potential Injury/Loss

3.2 Ecological Injuries - Determination and Quantification

The model system known as "SIMAP" (Spill Impact Model Analysis Package) was a primary tool used by the Trustees to evaluate and assess the ecological injuries for this spill. SIMAP is an oil spill modeling system comprised of two submodels: the Physical Fates model and the Biological Effects model. For the EVEREACH spill, the Trustees used the SIMAP model to assess the pathways and fate of the oil in the environment, to estimate oil exposure to the water surface, water column, sediments, shoreline and other habitats, and to estimate injuries to wildlife and aquatic organisms. The Physical Fates model is a three-dimensional model that estimates the distribution of oil (taking into account mass and concentration) on the water surface, on shorelines, in the water column and in the sediments. It is based on the Natural Resource Damage Assessment Model for Coastal and Marine Environments (NRDAM/CME, Version 2.4, April 1996). The model uses a variety of incident-specific data, such as on winds and currents, as well as transport and weathering algorithms, to calculate the mass balance of oil in the various components of the environment, surface oil distribution over time and concentrations of oil constituents in water and sediments.

Geographical data (habitat mapping and shoreline location) for this spill were obtained from existing Geographical Information System (GIS) databases based on Environmental Sensitivity Indices (ESI). Water depth inputs were based on NOAA's National Ocean Service (NOS) soundings databases. The trustees obtained hourly wind speed and direction data during and after the spill from a nearby meteorological station. Tidal and other currents were modeled from known water heights in the Charleston Harbor setting, using a hydrodynamic model based on the physical laws of hydrodynamics. Algorithms based on state-of-the-art published research are used to establish the spreading, evaporation, transport, dispersion, emulsification, entrainment, dissolution, volatilization, partitioning, sedimentation, and degradation of oil in the spill environment.

The Biological Effects model estimates short-term (acute) exposure of biota of various behavior types to floating oil and subsurface contamination (in water and subtidal sediments), resulting percent mortality, and sublethal effects on production (somatic growth). Acute mortality of water column and benthic resources is estimated as a function of temperature, concentration of dissolved aromatics and length of exposure. Acute mortality of other wildlife is estimated as a function of the area swept by oil, dosage and vulnerability. The model produces an estimate of the numbers of animals lost, based on the probability of direct mortality under the circumstances of exposure. Because the model estimates these numbers based on probabilities of mortality, the estimated numbers can include fractions of animals. Chronic effects of long-term oil concentration in sediments or via ingestion are not considered by this model.

The SIMAP modeling and results used in assessing resource injuries for the M/V EVERREACH oil spill are fully described in the Final Modeling of Physical Fates and Biological Injuries Report dated August 2006. The Executive Summary from this report is included in this Final RP/EA as Appendix B but the full report is included in the AR. The specific usage and results of this work for each of the six ecological resource categories evaluated by the Trustees are described below.

In undertaking this assessment, the interrelationships among natural resources in the Cooper River and Charleston Harbor ecosystems was also key. First, understanding these relationships helped ensure all potential resource injuries and service losses were accounted for in the assessment and that double-counting of injuries was avoided. Resources or services that may have been affected to such a limited extent that they could not be meaningfully quantified are still implicitly addressed through the quantification of service losses and determination of restoration requirements. Understanding these relationships also provided a foundation for restoration planning, as it permitted identification of appropriate and cost-effective options for restoring injured resources or services and the use of restoration options benefiting multiple natural resources and their ecological services.

3.2.1 Birds

A. Determination of Injury

During response and pre-assessment activities, a total of 18 to 23 brown pelicans were observed in the field as moderately or heavily oiled, with 30 other pelicans showing spots or oil stains. Tri-State Bird Rescue & Research, Inc., a bird rescue and rehabilitation contractor, treated and released 21 of the oiled pelicans (1 adult and 20 juveniles) as part of the response. Other oiled birds observed included: 1 great blue heron, several egrets, 1 double-crested cormorant, and 15 ruddy turnstones. All of these birds were captured or observed on Crab Bank in lower Charleston Harbor. This information was used to the extent possible as input to and to calibrate the SIMAP model.

Diving birds like pelicans and waterfowl are usually at greatest risk during oil spills, because they spend nearly all their time on the water surface. Waterfowl and wading birds may be directly oiled, and can become oiled on the upper body and feathers by coming in contact with oiled vegetation or prey while feeding. Shorebirds usually avoid oil, but may be impacted by loss of feeding areas or intertidal prey. Gulls, terns and raptors may be at risk because they are often attracted to and will prey on sick or injured prey. This behavior may result in oiling of feathers and the ingestion of oil.

Oiling of birds reduces the buoyancy, water repellency, and insulation provided by feathers, and may result in death by drowning or hypothermia. Preening of oiled feathers may also result in ingestion of oil resulting in irritation, sickness, or death. Determining the number of birds that actually die from oiling is difficult in aquatic environments because many oiled birds will retreat to marshy areas to die or they will lose buoyancy and sink. In breeding season oiled birds may take oil back to the nest and that oiling may impact the young and cause them to die.

B. Quantification of Injury

Aquatic bird injuries were estimated using the SIMAP model and data for areas swept by enough surface oil to oil a bird above a threshold dose level for effects. The modeling incorporates exposure estimates, information relating to the volatility and solubility of the released oil type, and assumed toxicity values based on laboratory bioassay data for particular species and life stages.

The SIMAP model estimated the total birds oiled at 175, including brown pelicans, black skimmers, terns, gulls, wading birds, and shorebirds (See Appendix B – *Final Modeling of Physical Fates and Biological Injuries Report, Executive Summary, 2006*). The number of oiled birds estimated by the model is higher than the number of birds actually observed as oiled in the field. This difference reflects several factors, including the fact that some oiled birds die and sink and that the model estimates injuries to birds throughout the harbor and in the rivers, not just to birds in the areas where the heaviest oiling was found.

The injury to birds was quantified in terms of the interim loss associated with the oiled birds. This was calculated based on the number of oiled birds estimated to be killed due to oiling, plus the loss of their first generation of progeny. Both the birds estimated to be directly killed and their lost future fledglings were quantified in terms of a number of bird-years lost[6].

The total of the bird-years lost was then divided by the bird-years that would be gained for each new fledgling. This yielded the number of fledglings that would need to be produced to effectively replace the bird-years lost. This approach permits a restoration action to be evaluated or scaled based on its ability to increase fledgling production, so that the amount of restoration required to replace the birds lost can be determined.

Thus, the interim loss is expressed in an equivalent number of age 0 animals (fledglings) lost. The loss is assumed to occur every year after 2002 until restoration in 2007. A discount rate of three percent is applied to the loss for every year between 2002 and 2007, to account for the difference in time between the initial kill and the later years when growth is foregone[7]. After discounting, the entire bird injury is expressed in terms of its value as of the date of the initial kill[8].

The estimated injuries to birds that results from this analysis is presented in Table 3.2 below. Because the model uses probabilities in estimating injuries, the resulting estimate may include a fraction of an animal.

Group Totals	**Birds Killed (#)**	**Observed (#)**	**Interim Loss (#-years)**	**# Fledgling Equivalents (in 2002)**	**# Fledgling Equivalents (in 2007)**
Waterfowl	0.06	-	0.1	0.1	0.1
Seabirds	89.2	49-54 (pelicans)	556	384	446
Wading birds	16.4	~ 4	31	36	41
Shorebirds	68.8	15	531	260	301
Raptors	0.14	-	1.0	0.5	0.6
Total birds	**174.6**		**1120**	**681**	**789**

Table 3.2: EVERREACH - Summary of estimated injuries to birds (French McCay et al., 2005a).

3.2.2 Aquatic Fauna

A. Determination of Injury

Though the Charleston Harbor area is heavily used by aquatic fauna, including blue crabs, shrimp, and other invertebrates, and numerous species of fish, no evidence of injury to aquatic fauna (i.e., fish kills, etc.) was observed or reported during the response. The Trustees, however, recognized that

[6] 'Bird years lost' refers to the number of birds lost and their lost future fledglings multiplied by their average life span.

[7] A discount rate must be applied when comparing resources or services across different time periods so that the calculated losses are adjusted to reflect the greater value that people assign to goods and services in the present, as compared to the future. The discount rate approximates this rate of societal time preference.

[8] For additional discussion concerning discounting, please refer to the NOAA technical document on discounting (NOAA, 1999) which is available at the following website: http://www.darrp.noaa.gov

mortality could occur at levels that might not have been easily detected or documented over the large area affected by the spill. The Trustees used the SIMAP model to evaluate the potential for such injuries based on potential exposure of these resources to likely concentrations of oil hydrocarbons and dissolved aromatics in the water column and subtidal habitats. The SIMAP model indicated subsurface concentrations of oil hydrocarbons and dissolved aromatics did not exceed 1 ppb in any water volume >140 m^3 (the resolution of the model grid for the subsurface plume) at any time after the spill. This level of exposure is not significantly toxic to organisms in the water column or to bottom-dwelling organisms in subtidal habitats, or known to result in sublethal injuries to these resources. The SIMAP estimate of total injury to subtidal fish and invertebrates was 0 kg (See Appendix B – *Final Modeling of Physical Fates and Biological Injuries Report, Executive Summary, 2006*). Accordingly, the Trustees did not determine an injury to aquatic fauna occurred due to the spill.

3.2.3 Shoreline Habitats

A. Determination of Injury

Approximately 31 miles of shorelines in the Charleston Harbor area were oiled to varied degrees as a result of the spill. Affected shoreline areas included the south shore of the Cooper River from Interstate 526 to the Cooper River Bridge, Shutes Folly, Crab Bank and the adjacent shoreline of Mt. Pleasant, the shoreline from Ft. Johnson to Ft. Sumter, Morris Island and Folly Beach.
The extent of shoreline oiling was determined using a combination of field observations, SCAT reports[9] and aerial photography. The degree of oiling was estimated by the Trustees using SCAT reports that described the extent and degree of observed shoreline oiling, by relating known oil locations to areas of shoreline using habitat maps, and by applying professional knowledge and judgment as needed. The process was undertaken cooperatively with the Responsible Party's technical representatives and consultants.

The shorelines affected by the Spill included a variety of different habitat types. Affected shorelines were grouped into four representative categories for injury assessment purposes: (1) Vegetated Shorelines (marsh), (2) Non-Vegetated Shorelines (mudflats, sandy beach, etc), (3) Oyster Reefs (large oyster beds) and (4) Man-made Structure (seawalls, piers, etc). This approach allowed the Trustees to calculate the acres of each habitat type exposed to heavy, moderate and light oiling, respectively. The determination of injury to these habitats takes into account the levels of exposure to oil, information relating to the volatility and solubility of the released oil type, and toxicity values for benthic and other organisms from published scientific data and studies. Table 3.3 shows the extent and degree of oiling by shoreline type.

[9] The Shoreline Clean-up Assessment Team (SCAT) process is used to evaluate oiled shorelines and their need and priority for clean-up as part of the spill response. The key element of the SCAT process is the use of trained observers to systematically document areas affected by an oil spill using standard terms and definitions of shoreline areas (the SCAT survey).

Shoreline Type	Degree of Oiling	Extent (Acres)
Marsh	Heavy	4.06
Marsh	Moderate	7.39
Marsh	Light	6.80
Hard Structure	Heavy	0.11
Hard Structure	Moderate	2.53
Hard Structure	Light	1.07
Non-Vegetated Shoreline (Sandy Beach/Shell Beach/Mudflat)	Heavy	0.00
Non-Vegetated Shoreline (Sandy Beach/Shell Beach/Mudflat)	Moderate	1.91
Non-Vegetated Shoreline (Sandy Beach/Shell Beach/Mudflat)	Light	14.31
Oyster Reef	Heavy	4.70
Oyster Reef	Moderate	7.70
Oyster Reef	Light	7.50

Table 3.3: Extent and Degree of Oiling by Shoreline Type

B. Quantification of Injury

Though the injury to shoreline habitats was apparent from pre-assessment observations and information, it was not immediately clear whether the extent of the injury, and more particularly its likely equivalent in available cost-effective restoration, was enough to justify the cost of pursuing additional studies of the injured habitats to further document and quantify the extent of the losses. The Trustees used an exercise to help inform their efforts to identify an appropriate, cost-reasonable injury assessment strategy. Specifically, the Trustees ran a preliminary Habitat Equivalency Analysis (HEA) using potential parameters[10]. This exercise yielded an early, albeit rough estimate of the amount of shoreline injury (i.e., total ecological service loss) that might have occurred and of the amount of restoration that might be needed to offset it. The results of this exercise indicated the size of the injury might not be sufficient to justify pursuing additional studies, considering its likely restoration equivalent.

As an alternative, the Trustees and the RP elected to seek consensus on a set of conservative assumptions[11] that could be used to estimate the potential losses and to identify the type and scale of an ecological restoration project sufficient to offset those losses, using the HEA framework. This alternative was viewed by the parties as a more cost-effective approach than undertaking additional

[10] HEA is a valid and reliable method that is frequently applied in NRDAs to quantify ecological losses associated with injuries to habitats and other resources. It is appropriate for use where service losses are primarily ecological and the creation of habitats or services like those injured or lost is technically feasible. It estimates the acres of habitat required to functionally replace ecological service losses, according to a technically-structured formula. Use of the HEA method facilitates assessments of restoration-based compensation for natural resource losses.
[11] This approach is a means of addressing technical uncertainties in an analysis. It involves the use of inputs or values that are protective of the natural resources and/or favor the public, and leads to higher estimates of injuries and losses.

focused studies in an attempt to reach agreement on the injury estimate for the shoreline habitats. Though technical agreement on the injury determination was never reached, the parties recognized that the restoration chosen can encompass differing injury estimates.

The Trustees took into account reductions in the entire flow of services provided by all affected habitats. In other words, for each affected habitat type, the reductions in likely service flows due to oiling included reductions in services the habitat provides to other resources. The results of this approach are, therefore, intended to capture the reduction in bird production that occurs when habitat services flows that support birds are disrupted or lost, the reduction in aquatic faunal production that occurs when habitat service flows supporting fish, shrimp, crabs, and other aquatic fauna are disrupted or lost, and the loss of other habitat services as appropriate. For each injured habitat type, this approach resulted in an estimate of the total number of lost 'acre-years' that likely resulted from the level or degree of observed oiling. An 'acre-year' is the total amount of ecological services that an acre of shoreline habitat will provide to all other natural resources in one year. Losses were evaluated for heavily oiled, moderately oiled and lightly oiled areas, respectively. Losses were assessed on an annual basis and discounted to reflect their present value as of October 2002 (the time of the spill) to produce the total estimated discounted service acre-years (DSAYs) lost. The DSAYs lost is the metric for determining the amount of habitat restoration, in acreage, required to restore or replace ecological services equivalent to the losses.

The HEA parameters and calculated service losses for each type of injured habitat are described below. Table 3.4 summarizes the key parameters and the results of the quantification of the DSAYs lost due to injury to shoreline habitats.

B.1 Vegetated Shorelines

Heavy oiling in marsh was estimated to cause an 80 percent service loss immediately following the spill. Losses were estimated to decline and then recover linearly, with return to baseline conditions after three years. In moderately oiled marsh, initial service losses were estimated to be 50 percent, with linear recovery and return to baseline after two years. In lightly oiled areas, the initial service loss was estimated to be 10 percent, with linear recovery and return to baseline after six months. The above service loss and recovery parameters are based on results of previous studies of injury to and recovery of marshes following oil spills, as presented in Michel et al. (2002) and Penn and Tomasi (2002). In these previous studies, service losses and recovery of marsh were determined for heavy, moderate, and light oiling based on biological metrics for vegetation services, including stem density and plant biomass, and measurements of soil services such as nutrient cycling. The parameters selected for use in this assessment fall within the range of these parameters found in these previous spill studies.

Total estimated ecological service losses for injury to vegetated shorelines: 8.51 DSAYs.

B.2 Man-made Structures

Man-made structures can serve as surrogates for other naturally occurring hard substrates, such as hard bottom or oyster reef, and become habitat for a variety of subtidal plants and animals. These epibiotic organisms are, in turn, sources of food and shelter for many types of other organisms. Though lacking the complexity of natural habitats, they can be an important component of subtidal systems. Man-made structures are less vulnerable to the effects of oil and recovery to baseline occurs more quickly than in most natural habitats because they can be cleaned more easily, lack habitat complexity, and re-colonize rapidly. Evidence and information obtained during the pre-assessment phase was not sufficient to support a direct assessment of likely losses and of the recovery of resource services. Service losses associated with this type of shoreline habitat were evaluated and assessed based on the expertise and professional judgment of state and federal scientists involved in the assessment. Initial service losses in heavily, moderately and lightly oiled areas were estimated to be 15, 10 and 5 percent respectively, with a linear recovery and return to baseline after six months.

Total estimated ecological service losses for injury to man-made structures: 0.08 DSAYs.

B.3 Non-Vegetated Shoreline

Non-vegetated shorelines are areas found around the high or low watermarks in tidal and intertidal zones. They are characterized by loose, unconsolidated sediments that serve as habitat for mollusks, crabs, shrimp and worms. These organisms are the primary sources of food for many larger estuarine organisms such as fish. Evidence and information obtained during the pre-assessment phase was not sufficient to support a direct assessment of likely losses and of the recovery of resource services for non-vegetated shorelines. Service losses associated with this shoreline habitat were evaluated and assessed based on the expertise and professional judgment of state and federal scientists involved in the assessment. No heavy oiling was observed or documented in non-vegetated shoreline areas. In moderately oiled areas, initial service losses were estimated to be 50 percent, with linear recovery and return to baseline after three years. In lightly oiled areas, initial service losses were estimated to be 10 percent, with linear recovery and return to baseline after six months.

Total estimated ecological service losses for injury to non-vegetated shoreline: 1.74 DSAYs.

B.4 Oyster Reefs

Similarly, initial service losses in heavily, moderately and lightly oiled areas were estimated to be 75, 35 and 15 percent respectively, with a linear recovery and return to baseline after six months.

Total estimated ecological service losses for injury to oyster reefs: 1.82 DSAYs.

Table 3.4: Key HEA Parameters and Lost DSAY Calculations by Shoreline Habitat Category

HEA Injury Categories	Degree of Injury	Acres	Initial % Service Loss	Recovery Time (Years)	DSAYs[12] Lost
Marsh	Heavy	4.06	80%	3	4.72
Marsh	Moderate	7.39	50%	2	3.62

[12] The DSAYs Lost indicated on this table are converted to a common metric in order to evaluate the scale of restoration required to compensate for losses. This process is further discussed in section 5.1.4.

Marsh	Light	6.80	10%	0.5	0.17
Hard Structure	Heavy	0.11	15%	0.5	0.004
Hard Structure	Moderate	2.53	10%	0.5	0.063
Hard Structure	Light	1.07	5%	0.5	0.013
Non-Vegetated Shoreline	Heavy				
Non-Vegetated Shoreline	Moderate	1.91	50%	3	1.38
Non-Vegetated Shoreline	Light	14.31	10%	0.5	0.36
Oyster Reef	Heavy	4.70	75%	0.5	0.88
Oyster Reef	Moderate	7.70	35%	0.5	0.67
Oyster Reef	Light	7.50	15%	0.5	0.28

3.3 Lost Recreational Services – Determination & Quantification of Losses

Among the many services provided by a natural resource are those for public recreation. When a resource is injured or access to that resource disrupted by a spill, the public's recreational use of the resource can be lost or diminished. Such losses are part of the natural resources damages that are recoverable under OPA and addressed in the Natural Resource Damage Assessment (NRDA) process. This subsection summarizes the data and methods used to evaluate, identify and calculate lost-use damages for recreational losses due to the EVERREACH oil spill. The term "lost-use damages" refers to the decline in value of recreational uses associated with resources affected by the Spill

The EVERREACH spill affected recreational shrimp baiting and recreational shellfishing. The Trustees determined that the EVERREACH oil spill caused a reduction in the number of shrimp baiting and shellfishing trips taken in the Charleston Harbor area in the fall of 2002 and also that the value of shrimp baiting trips taken under spill conditions was reduced. The assessment undertaken to identify and quantify these losses (i.e., to determine the number of affected trips and the total value of those losses) is described below. This assessment was undertaken cooperatively with the RP. The Trustees also examined potential effects of the spill on beach use and recreational boating but determined that impacts to these activities, if any, were likely very small and did not warrant further assessment. Further details of the lost recreational use injury assessment are described in English et al. (2004).

3.3.1 Recreational Shrimp Baiting

Recreational shrimp baiting takes place throughout Charleston Harbor and in several other areas of coastal South Carolina within an annually noticed season (typically about 60 days) that normally begins in mid-September and extends into November. The fishery usually involves marking several spots with poles, setting bait in the water, and casting a net over the shrimp that are drawn to the bait. The activity typically takes place at night to improve catch and is almost always undertaken using a boat. Well over 10,000 permits for this recreational season are sold annually by SCDNR. Over 3000 Charleston County residents purchased a permit for the 2002 season.

The 2002 season began on September 13th and ended on November 12th. The EVERREACH spill into Charleston Harbor occurred on or about September 30th of that year. Recreational shrimp baiting activities were adversely affected by the presence of oil in these waters, the potential for shrimp to be contaminated, and response activities (including necessary public warnings and closures) over the remainder of the 2002 season. As part of the NRDA for this spill, the Trustees investigated and determined the extent to which shrimp baiting activities were lost or diminished in value during the last 43 days of the 2002 season.

Losses of recreational shrimp baiting due to the spill were determined from information obtained as part of the post-season survey of shrimp baiting license holders administered annually by the SCDNR. Questions designed to reveal the effect of the spill on shrimp baiting activities for the 2002 season were added to the November 2002 survey and the responses to these questions were used to assess the 2002 recreational shrimp baiting losses attributable to the spill.

The questions added to the survey focused on changes in the location of respondents' shrimp baiting trips. In particular, respondents were asked if they took fewer trips than planned to the Charleston area during the 2002 season, and if so, to state the reason. From those respondents reporting fewer trips to Charleston and giving the oil spill as the reason, the total number of trips affected by the spill was determined. The total estimated number of lost trips due to the spill was 4,232.

The total monetary value of all shrimp baiting losses was then estimated with a Random Utility Model (RUM) travel cost method. This is a standard econometric technique. It uses the number of lost trips in combination with other data (including the approximate location where shrimp baiters live, the sites they visit, the costs of reaching the available shrimp baiting sites ("transportation costs") and other data from publicly available sources to estimate the value of changes at a recreational site, such as may result from temporary reductions in the quality of a site due to an oil spill. The analytical methods applied involved econometric estimation of recreation demand and were drawn from sources in the peer-reviewed economics literature. Specific details of the RUM travel cost analysis performed for the EVERREACH spill are provided in English et al. (2004), a copy of which is included in the AR.

The RUM travel cost analysis produced estimates of the lost value associated with both lost and degraded trips. The term "lost trips" refers to the total decline in the number of shrimp baiting trips to the Charleston Harbor area. Some of the "lost trips" involved use of alternative shrimp baiting sites not affected by the spill and some involved trips that were foregone altogether. The term "degraded trips" refers to trips taken to the Charleston site under degraded conditions. Some lost or degraded trips may have resulted from perceptions about potential oiling in locations that were not directly impacted by the oil. All affected trips involve a loss in value and the total quantified losses are the assessed damages.

Total losses to recreational shrimp baiting resulting from the oil spill were estimated at a range of $74,476 to $114,452 in 2002 dollars. These losses must be adjusted over time to account for discounting and inflation. The value of the estimated losses would be $105,905 to $162,708 in November 2008 dollars[13].

[13] This figure is as it appeared in the Draft RP/EA released in 2009.

3.3.2 Recreational Shellfishing

The SCDHEC closed shellfish bed S200 on October 1, 2002, due to potential contamination from the spill. SCDHEC lifted the closure November 5, 2002. The designated area S200 is located near Folly Island, and is accessed primarily from the Folly River boat landing located on State Route 171. There are four other shellfish beds in or adjacent to Folly River which are open to recreational use and are accessed from the same boat landing. These other shellfish beds were not closed following the spill. There are additional shellfishing areas nearby in the Kiawah River and Clark Sound.

To determine recreational shellfishing losses, the number of lost trips was estimated for the 35-day closure of bed S200. Information on shellfishing trips in the Folly River area was taken from a 1990 report entitled "South Carolina Marine Recreational Fish and Shellfish Fishery Surveys, 1988" (Waltz, *et al*., 1990). This report was the most recent source of information on recreational shellfishing trips available for the relevant area. Based on intercept surveys administered during the 1988-1989 season, the report concluded that an average of 13.8 people accessed the Folly River each day and that for most of them (92.5 percent) shellfishing was the primary purpose of their visit. Therefore, 13.8 trips per day was used in calculating the shellfishing losses due to the spill. Multiplied by 35 days, the total number of lost trips was estimated at 497.[14]

The value of each shellfishing trip was estimated based on evidence from the shrimp baiting survey, because that survey captured the practices and preferences of South Carolina residents for a similar marine-based, recreational-fishing activity. However, there is other evidence to indicate that shellfishing trips may have slightly lower value than shrimp baiting trips. In particular, shrimp baiting draws a greater share of its participants from inland counties compared to shellfishing (Waltz, 1996). In the context of recreational demand, this implies that shellfishing is a less valuable recreational activity. The range in value for "person-trips" in the travel cost analysis for shrimp baiting is $17.60 to $27.04. For shellfishing, a slightly lower range of $15.00 to $20.00 was assumed, consistent with this evidence. Applying this range of values to 497 lost trips, total losses to shellfishing as a result of the spill are calculated to be $7,452 to $9,936 in 2002 dollars. Here again, losses must be adjusted over time to account for discounting and inflation. When these adjustments are made, the value of these losses would be $10,598 to 14,131 in November 2008 dollars[15].

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[14] Several points relating to this estimate are worth noting. First, there is no information available to indicate whether the level of shellfishing activity in Folly River in 2002 may have been higher or lower than in 1989 or the trends in this activity over time. Second, the figures in the 1990 report reflect use at the three shellfish beds that were open in 1989 and accessible from the Folly River boat landing, including S200. Since only S200 was closed following the spill, the 13.8 trips per day figure could overestimate the trips lost due to the spill. Conversely, though several areas of the Folly River near S200 were not closed, public misunderstanding or misperception regarding the closure may have affected trips and led to losses in other recreational shellfishing areas as well. In 2002, there were five areas in or adjacent to Folly River designated for recreational shellfishing (S189, S196, S200, S206 and R201). Additionally, this list includes two additional recreational beds designated since 1989 when the original data were collected. These factors imply the 13.8 trips per day figure is an underestimate of the trips affected by the spill. The net effect of all the above factors is unknown. The Trustees determined further surveys to refine the estimate of trips per day for use in this analysis was not warranted, in light of the modest identified losses and the potential time and cost of such additional investigation.

[15] This figure is as it appeared in the Draft RP/EA released in 2009.

3.3.3 Beach Use

Following the spill, some oiling was observed at Folly Beach, a county-operated recreation site located directly on the Atlantic Ocean south of the entrance to Charleston Harbor. Because Charleston County beaches continue to have considerable levels of use during late September and early October, particularly on weekends, the Trustees initiated a preliminary investigation into potential spill-related losses at Folly Beach. Data on attendance at Folly Beach was obtained, along with data for two other Charleston County beaches: Beachwalker County Park, located south of Folly Beach on Kiawah Island, and Isle of Palms County Park, located north of Folly Beach. Neither the Kiawah Island nor Isle of Palms beaches were directly impacted by the oil spill. Using the attendance data for the two nearby beaches as controls indicative of the possible influence of weather, the Trustees analysis did not indicate any significant change in attendance at Folly Beach associated with the oil spill.

3.3.4 Recreational Boating

The Trustees also conducted a preliminary investigation of potential public recreational boating losses in Charleston Harbor due to the spill. This investigation focused on potential losses associated with the disruption of access to and use of the waters of the Harbor by recreational boaters using the Cooper River Marina. Considerable oiling occurred in the vicinity of this marina, and during the course of containment and cleanup activities, an oil boom was placed around the perimeter of the marina. As a consequence, boats moored at this marina had no access to the waters of the Harbor for a period of ten days. At the same time, however, the hulls of most of the boats at the marina were oiled to some degree and, independent of the containment booming, this condition prevented their use until they could be cleaned[16]. Any disruption in recreational boating that could be attributed solely to the containment booming was likely minimal since the booms were in place for only 10 days and the affected area of the river was small. Aside from boating access at this marina, the Trustees' are not aware of any other potentially notable interference with recreational boating access. Taking into account all circumstances, the Trustees found that assessing public recreational boating losses associated with boaters originating from this marina would be difficult and likely involve costs in excess of the amount of any potential public claim. For these reasons, the Trustees determined that further action to assess public recreational boating losses based on this temporary interruption in access to area waters was not warranted.

[16] The oiling of these boats gave rise to private loss claims that were separately responded to and addressed by the RP for this spill.

4.0 RESTORATION PLANNING PROCESS

4.1 Overview

The goal of restoration planning under OPA is to identify restoration actions that are appropriate to restore, rehabilitate, replace or acquire natural resources or services equivalent to those injured or lost due to unlawful discharges of oil. Restoration planning may involve two components: primary restoration and compensatory restoration. Primary restoration actions are actions designed to assist or accelerate the return of resources and services to their pre-injury or baseline levels. Compensatory restoration actions, on the other hand, are actions taken to compensate for interim losses of natural resources and services, pending return of these resources and services to their baseline levels. For this Spill, response actions taken following the incident were sufficient to protect natural resources from further or future harm and to allow natural resources to return to pre-injury or baseline conditions within a reasonable period of time. Under these circumstances, it is unnecessary for the Trustees to consider or plan for primary restoration actions. Accordingly, this Final RP/EA addresses only compensatory restoration.

The goal of a compensatory restoration action is to restore, replace or acquire natural resources or services of the same type and quality, and of comparable value as those lost. To meet this objective, the NRDA regulations identify a variety of methods that may be used to evaluate or scale such actions. Trustees must consider using a service-to-service approach first. Under this approach, trustees determine the scale or amount of restoration that will provide a flow of natural resource services over time that will be equivalent to the quantity of services lost as a result of the resource injuries, taking into account the different time periods in which the services are provided through the use of discounting. When the service-to-service approach is not appropriate, trustees may use "valuation scaling". This approach explicitly measures the value of the resources and/or services lost; the scale of restoration is then defined as that required to produce natural resources and/or services of an equivalent value to the public. If, in the judgment of the trustees, use of the valuation scaling approach is not practicable, or cannot be performed within a reasonable time frame or at a reasonable cost, restoration is scaled using a "value to cost" approach. Under this approach, the scale of restoration will be that which can be achieved at a cost that is equivalent to the value of the resources and/or services lost.

The Trustees used a service-to-service approach to identify restoration sufficient to compensate for the ecological losses described in subsection 3.2. With respect to the ecological injuries, the Trustees identified and evaluated a reasonable range of restoration alternatives that would be potentially appropriate compensation for these. Consistent with the NRDA regulations, only those alternatives considered technically feasible and capable of being implemented in accordance with applicable laws, regulations and/or permits were considered (15 C.F.R. 990.53). The ecological restoration alternatives identified by the Trustees were then evaluated based on the criteria outlined in subsection 4.2 below. The "No Action" alternative was also considered, as required by NEPA and the NRDA regulations. In evaluating the alternatives, the Trustees sought to ensure that the restoration actions proposed for use would be capable of providing multiple benefits or services, so that restoration actions undertaken will also provide the greatest overall benefit to the public.

Section 5.0 presents the Restoration Plan selected as compensation for the ecological losses caused by the Spill (i.e., those losses identified in subsection 3.2 above). This section identifies the alternatives considered, the results of the Trustees' evaluation of those alternatives in light of the restoration objectives for the ecological injuries and the basis for selecting the preferred action. Consistent with its role as an Environmental Assessment under NEPA, this Final RP/EA includes information relating to potential environmental, social, and economic consequences of restoration in this setting and that the Trustees have considered in identifying the proposed restoration action.

The Restoration Plan presented in Section 5.0 does NOT address the recreational losses caused by the Spill (i.e., those identified in subsection 3.3 above). A separate Restoration Plan will be developed at a later time for those losses. This is appropriate in part because the value-to-cost approach will determine the "restoration scale" for the recreational losses, meaning that the amount of compensatory restoration for these losses will be equivalent in cost to (or achievable with) the dollar value of the recreational losses identified in subsection 3.3. The value-to-cost approach is being used because the methods required to implement either the service-to-service and valuation scaling approaches for these losses could not be applied without incurring significant additional costs and, based on the evidence available for this Spill, would be unlikely to yield a difference in restoration scale sufficient to justify the additional costs. Deferred plan development is also appropriate because the restoration goals for these losses are different and uncertainties associated with this planning (i.e., amount of restoration funds; community planning considerations; availability of matching funds; timing; necessary partnerships; etc.) make it difficult for trustees to complete a viable plan before funds are recovered. However, the Trustees intend to seek one project to compensate for both Shrimp baiting and Shellfishing recreational losses. The Trustees will develop a restoration plan for these losses as soon as is possible following any damages recovery, including with public input, prior to selecting a project for this purpose.

The remainder of this Section provides additional information pertaining to the restoration planning process undertaken for this Spill.

4.2 Restoration Selection Criteria

Consistent with the NRDA regulations, the following criteria were used to evaluate restoration project alternatives and to identify the restoration actions that where preferred for implementation:

<u>*The extent to which each alternative is expected to meet the Trustees' restoration goals and objectives*</u>: The primary goal of any compensatory restoration plan is to provide resources and services comparable to those lost. In meeting that goal for this Spill, the Trustees propose to create and/or enhance estuarine habitats and to enhance recreational access in and around the Cooper River/Charleston Harbor to offset assessed ecological and recreational losses. In addressing ecological losses, the potential relative productivity of restored habitat and whether the habitat is being created or enhanced is considered. Future management of the restoration site is also considered because management issues can influence the extent to which a restoration action meets its objective.

<u>*The cost to carry out the alternative*</u>: The benefits of an action relative to its cost are a major factor in evaluating restoration alternatives. Factors that can affect and potentially increase the costs of implementing a restoration alternative can include project timing, access to the restoration site (e.g., with heavy equipment or for public use), acquisition of state or federal permits, acquisition of the

land needed to complete a project, measures needed to provide for long-term protection of the restoration site, and the potential liability from project construction. The cost of monitoring sufficient to document restoration performance is a necessary component. Total project costs, and the potential availability of matching funds, if any, can also be considered.

The likelihood of success of each restoration alternative: The Trustees consider technical factors that represent risk to successful project construction, project function, long-term viability and sustainability of a restoration action. Alternatives susceptible to future degradation or loss, such as due to subsidence or erosion, are considered less viable. The Trustees also consider whether difficulties in project implementation are likely and whether long-term maintenance of project features is likely to be necessary and feasible.

The extent to which each alternative will avoid collateral injury to natural resources as a result of implementing the alternative: Restoration actions should not result in significant additional losses of natural resources and should minimize the potential to affect surrounding resources during implementation. Restoration actions with less potential to adversely impact surrounding resources are generally viewed more favorably. Compatibility of a restoration action with the surrounding land use and potential conflicts with endangered species are also considered.

The extent to which each alternative benefits more than one natural resource or service: This criterion addresses the interrelationships among natural resources, and between natural resources and the services they provide. Projects that provide benefits to more than one resource and/or yield more beneficial services overall, are viewed more favorably.

The effect of each alternative on public health and safety: Restoration actions that would negatively affect public health or safety are not appropriate.

The NRDA regulations give the Trustees discretion to prioritize these criteria and to use additional criteria, as appropriate. In developing this Final RP/EA, the first criterion listed above has been a primary consideration, because it is critical to ensuring that restoration will compensate the public for the resource injuries and losses attributed to this Spill through the Trustees' assessment. The evaluation of restoration alternatives using these criteria involves a balancing of interests in order to determine the best way to meet the restoration objective.

The Trustees approached restoration planning with the view that the injured natural resources and recreational services lost are part of an integrated ecological and recreational system and that the Cooper River/Charleston Harbor area represents the relevant geographical area for siting restoration actions. Areas outside the Cooper River/Charleston Harbor area were considered less geographically relevant as compensation for this Spill. This helped to ensure the benefits of restoration actions were related, or had an appropriate nexus, to the natural resource injuries and losses attributed to this Spill. The Trustees also recognized restoration actions should be consistent with local community objectives. Alternatives were considered more favorably if complementary with other community development plans/goals.

NEPA and the NRDA regulations required the Trustees to evaluate the "No Action" alternative, which for compensatory restoration equates to "No Compensation." Under this alternative, the

Trustees would take no action to compensate for interim losses associated with the evaluated natural resources.

4.3 Identification of Appropriate Restoration Alternatives

4.3.1 First Tier Screening of Potential Alternatives

At the outset of the restoration planning process, the Trustees used a matrix (Table 4.1) to compare potential restoration actions in the Cooper River/Charleston Harbor area to each of the ecological injuries and recreational impacts caused by the Spill. This exercise allowed the Trustees to identify restoration alternatives suited to meeting the stated restoration goal for each injury or loss. In this exercise, the Trustees rated each potential restoration alternative based on its ability to meet the primary restoration criterion for each type of injury or loss. Each injury/restoration alternative pairing was evaluated and assigned one of the following four ratings:

> **First Order Nexus –** Project type provides same resource services as were lost due to the injury.
>
> **Second Order Nexus –** Project type provides some of the same resource services as were lost due to the injury, and others that are similar.
>
> **Third Order Nexus –** Project type only provides resource services that are comparable and/or similar to those lost due to the injury.
>
> **No Nexus --** Project type does not provide any of the same resource services as were lost due to the injury, and does not provide any that are comparable or similar.

As a result of this comparative screening evaluation, the Trustees found that for the shoreline and bird injuries a Multi-Habitat Acquisition/Creation/Enhancement Project (Marsh, Upland, Oyster) was most closely aligned with the primary restoration selection criterion. This alternative was followed closely by implementation of Wetland or Oyster Reef-based actions.

For the Shrimp baiting and Shellfishing recreational losses, this screening evaluation indicated actions that would improve Boating Access would be likely to meet the primary selection alternative. This information will be carried over and help the Trustees develop a restoration plan for those losses in the future.

Potential Injury Types and Appropriate Potential Compensatory Restoration Alternatives		Creation of Wetlands	Creation of Wetland/Oyster Area	Restoration of Degraded or Impounded Wetlands	Restoration of Degraded Wetland/Oyster Area	Protection of existing wetlands (erosion...)	Protection of Wetland/Oyster Area	Oyster Reef Creation	Acquisition of multi-habitat area (upland, wetland, beach, oyster) (under threat of development)	Boating Access (ramps etc.)	Enhancement of Bird Rehabilitation Capabilities	Enhancement of Bird Rookeries (Dredge Material Placement, etc.)	Mulit-Habitat Creation/Enhancement Project (Marsh, Upland, Oyster)	Beach Protection Projects (dunes, etc.)
Shoreline														
Vegetated Shoreline		Green	Green	Green	Green	Green	Green	Yellow	Green	Red	Red	Orange	Green	Red
Non-Vegetated Shoreline		Yellow	Yellow	Yellow	Yellow	Yellow	Yellow	Orange	Green	Red	Red	Yellow	Green	Red
Hard Structure		Orange	Yellow	Orange	Yellow	Orange	Yellow	Yellow	Yellow	Red	Red	Red	Yellow	Red
Oyster Reef		Yellow	Green	Orange	Green	Orange	Green	Green	Green	Red	Red	Yellow	Green	Red
Birds														
Shorebirds		Yellow	Yellow	Yellow	Yellow	Yellow	Yellow	Yellow	Green	Red	Green	Green	Green	Green
Marsh Birds		Green	Green	Green	Green	Green	Green	Orange	Green	Red	Green	Green	Green	Red
Wading Birds		Green	Green	Green	Green	Green	Green	Yellow	Green	Red	Green	Green	Green	Red
Seabirds		Yellow	Yellow	Yellow	Yellow	Yellow	Yellow	Orange	Green	Red	Green	Green	Green	Green
Recreational Lost Use														
Shrimp Baiting		Orange	Orange	Orange	Orange	Orange	Orange	Orange	Orange	Green	Red	Red	Orange	Red
Oyster Harvesting		Orange	Yellow	Orange	Yellow	Orange	Yellow	Green	Orange	Green	Red	Red	Yellow	Red

Ranking: The potential restoration alternatives above should me ranked compared to the various injury categories along the left side based on the criteria below.

Symbol & Rank		Definition of Ranking
Green	First Order Nexus	A project that provide the same services compared to those that were lost as a result of the injury.
Yellow	Second Order Nexus	A project that provides some services that are the same and others which are similar to those lost as result of the injury.
Orange	Third Order Nexus	A project that provides comparable and similar services to those that were lost as a result of the injury.
Red	No Nexus	A project that does not provide the same or comparable service to those that were lost as result of the injury.

Table 4.1: Restoration Alternatives Matrix

4.3.2 Second Tier Screening - Identification of Project Alternatives

Having identified the types of restoration actions most likely to meet the restoration goal for each injury or loss, the Trustees began reviewing the specific project opportunities in the Cooper River/Charleston Harbor area consistent with these types of actions.

In 2003, the Trustees developed a list of more than 50 potential restoration opportunities in the Charleston Harbor area (Ridolfi Inc. 2003). Working cooperatively with the RP, the Trustees narrowed that list based on the following factors:

- Preference for projects that could be implemented in the short term.
- Preference for projects with a strong nexus to the injured resources.
- Preference for projects with a high degree of habitat enhancement.
- Preference for projects that limit disruption to existing resources.

Through that process, the following projects emerged as potential restoration alternatives for addressing the Shoreline and Bird injuries caused by this Spill:

- Noisette Creek Golf Course Wetland Restoration – Wetland restoration by breaching of a berm, adding a network of tidal creeks and lowering elevation of portions of the site of an abandoned golf course.
- Saltmarsh Creation/Enhancement at Long Branch Creek (Installation of Water Structure in Diagonal Berm) - Saltmarsh enhancement/creation by installing water conduit structure in an existing berm that was built at a "diagonal" axis to the creek.
- Saltmarsh Enhancement at Long Branch Creek (Culvert, Flap-gate & Berm Removal) - Saltmarsh enhancement by removing a water control structure and associated berms that were used to prevent saltwater from inundating upstream areas.
- Saltmarsh Enhancement at Long Branch Creek (Highway 17 Box Culverts Upgrade) - Saltmarsh enhancement by upgrading existing box culverts where Long Branch Creek flows under State Highway 17.
- Saltmarsh Enhancement at Long Branch Creek (Greenway Culvert Replacement) – Saltmarsh enhancement by replacing currently undersized culverts with a pedestrian bridge and/or properly sized culverts.
- Saltmarsh Creation/Enhancement at Noisette Creek (Concrete Perimeter Road Removal) – Saltmarsh enhancement/creation by removing an existing concrete causeway, grading and then planting *Spartina*.
- No Action.

The Trustees evaluated these alternatives using the criteria listed in subsection 4.2. The Trustees' evaluation of these alternatives is summarized in Table 4.2 (reflected by scale of zero to plus three). The preferred restoration alternative - Noisette Creek Golf Course Wetland Creation – is highlighted in bold. The Restoration Plan for Ecological Injuries presented in

Section 5.0 provides further information regarding the basis for choosing this restoration alternative and the evaluation of the non-preferred alternatives.

Restoration Alternative	Implementable in short term	Strong nexus between injured & restored habitats	Amount of habitat function enhancement	Avoids injury to existing resources
Long Branch Creek Diagonal Berm	No	+++	+++	Yes
Long Branch Creek Tidegate and Berm Removal	No	+++	+++	Yes
Long Branch Creek Highway 17 Box Culverts Upgrade	No	+++	+	Yes
Long Branch Creek Greenway Culvert Replacement	No	+++	+	Yes
Noisette Creek Golf Course	Yes	+++	+++	Yes
Noisette Creek Concrete Perimeter Road Removal	Yes	+++	++	Yes
No action	Yes	0	0	0

Table 4.2 Summary of Trustees' Second Tier Screening of Restoration Alternatives

5.0 RESTORATION PLAN FOR ECOLOGICAL INJURIES AND ANALYSIS FOR NEPA REQUIREMENT

The restoration project selected to compensate for ecological injuries is identified in subsection 5.1. Subsection 5.2 describes the other project alternatives that were considered but not selected.

5.1 Selected Alternative: Noisette Creek Golf Course Wetland Restoration

The selected project will restore saltmarsh habitat at the site of the former Navy golf course along Noisette Creek in North Charleston. This land is owned by the city of North Charleston and the Noisette Company and is identified as a priority site for restoration in the Noisette Creek Restoration Plan. The project will entail breaching a berm in two areas along Noisette Creek and construction of a network of tidal creeks throughout the property. Roads, drainage tiles, rip-rap and other sources of debris will be also be removed. These actions will result in increased tidal exchange across the site that will restore and improve tidal marsh habitat for fish and invertebrates. A total of 11.7 acres of saltmarsh habitat will be restored. Additionally, five upland islands totaling .45 acres will remain within the marsh and perimeter uplands bordering the entire site will be restored to functional marsh buffer habitat for such species groups as passerine birds.

Figure 5.1 Aerial view of the Noisette Creek Project Site

5.1.1 Historic and Current Project Site Conditions

Land Use

The project site is located close to the confluence of Noisette Creek and the Cooper River. The area has a long history of habitation. In the late 17th century, plantations were established north and south of the creek and focused on the development of land for agriculture. In 1901, the City of Charleston provided the land to the U.S. Navy for development of a naval base. To create more useable land within the base, the Navy placed dredge spoils and other fill in nearby marshes. As part of this effort, the Navy filled in the marsh on the south side of Noisette Creek to create an executive golf course. Use of the site as a golf course continued until the Navy closed the base in 1996. The land was subsequently transferred to the City of North Charleston. Today, the majority of the land encompassing the former golf course is owned by the City of North Charleston; a small part of the site's most upland reach is owned by the Noisette Company. In recent years, the site has been unmanaged and is now largely overgrown with vegetation.

In 2002, the City of North Charleston entered into a Purchase and Sale Agreement with the Noisette Company to redevelop the former naval base property. Under this agreement, the Noisette Company was to provide master planning services for an approximately 4 $miles^2$ area that encompassed the former naval base property as well as adjacent incorporated areas of the City of North Charleston. A central feature of this agreement was the delineation of a 135 acre "recreation and nature preserve at the heart of the redevelopment, located around Noisette Creek and its marshes, creeks and inlets" called the Noisette Preserve. The Preserve area consists of 72 acres of existing marshes and open water, 55.6 acres that the City has contributed, and 7.3 acres that the Noisette Company plans to contribute.

In 2005, the Noisette Preserve Plan was developed. This plan outlines specific ecological restoration needs and management plans for the Preserve. The Preserve Plan included plans to restore the former Navy golf course site back to a tidal marsh environment as well as other recommendations for the entire 1400 acre Noisette Creek watershed intended to protect and enhance the Preserve.

Hydrology

The hydrology at the project site reflects the matrix of complex hydrological modifications carried out during past filling of the marsh and construction of the golf course. These modifications blocked routine tidal inundation from Noisette Creek. With the exception of the course's greens, a central north-south berm, and several roadways, the filling of the golf course was inadequate to fully raise it above tidal elevations. The greens, berm and roadways appear to have been created using fill from excavation of a pond on site, but also may have required fill from offsite. The site also features approximately 5,000 linear feet of subsurface drainage tiles that are connected to surface grates.

Topographic studies[17] and field observations indicate that the current tidal range within the site is muted compared to the tidal range reported outside of the water control structures, and that drainage is impeded by the structures and clogged drainage tiles (Figure 5.2). In addition, the site's north-south berm (Figure 5.2) separates the east and central drainage basins and appears to prevent free exchange of tidal waters with Noisette Creek, slows freshwater drainage from

[17] Topographic survey results from December 4-7, 2006 show a range of present elevations across the site, from a minimum +0.9 ft NGVD in the unvegetated portions of the constructed pond to a maximum +5.2 NGVD at the top of the highest former green. The majority of the site, however, features elevations between +3.0 and +4.0 ft NGVD (Figure 5.2). Reports indicate the 2006 mean range of tides at the Customhouse Wharf in Charleston is 5.3 feet, with the Mean Higher High Water (MHHW) reported to be + 6.1 feet Mean Lower Low Water (MLLW), and Mean Tide (MT) reported as +2.8 ft MLLW.

rainfall and slows upland drainage across the site.

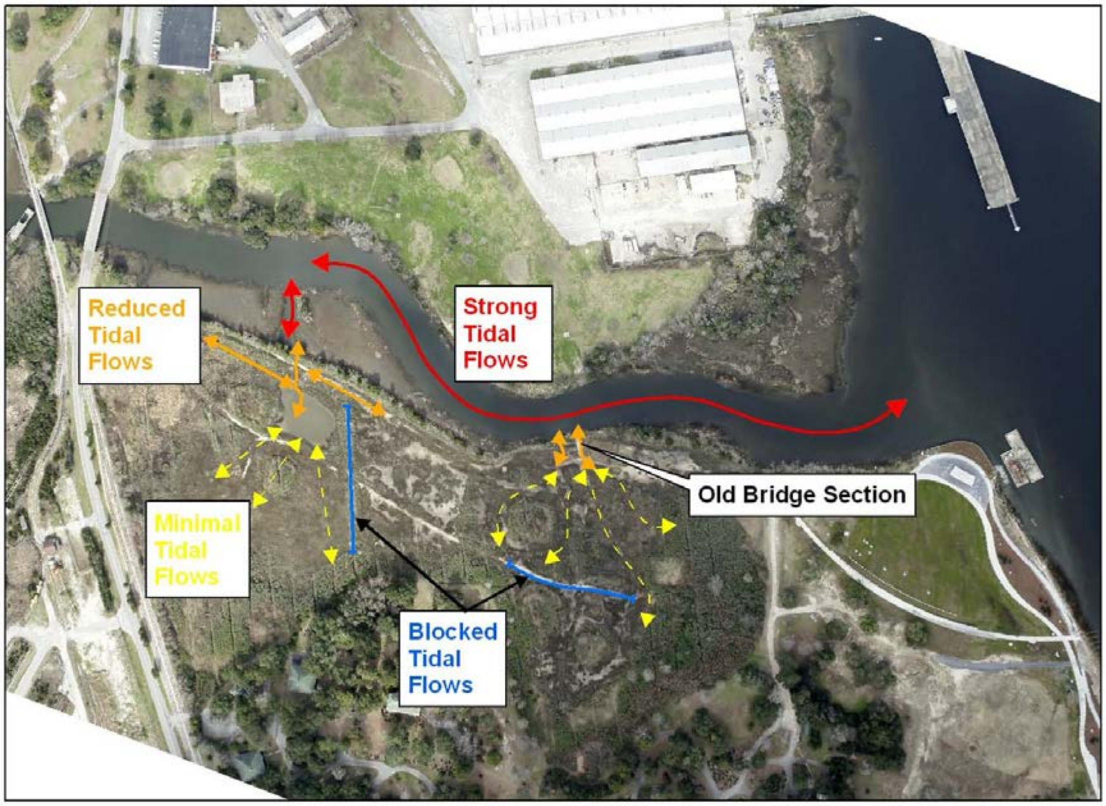

Figure 5.2 Current Hydrology of the Noisette Creek Site

Vegetation

Topographic maps included and data collected as part of the December 2006 survey indicate that most of the Noisette Creek landscape was saltmarsh prior to construction of the golf course. As saltmarsh, the site would have been dominated by smooth cordgrass (*Spartina alterniflora*). The site would have been characterized by taller and more vigorous growth of this species alongside Noisette Creek but these plants would have become shorter, sparser and intermixed with beach cordgrass and other salt-tolerant species further from the channel. Along the site's upland edge, the smooth cordgrass might have been replaced by zones of more salt-tolerant low-growing wetland plants. Where freshwater entered the marsh, there would likely have been stands of black rush (*Juncus roemerianus*).

Turf grasses were presumably planted on the greens and fairways when the golf course was constructed. Though the trustees have no records showing what species were planted in creating the course, Bermuda grass is present on the greens now and suggests some variety of *Cynodon dactylon* was used on parts of the course.

The status of vegetation communities at the site today indicates the golf course was abandoned at least 15 years ago. Natural ecosystem recovery processes have allowed coastal wetland plants to re-establish across most of the site but only to a limited degree as topographic and hydrological alterations, exotic plant invasion, and human disturbance (including periodic mowing) have interfered with normal succession and recovery patterns. Eighty-one (81) species of plants were identified during the December 2006 survey. Most of the species on the site now can be generally grouped into one of the following four (4) categories of vegetation types: Salt Marsh, Brackish Marsh, Salt Flat and Salt Shrub Thicket. Although the site's elevated greens and berm along the creek are man-made landscape features (and not directly analogous to any of the site's original South Carolina habitats), these areas have been colonized by native plants and have begun to function like natural communities in the years since the course was abandoned. However, continuing human disturbance (including periodic past mowing) and invasion by exotic plant species are preventing these areas from progressing towards a higher level of ecological function.

Fauna
Observations of fauna at the site in recent years involve mainly passerine birds, a few wading birds, some small fish species and some invertebrates. No mammals were observed, but raccoon (*Procyon lotor*) and opossum (*Didelphis virginiana)* are likely residents. Small passerine birds observed using the site include a white-eyed vireo (*Vireo griseus*), blue jay (*Cyanocitta cristata*), cardinal and loggerhead shrike (*Lanius ludovicianus*). A northern harrier (*Circus cyaneus*) was spotted cruising over the marsh. The wading birds observed were six white ibis (*Eucocimus albus*) (overhead) and one snowy egret (*Egretta thula*). Calls of clapper rails (*Rallus longrostris*) were heard on occasion. Use of the site for feeding by herons and egrets appears largely non-existent. Likely this is due to the lack of shallow tidal creeks suitable to allow small fish to enter and exit the site.

Invertebrates observed included fiddler crabs (*Uca* spp.) and the marsh periwinkle (*Littorina littorea*). The total numbers of these species appeared to be very low, however, and they were observed only in a few specific locations suitable to survival under the wide range of flooding and drying conditions, and wide variability in salinities.

5.1.2 Description of Selected Restoration Actions

The hydrologic alterations, exotic plant invasion and human disturbances collectively continue to hinder recovery and to prevent full functioning of wetlands at the site. The vegetation communities struggle to progress through natural succession within disturbed areas and fauna diversity is limited due to the unavailability of suitable habitat. The site's value as wetland habitat can be increased through restoration actions. The Project involves activities needed to restore the site's hydrologic regime, increase the area of marsh, accelerate natural recovery of wetland vegetation, increase faunal diversity, and enhance wetland functioning.

The Project involves the removal of existing roads, the creation of tidal creeks, the removal of all the drainage tile systems, breaching of the north-south berm at two locations and removal of the creek side berm in the area where the major tidal connection and drainage pipes exist (Figure 5.3). These actions will increase the tidal range over the site and result in a more normal drainage pattern of freshwater flow from rainfall and uplands. This will allow for increased mixing of marine and freshwater and result in re-establishment of a salinity regime suitable for the growth of salt marsh vegetation and healthy functioning of tidal wetlands. Restoration of tidal flow and normalization of the salinity regime are necessary elements for restoring and improving habitat conditions at this site. The habitat improvements will encourage colonization and use of these wetlands by the small estuarine fish and invertebrates normally seen in these habitats.

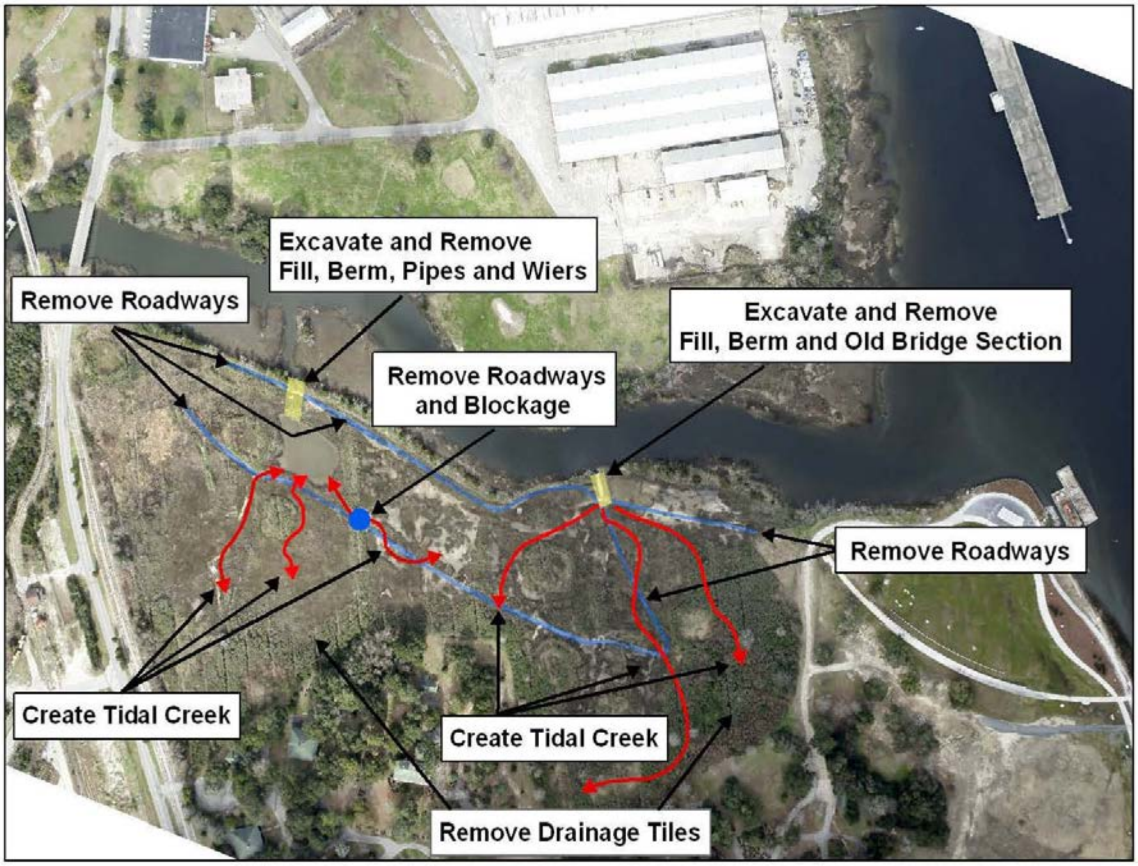

Figure 5.3 Overview of Selected Restoration Actions

Figure 5.3 provides an overview of the restoration activities associated with the Project. The Project is expected to result in enhanced functioning of tidal marsh habitat over 11.70 acres. Two tidal connections will be constructed (0.12 acres). Five upland islands within the marsh (0.45 acres) and the existing pond (0.36 acres) will remain. The 0.45 acre of island uplands and the perimeter uplands will be restored to functional marsh buffer habitat. This will be achieved by removing exotic plant species (primarily Chinese tallow) and planting of native upland species such as red cedar and southern red oak.

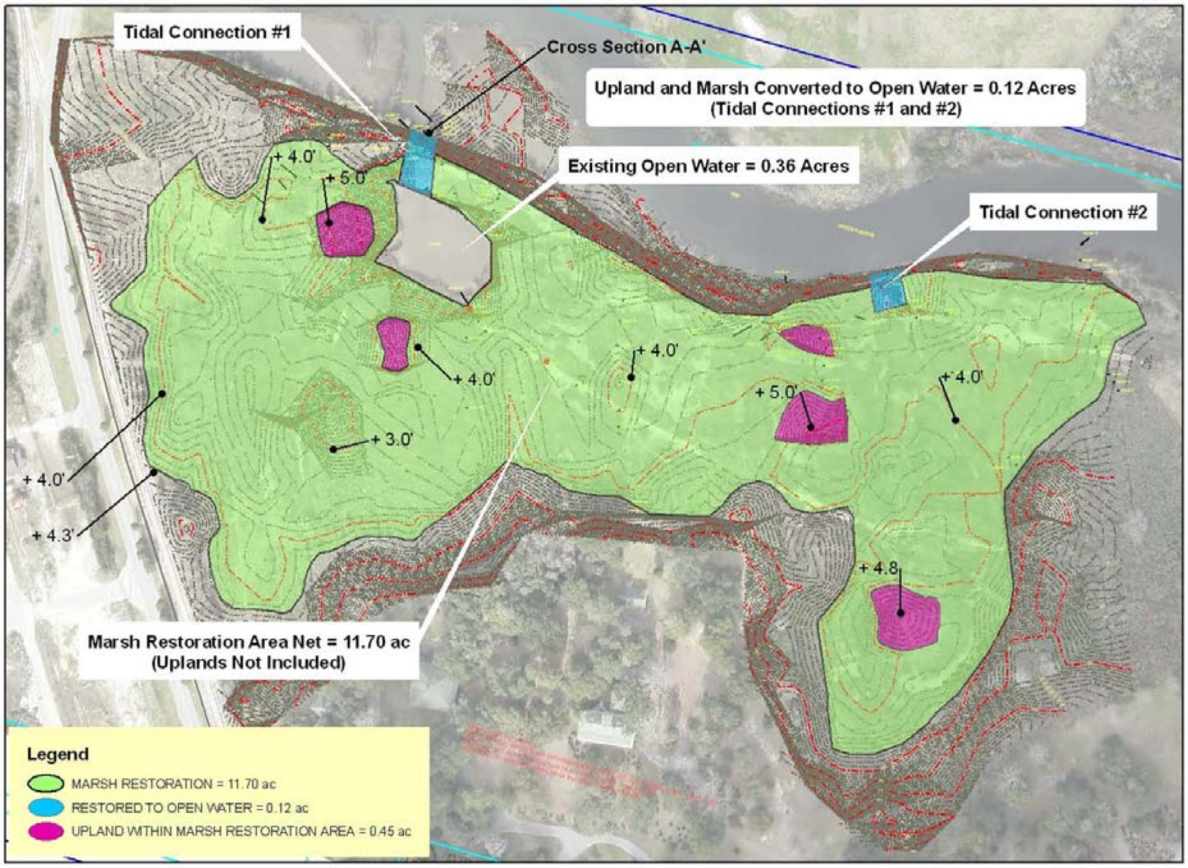

Figure 5.4 Expected Site Characteristics Post-Restoration

To ensure the restoration actions result in the establishment of the expected structural and functional site characteristics, detailed monitoring activities of the site will be conducted to ensure specified success criteria will be met at appropriate time horizons. Details of this process will be explained in a Restoration Implementation Monitoring Plan.

5.1.3 Evaluation of Alternative

The selected Project represents an opportunity for successful estuarine habitat restoration using a very cost-effective approach: the re-introduction of tidal flow. The Project site is within the Cooper River and Charleston Harbor environment affected by the spill and is central to the areas where injuries to birds and shoreline habitats occurred. The improved salt marsh habitat will provide shoreline habitat services comparable to those lost and habitat and food sources needed to locally enhance affected bird populations. The planned restoration activities, including the techniques to be used in implementation, have a high likelihood of success. The restored wetland is expected to require minimal intervention following implementation in order to achieve functional success, to be largely self-sustaining, and to provide an uninterrupted flow of services into the future. The Project is consistent with the public objectives and master plan for re-development of the approximately 4 square mile area encompassing the former naval base property as well as the Noisette Preserve Plan which describes both restoration needs and management plans for this site within the 135 acre Noisette Preserve. The public owners and partners involved in planning and restoration of lands within the Preserve approve of the proposed restoration actions at the site, will allow access to the site for implementation and monitoring and will ensure long-term protection of the restored site through appropriate measures. The nature of the Project and the setting for implementation would present no human health or safety issues beyond those met by standard procedures for safe construction.

5.1.4 Evaluation of Restoration Scale

The scale, or size, of a restoration project should provide enough ecological service gains to offset assessed losses. This section describes the Trustees' evaluation of the scale of restoration required to compensate for the bird and shoreline losses described in subsection 3.2 and the ability of the proposed Project to provide offsetting ecological gains. The scale of restoration required is first presented in terms of the amount of salt marsh *creation* required to offset the assessed losses. The Project described in subsection 5.1, however, is focused on a site with areas currently providing some wetland functioning, albeit in a degraded state. The Project will result in "enhancement" of the functioning of these existing wetlands, not the "creation" of new wetlands. On a per-acre basis, "enhancement" will yield a percentage of the wetland services that would be gained via creation of a new wetland acre. The means by which the Trustees translated the marsh "creation" requirements derived for the bird and shoreline injuries for use in evaluating the "enhancement" gains expected from implementation of the Project is also described in this section. The comparison of losses and gains is expressed in terms of "discounted service-acre-years", or DSAYs, lost. To allow comparison, 'service-acre-years' have to be discounted to account for the difference in time between when losses occur and services gained through restoration are delivered.

A. Restoration Requirement for Bird Injuries

For bird losses, the amount of salt marsh restoration required to offset the assessed bird losses was estimated using food web modeling and HEA calculations. This was a two step process involving (1) the use of trophic transfer modeling to estimate the compensatory bird food production rate per unit of salt marsh created and (2) determining the amount of food required to produce additional fledglings. This information was then used to calculate the area of marsh required to offset the assessed loss, that is, to produce the same number of fledglings assessed as equivalent to the bird losses in subsection 3.2.1. This approach recognizes that the creation of saltmarsh increases invertebrate and fish production, the additional production represents appropriate bird food (i.e. added prey biomass) for the injured bird species, and increases in the prey biomass for birds can contribute directly to increasing fledgling production and survival.

Following this method, the Trustees estimate that 5.8 acres of salt marsh creation (75.95 DSAYs) would be required to produce sufficient food to feed a sufficient number of fledglings to compensate over time for the bird losses. Further details of this scaling analysis for birds may be found in the *Final Report on Restoration Scaling for Bird Injuries*, November 13, 2006, included in this RP/EA as Appendix C.

Injury Basis	**Number of Birds**	**Created Wetland Acres Required (to feed the fledglings)**
Observed heavily oiled birds	19-24	1.3
Observed lightly oiled birds	101-106	*2.3*
Based on SIMAP modeling	45-50	2.2
Total Birds	175	5.8

Table 5.1: Estimated Restoration Requirements for Birds[18]

The largest wetland creation requirement is associated with the bird losses.

B. Restoration Requirement for Shoreline Injuries

Subsection 3.2.3 describes in the shoreline losses estimated using the HEA method. This represents the 'debit side' of this model[19]. The HEA method can also be used to estimate the extent of restoration needed to compensate for these losses. The total ecological service losses for the four types of shoreline habitats affected by the Spill are estimated to be 12.22 DSAYs.

To determine the salt marsh *creation* needed to offset the shoreline losses, the Trustees assumed that a salt marsh creation project would begin in the year 2009, take 15 years to reach 80% of full function, and have a project lifespan of 50 years. Applying these assumptions, the Trustees estimated that one acre of salt marsh creation would yield 13.095 DSAYs over its lifespan. Offset of the assessed shoreline losses then would require .93 acres of salt marsh creation.

The Trustees' evaluation of the gains (DSAYs of new salt marsh services) estimated from the proposed Project over its lifespan are described below.

C. Selected Project - Restoration Credit Analysis

The Noisette Creek Golf Course Wetland Restoration Project will restore 11.7 acres of saltmarsh. As explained earlier, the site has already begun a slow natural transition towards re-establishing itself as a wetland. The Trustees estimate[20] that the site's present level of functioning provides approximately 25% of the services that a natural wetland would normally

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[18] The values in this table have been adjusted to correspond to restoration implementation in 2009. The same table in the Final Report on Restoration Scaling for Bird Injuries (Appendix D) presented values assuming restoration implementation in 2007.

[19] HEA begins with the injury assessment and an identification of the habitat-specific resource services that were lost due to the incident. A "debit" is specified for the lost services for each type of resource habitat. The debit equals the loss in service-acre-years from the injury to the habitat, as a result of the incident, in present-value terms. For each debit, the scale of a compensatory restoration project is determined by calculating the credit, per acre, that a restoration project will generate over its lifespan. This credit is the present value of the ecological services provided by the project. The size of the compensating project needed to produce total service gains over time that equate to the total services lost is then determined.

[20] This estimate is based on the collective expertise and best professional judgment of the Trustees' technical staff.

provide. When estimated, restoration actions at the site were expected to occur in the year 2009, with the site expected to reach maximum wetland functioning (80% relative value compared to a natural marsh) in the year 2024. The Project is expected to have a 50 year lifespan. Using these as input parameters, the Trustee's calculated that the Project would yield a net increase in wetland services of 9.003 DSAYs per acre over the lifespan of the 11.7 restored acres. This results in an estimate that the Project would yield a total of 105.7 in additional DSAYs over its lifespan. These service gains would be sufficient to offset the losses assessed for the bird and shoreline injuries.

5.1.5 Environmental & Socio-Economic Impacts

The environmental and socio-economic impacts of the described restoration actions are largely beneficial. The actions to be implemented will increase tidal exchange over the site, improve and enhance a tidal marsh habitat, improve and enhance adjacent buffer and upland areas, and increase the site's overall diversity, value and usage as habitat for fish, invertebrates, birds and other wildlife. These effects, in turn, will contribute to improving the overall quality of the environment within Charleston Harbor, allowing for increased populations of birds, improved habitat for marine mammals**,** improved habitat for intertidal and subtidal biota, and other benefits for a variety of federally threatened and endangered species and State-listed sensitive species in this system. Certain restoration actions (e.g., berm breaching; excavation and removal of roads, drainage system and debris; creating tidal creek network, etc.) have associated adverse effects, including noise, added traffic, and turbidity in surface waters. These effects, however, will be localized and of very limited duration. Potential impacts from invasive species as a result of site modifications will be minimal, as the restoration action will create habitat conditions conducive to the re-establishment of native species. To eliminate the potential of invasive introduction to the project site, no invasive materials will be transported from off-site, and local contractors and equipment will be utilized for construction. Post-construction monitoring will include observations and actions as needed to prevent or control invasive species. The Project will have only positive impacts in the local community. The actions to be undertaken will restore an area adjacent to a city park and residential community that is currently run-down and overgrown. These improvements will contribute to and increase the value of the Noisette Preserve area as a public amenity within the community. Such improvements also help support or increase local property values and contribute to the overall quality of life in North Charleston. The Project's location directly adjacent to a city park may allow for increased educational opportunities. Both recreational and commercial fisheries in the Charleston Harbor area have the potential to indirectly benefit as the proposed Project will improve habitat in the system that many economically important species of finfish and invertebrates rely on during various life stages.

The project, as described in section 5.1.2 above, is not expected to have a significant cumulative effect on the human environment since it alone, or in combination with other wetland restoration projects in the vicinity, will not result in any change in the larger current pattern of hydrologic discharge, boat traffic, economic activity or land-use in the Charleston Harbor watershed.

Additional information on the likely ecological and socio-economic effects of the Project is found in subsection 6.1 (NEPA Significance Analyses).

5.2 Non-Selected Restoration Alternatives

5.2.1 Saltmarsh Creation/Enhancement at Long Branch Creek (Installation of Water Structure in Diagonal Berm) - This project involves the installation of a water conduit structure in an existing berm that was built at a "diagonal" axis to Long Branch Creek. This berm currently restricts tidal flow. The proposed structure would serve to increase tidal flow to the impounded area and result in an improvement in salt marsh habitat for fish and invertebrates.

Evaluation of Alternative
While this project could conceptually meet the Trustees' goals and objectives in this Final RP/EA and also presents a high likelihood of success, the project was not favored because of inherent complications, delays, and additional costs associated with relocating utility lines that are currently buried in the berm. The project also has foreseeable potential permitting problems since it involves exposing an area currently designated as "jurisdictional freshwater wetlands" to increased tidal flow and salinity intrusion. Indeed, these wetlands are already proposed to be protected in their current freshwater condition as part of a master plan for an adjacent residential development. Taking into account the complications and costs associated with gaining the support of stakeholders, relocating the utility lines and the obstacles to obtaining necessary permits, the Trustees concluded this was likely not a viable option for use to compensate for injuries and losses caused by this Spill.

Environmental and Socio-Economic Impacts
The environmental impacts of this project would be similar in nature to those of the preferred project and largely beneficial (i.e., would add ecological services comparable to those lost, including habitat and food sources needed to enhance fish, invertebrates, and affected bird populations, would be largely self-sustaining, and would provide an uninterrupted flow of services into the future). The effects would benefit a wide variety of fish and wildlife, including those of recreational and commercial importance. Construction may disturb or displace resources within the footprint and immediate vicinity of the project area, but these impacts would be minimal, largely temporary, and result in no long-term effects other than the positive effects associated with the future functioning of the enhanced marsh. Further, its implementation would present no human health or safety issues beyond those met by standard procedures for safe construction.

5.2.2 Saltmarsh Enhancement at Long Branch Creek (Culvert with Flap Gate & Berm Removal)- This project would entail the removal of a water control structure (culvert with one-way flap gate), together with its associated berms. Removal of these structures would increase tidal flow and circulation and restore salt marsh habitat to the relic impounded area.

Evaluation of Alternative
This project represents a cost-effective means of restoring salt marsh, has a high likelihood of success and is consistent with the goals and objectives of the restoration planning for this Spill. However, plans already approved for an adjacent residential development provide for incorporating this berm into a system of walking trails for residents of the development and the owners/developers of this land have indicated they are not willing to modify that plan. The Trustees believe that the actions involved in this

project could be designed to be compatible with use of this berm as part of the residential walking trail, however, until the current owners of the berm area will agree to these modifications, or until ownership is transferred to another entity (such as a homeowners association), project implementation will not be feasible.

Environmental and Socio-Economic Impacts
The environmental impacts of this project would be similar in nature to those of the proposed project and largely beneficial (i.e., would add ecological services comparable to those lost, including habitat and food sources needed to enhance fish, invertebrates, and affected bird populations, would be largely self-sustaining, and would provide an uninterrupted flow of services into the future). The effects would benefit a wide variety of fish and wildlife, including those of recreational and commercial importance. Construction may disturb or displace resources within the footprint and immediate vicinity of the project area, but these impacts would be minimal, largely temporary, and result in no long-term effects other than the positive effects associated with the future functioning of the enhanced marsh. Further, its implementation would present no human health or safety issues beyond those met by standard procedures for safe construction.

5.2.3 Saltmarsh Enhancement at Long Branch Creek (Highway 17 Box Culverts Upgrade) – This restoration alternative involves upgrading existing box culverts where Long Branch Creek flows under State Highway 17. This action would improve hydrologic conditions by increasing tidal flow that would result in enhanced functioning of an existing salt marsh.

Evaluation of Alternative
This project would have a high likelihood of success and is also consistent with the goals and objectives of the restoration planning for this Spill but several factors weighed against its selection. Though the existing culverts are slightly undersized (they are not visible at high tide), they appear to provide adequate tidal exchange. Costly engineering studies would be needed both to understand the extent of the hydrologic benefits that could be realized as well as to determine the risk to local properties and infrastructure from any hydrologic alteration. Also, Highway 17 is a major transportation artery and disrupting that critical traffic flow for any period of time would involve political, public relations, and financial challenges, a longer period for project planning with South Carolina Department of Transportation and project delay.

Environmental and Socio-Economic Impacts
The environmental impacts of this project would be similar in nature to those of the proposed project and largely beneficial (i.e., would add ecological services comparable to those lost, including habitat and food sources needed to enhance fish, invertebrates, and affected bird populations, would be largely self-sustaining, and would provide an uninterrupted flow of services into the future). The effects would benefit a wide variety of fish and wildlife, including those of recreational and commercial importance. Construction may disturb or displace resources within the footprint and immediate vicinity of the project area, but these impacts would be minimal, largely temporary, and result in no long-term effects other than the positive effects associated with the increased tidal hydrology and exchange resulting from the restoration project.

5.2.4 Saltmarsh Enhancement at Long Branch Creek (Greenway Culvert Replacement) – This project involves increasing tidal flow through a large berm that is the first point of tidal restriction on Long Branch Creek. The berm is part of a community greenway that is built over two undersized culverts, located approximately 1300 feet downstream from Highway 17. This project alternative would increase tidal exchange for the entire Long Branch Creek system by constructing a pedestrian bridge and/or incorporating properly sized culverts. This action would improve hydrologic conditions by increasing tidal flow that would result in enhanced functioning of an existing salt marsh.

Evaluation of Alternative
This project would have a high likelihood of success and is consistent with the goals and objectives of the restoration planning for this Spill, however, several factors weighed against its selection. Costly preliminary studies (i.e.: detailed hydrological modeling) are needed to assess the extent to which increasing the tidal prism at this point in the creek would put undue pressure on the undersized box culverts located at Highway 17. The results of these studies are critical to determining the project's overall desirability and feasibility. These studies have not been conducted by local agencies to date due to lack of funds. There is also uncertainty as to whether increasing the flow to the creek system would result in sufficient improvement in the system to meet the compensatory goal of this restoration plan. All of these factors weighed against preferring this alternative.

Environmental and Socio-Economic Impacts
The environmental impacts of this project would be similar in nature to those of the proposed project and largely beneficial (i.e., would add ecological services comparable to those lost, including habitat and food sources needed to enhance fish, invertebrates, and affected bird populations, would be largely self-sustaining, and would provide an uninterrupted flow of services into the future. The effects would benefit a wide variety of fish and wildlife, including those of recreational and commercial importance. Construction may disturb or displace resources within the footprint and immediate vicinity of the project area, but these impacts would be minimal, largely temporary, and result in no long-term effects other than the positive effects associated with the increased tidal hydrology and exchange resulting from the restoration project.

5.2.5 Saltmarsh Creation/Enhancement at Noisette Creek (Concrete Perimeter Road Removal) – This project, which would also occur on the former Charleston Naval Shipyards site, involves removing an existing concrete causeway and removing and re-grading fill material to reintroduce tidal flow and restore salt marsh.

Evaluation of Alternative
While this project could conceptually meet the Trustees' goals and objectives in this Final RP/EA, the project site is the subject of ongoing environmental investigations for soil and sediment contamination. The potential presence of contamination raises questions about its suitability for restoration and its likelihood of success. Further, these investigations will delay planning and implementation of any restoration project and may lead to further delays and costs if clean up is determined to be necessary. The Trustees did not prefer this alternative for these reasons.

Environmental and Socio-Economic Impacts
The environmental impacts of this project would be similar in nature to those of the selected project and largely beneficial (i.e., would add ecological services comparable to those lost, including habitat and food sources needed to enhance fish, invertebrates, and affected bird populations, would be largely self-sustaining, and would provide an uninterrupted flow of services into the future). The effects would benefit a wide variety of fish and wildlife, including those of recreational and commercial importance. Construction may disturb or displace resources within the footprint and immediate vicinity of the project area, but these impacts would be minimal, largely temporary, and result in no long-term effects other than the positive effects associated with the increased tidal hydrology and exchange resulting from the restoration project. .

5.2.6 No Action – Under this alternative, the Trustees would take no direct action to restore injured natural resources or compensate for lost services pending natural recovery.

Evaluation of the Alternative
NEPA requires the Trustees to consider a “no action” alternative, and the OPA regulations require consideration of the natural recovery option. These alternative options are equivalent. Under this alternative, the Trustees would rely on natural processes for recovery of the injured natural resources. While natural recovery would occur over varying time scales for the injured resources, the interim losses suffered would not be compensated under the “no action” alternative.

Environmental and Socio-Economic Impacts
This approach relies on the capacity of ecosystems to “self-heal”. The principal advantages of this approach, where it is appropriate, are its ease of implementation and low cost. In this restoration planning process, however, the Trustees objective is to compensate for assessed losses in the form of actions that will restore, replace, or provide services equivalent to those lost. Under the “no action” alternative, restoration actions needed to make the environment and the public whole for its losses would not occur. This is inconsistent with the goals of natural resource damage provisions under OPA, and the compensatory objective of this restoration plan. Thus, the Trustees have determined that the “no action” alternative *(*i.e., no compensatory restoration) must be rejected on that basis.

6.0 NEPA, ENDANGERED SPECIES ACT AND ESSENTIAL FISH HABITAT: ANALYSES AND FINDING OF NO SIGNIFICANT IMPACT

6.1 NEPA Significance Analyses and Finding of No Significant Impact

As noted in subsection 1.5, NEPA requires federal agencies to prepare an environmental impact statement (EIS) if they are contemplating implementation of a major federal action expected to have significant impacts on the quality of the human environment. NEPA defines the human environment comprehensively to include the "natural and physical environment and the relationship of people with that environment". 40 C.F.R. § 1508.14. All reasonably foreseeable direct and indirect effects of implementing a project, including beneficial effect, must be evaluated. 40 C.F.R. § 1508.8. Federal agencies prepare an environmental assessment (EA) to consider these effects and evaluate the need for an EIS. If the EA demonstrates that the proposed action will not significantly impact the quality of the human environment, the agency issues a Finding of No Significant Impact (FONSI), which satisfies the requirements of NEPA, and no EIS is required.

In accordance with NEPA and its implementing regulations, an EA is integrated into this Final RP/EA. The main body of this document summarizes the environmental setting, describes the purpose and need for restoration, identifies the alternatives considered, assesses their applicability and potential environmental consequences and summarizes the opportunity the Trustees provided for public participation in the development of this Final RP/EA.

This section of the document specifically addresses the factors and criteria that federal agencies are to consider in evaluating the potential significance of proposed actions, as identified in Section 1508.27 of the NEPA regulations. 40 C.F.R. § 1508.27. The regulations explain that significance embodies considerations of both context and intensity. In the case of a site-specific restoration project, as proposed in this Final RP/EA**,** the appropriate context for considering significance of the action is local, as opposed to national or worldwide.

With respect to intensity of the impacts of the proposed restoration action, the NEPA regulations suggest consideration of the following factors:

- likely impacts of the proposed project including on biodiversity and/or ecosystem function
- likely effects of the project on public health and safety,
- unique characteristics of the geographic area in which the project is to be implemented,
- controversial aspects of the project or its likely effects,
- degree to which possible effects of implementing the project are highly uncertain or involve unknown risks,
- precedential effect of the project on future actions that may significantly affect the human environment,
- possible significance of cumulative impacts from implementing this and other similar projects,
- effects of the project on sites listed on the National Register of Historic Places, or likely impacts to significant cultural, scientific or historic resources,

- degree to which the project may adversely affect endangered or threatened species or their critical habitat
- likely impacts resulting from the introduction or spread of nonindigenous species, and
- potential violations of environmental protection laws.

These factors, together with the federal Trustees' conclusion concerning the likely significance of the preferred restoration Project (preferred alternative), are reviewed below.

Nature of Likely Impacts, including on Biodiversity and Ecosystem Function
The anticipated restoration actions will increase tidal exchange to accelerate recovery and enhance 11.7 acres that are slowing transitioning to estuarine wetlands. The restoration actions will increase marsh habitat function and habitat diversity at the site. Additionally, the action will generally provide improved nursery, foraging, and cover habitat for numerous species of fish that utilize fringe marsh, as well as other species that inhabit or utilize interior estuarine marsh and surrounding areas. The anticipated actions will restore wetlands and increase their services and benefits to resources within the Charleston Harbor Estuary. The enhanced and increased marsh habitat resulting from these actions will also provide improved (from current conditions) areas for birds and other wildlife species to nest, forage, and seek protection. Aesthetic and recreational benefits to humans will also accrue, consistent with public access and usage afforded by owners and managers of the Noisette Preserve.

Effects on Public Health and Safety
The Trustees evaluated the potential for the planned restoration actions to impact public health and safety by considering the following: air and noise pollution, water use and quality, geological resources, soils, topography, environmental justice, energy resources, recreation, traffic, and contaminants.

Air Quality: Minor temporary adverse impacts would result from the Project's construction activities. Exhaust emissions from earth-moving equipment would occur but only during the construction phase of the project, the amounts would be small, and should be quickly dissipated by prevailing winds. There would be no long-term negative impacts to air quality.

Noise: Noise associated with earth-moving equipment represents a short-term adverse impact during the construction phase. Though present wildlife usage of the site appears to be limited, it is possible that equipment may temporarily disturb wildlife in the immediate vicinity, or cause movement of wildlife away from the site. Similarly, though the site does not support much if any active recreation by humans, it is possible that some persons may avoid this area due to noise during construction, but as with wildlife, such disruption will be limited to the construction phase, and there are many better substitute recreation sites readily available in the Cooper River and Charleston Harbor area. No long-term effects would occur as a result of noise during construction.

Water Quality: In the short term earth moving activities might temporarily increase turbidity in waters immediately adjacent to the site. If this is a risk, there are measures that can be taken during construction (*e.g.*, turbidity curtains) that will minimize this effect. Over the longer term, the anticipated restoration actions will accelerate recovery of and enhance estuarine wetlands at the site. Local water quality will benefit from increased exchange and filtration of tidal waters.

Geology: None of the anticipated restoration actions have the potential to directly or indirectly affect, positively or negatively, the geology of the area.

Energy: No energy production, transport, or infrastructure occurs in vicinity of the restoration site and none of the anticipated restoration actions have the potential to in any way affect energy production, transport, or infrastructure in the Cooper River or Charleston Harbor area.

Recreation: Though noise and increased turbidity of surface waters due to earth-moving activities during construction can temporarily discourage and decrease recreational activities in the vicinity of a site, this site does not currently support much if any active recreation. Nonetheless, it is possible that some persons may avoid this area due to noise during construction, but such disruption would be minor and limited to the construction phase, and there are many better substitute recreation sites readily available in the Cooper River and Charleston Harbor area. In the longer term, the anticipated restoration actions may increase and enhance the aesthetics and recreational opportunities within the Noisette Preserve, consistent with public access and usage afforded by owners and managers of that area.

Traffic: Land-based equipment traffic will occur or increase at the site during the period of construction. There is little to no other land-based traffic in the area, so no affects on other land-based traffic will occur. Once construction is complete, the added land-based equipment traffic will end. No other impacts to traffic in the area are indicated.

Contaminants: The Trustees have no reason to believe there are any contaminants of concern at the restoration site. As part of the process for closure of the former naval base and prior to transfer of those lands to the City of North Charleston, extensive investigations of the former naval base lands were undertaken for the purpose of identifying contaminants on the property and defining necessary clean-up actions. These investigations did not identify any contaminants of concern associated with lands comprising the former base golf course.

Unique Characteristics of the Geographic Area
The project will be conducted in an area that has been significantly influenced by human disturbance. Originally a saltmarsh, the area was filled in order to serve as a golf course, but has been abandoned in recent years. Today, the site is occasionally inundated during periods of extreme high tides. There area contains limited amount of coastal wetland plants, exotic invasive plants and passerine birds. Due to the former disturbance of the area, no unique or rare habitat would be lost or affected in undertaking the proposed restoration actions.

Controversial Aspects of the Project or its Effects
The planned restoration actions are expected to benefit ecological resources and to benefit local aesthetics and humans consistent with public access and usage afforded by owners and managers of the Preserve. There are no known historic sites or cultural resources in the area that will be affected by these restoration actions. This has been confirmed with the South Carolina State Historic Preservation Office (SHPO) within the South Carolina Department of Archives and History. The project appears to have no elements or environmental effects that are controversial or likely to cause adverse public reaction.

Uncertain Effects or Unknown Risks
Given the setting and information available, the federal Trustees do not believe there is any

significant uncertainty as to potential effects or unknown risks to the environment associated with implementing the planned restoration actions.

Precedential Effects of Implementing the Project
Wetland restoration and creation projects have previously been planned and undertaken in coastal South Carolina environments, including as a means of compensating the public for other natural resource damage claims. The project does not, in and of itself, create a precedent for future actions of a type that would significantly affect the quality of the human environment.

Possible, Significant Cumulative Impacts
Project impacts will be cumulative in the sense that accelerating the recovery and enhancement of estuarine marsh at this site will provide ecological services into the future. The project is not expected to have a significant cumulative effect on the human environment since it alone, or in combination with other wetland restoration projects in the vicinity, will not result in any change in the larger current pattern of hydrologic discharge, boat traffic, economic activity or land-use in the Charleston Harbor watershed. The project actions will only restore habitat that originally existed and occurred naturally at this location. Further, the restoration actions to be undertaken will compensate the public, *i.e.*, make the public and the environment whole, for resources injuries caused by an oil spill in the Charleston Harbor area. The planned restoration actions are not part of any larger systematic or comprehensive plan for restoration of coastal wetlands in South Carolina.

Effects on Sites Listed on the National Register of Historic Places or Significant Cultural, Scientific or Historic Resources
NOAA, in consultation with the South Carolina State Historic Preservation Officer (SHPO) pursuant to 36 C.F.R. Part 800 of the regulations implementing Section 106 of the National Historic Preservation Act (16 U.S.C. § 470f), recognized that the restoration action may have an adverse effect on the Charleston Navy Yard Officers' Quarters District, which is listed in the National Register of Historic Places. While there may be a minor adverse effect to the historic property, NOAA and the Trustees have determined that the effect will be minimal and will not significantly impact the quality of the human environment.

In order to account for the effect of the restoration action on historic properties, NOAA, the SHPO and Evergreen International S. A. have agreed that the undertaking shall be implemented in accordance with specific stipulations regarding the development and inclusion of interpretative signage at the project site. This agreement is documented by a Memorandum of Agreement (MOA) between NOAA, the SHPO and Evergreen International S.A. This MOA is part of the Administrative Record.

Effects on Endangered or Threatened Species, and Their Critical Habitat
Endangered and threatened species known to occur in the Charleston Harbor estuary are listed in Table 6.1 (USFWS 2005, Sandifer et al. 1980). Many of these species, including the wood stork (*Mycteria americana*), piping plover (*Charadrius melodus*), green sea turtle (*Chelonia mydas*), Kemp's ridley sea turtle (*Lepidochelys kempi*), and loggerhead sea turtle (*Caretta caretta*) have been documented in or are believed to utilize the Charleston Harbor estuary. Most species would be present in the estuary incident to migration through the area. The estuary's habitats provide general support for any threatened and endangered species migrating through or utilizing these communities.

Likely impacts resulting from the introduction or spread of nonindigenous species

As discussed in section 5.1.5, measures will be taken to prevent possible introduction of nonidigenous species during construction. Therefore no adverse impacts resulting from the introduction or spread of nonindigenous species from project construction activities are anticipated.

Table 6.1 Federal and State Endangered or Threatened Species in the Charleston Harbor Area

Common Name	**Scientific Name**	**Status**
Mammals		
West Indian manatee	*Trichechus manatus*	FE, SE
Birds		
Bachman's warbler	*Vermivora bachmanii*	FE, ST
Kirtland's warbler	*Dendroica kirtlandii*	FE, ST
Piping plover	*Charadruis melodus*	FT, Critical Habitat
Red-cockaded woodpecker	*Picoides borealis*	FE, ST
Bald eagle	*Haliaeetus leucocephalus*	ST
Wood stork	*Mycteria americana*	FE, SE
Reptiles and Amphibians		
Green sea turtle	*Chelonia mydas*	FT
Leatherback turtle	*Dermochelys coriacea*	FE, SE
Loggerhead sea turtle	*Caretta caretta*	FT, ST
Kemp's ridley turtle	*Lepidochelys kempii*	FE, SE
Flatwoods salamander	*Ambystoma cingulatur*	FR
Fish		
Shortnose sturgeon	*Acipenser brevirostrum*	FE, SE
Plants		
Sea-beach amaranth	*Amaranthus pumilus*	FT
Canby's dropwort	*Oxypolis canbyi*	FE
Pondberry	*Lindera melissifolia*	FE
Chaff-seed	*Schwalbea americana*	FE

Recent studies of the project site indicated no presence of endangered or threatened species. Additionally, the general locale where the restoration actions would be sited is not critical habitat for any listed species. The Trustees know of no direct or indirect impacts of the proposed restoration actions on threatened or endangered species, or their designated critical habitats.

Violation of Environmental Protection Laws

Wetland restoration projects have been implemented in coastal South Carolina consistent with federal, state and local laws designed to protect the environment. The proposed Project has no unique attributes or characteristics in that regard. Therefore, the Trustees have no reason to believe, and do not anticipate, that any federal, state or local laws would be violated incident to or as a consequence of the implementation of the proposed restoration actions.

Finding of No Significant Impact

Under 40 C.F.R. §§ 1501.5 and 1501.6, for the purposes of this NEPA analysis, NOAA is the lead agency and USFWS is a cooperating agency. Based on the analysis of the available information presented in this document, the federal Trustees have concluded that implementation of the Noisette Creek Golf Course Wetland Restoration Project, as described in this Final RP/EA, will not significantly impact the quality of the human environment. All potential beneficial and adverse impacts have been considered in reaching this conclusion. No potential for significant impacts was revealed through the public review and comment process on the Draft RP/EA. Accordingly, an Environmental Impact Statement (EIS) will not be prepared with respect to the selected restoration actions.

Based upon the Environmental Assessment included in this document, NOAA has issued a Finding of No Significant Impact (FONSI) on behalf of NOAA and the USFWS. Issuance of this FONSI fulfills and concludes all requirements for compliance with NEPA by the federal Trustees. A copy of the FONSI determination signed by NOAA is included as Appendix D.

6.2 Likely Impacts of the Project on Essential Fish Habitat (EFH)\

The Trustees do not believe that the planned restoration actions will have a net adverse impact on EFH as designated under the Magnuson-Stevens Fishery Conservation and Management Act, as amended and reauthorized by the Sustainable Fisheries Act (Public Law 104-297) (Magnuson-Stevens Act), 16 U.S.C. §§1801 et seq. During the construction phase of this project, some short-term and very localized adverse impacts could occur from increases in turbidity within and near the project site during construction. These conditions may affect fish and filter feeders in the local area, by clogging gills, increasing mucus production and smothering organisms found in any shallow open-water area in the vicinity. Mobile fish and invertebrates would probably not be affected, since these would most likely leave the area, and return after project completion. Increased noise levels due to the operation of earth-moving equipment would also cause mobile fish to leave the area until operations end. The EFH would be positively impacted by the accelerated recovery and enhancement of marsh services that will be achieved through the proposed restoration actions, including by increasing and providing continual access to marsh within the site. The restored marsh will serve as habitat for prey species for a variety of managed fish species and provide a nursery for the larvae and juvenile stages of many managed species.

7.0 COMPLIANCE WITH OTHER KEY STATUTES, REGULATIONS AND POLICIES

***Clean Water Act (CWA), 33 U.S.C. § 1251* et seq.**
The CWA is the principal law governing pollution control and water quality of the nation's waterways. Section 404 of the law authorizes a permit program for the beneficial uses of dredged or fill material. The U. S. Army Corps of Engineers administers the program. Wetland restoration projects usually involve movement of material into or out of jurisdictional waters or wetlands, including in hydrologic restoration of marshes, and therefore require 404 permits. Under Section 401 of the CWA, restoration projects that involve discharge or fill into wetlands or navigable waters must obtain certification of compliance with state water quality standards. All necessary 404 permits and 401 certifications will be obtained for the selected Project prior to implementation.

***Rivers and Harbors Act, 33 U.S.C. § 401* et seq.**
The Rivers and Harbors Act regulates development and use of the nation's navigable waterways. Section 10 of the Act prohibits unauthorized obstruction or alteration of navigable waters and vests the U. S. Army Corps of Engineers with authority to regulate discharges of fill and other materials into such waters. Restoration actions that must comply with the substantive requirements of Section 404 must also comply with the substantive requirements of Section 10.

Coastal Zone Management Act (CZMA), 16 U.S.C. § 1451* et seq., *15 C.F.R. Part 923
The goal of the CZMA is to encourage states to preserve, protect, develop, and, where possible, restore and enhance the nation's coastal resources. Under Section 1456 of the CZMA, restoration actions undertaken or authorized by federal agencies within a state's coastal zone are required to comply, to the maximum extent practicable, with the enforceable policies of a state's federally approved Coastal Zone Management Program. The Trustees believe that the restoration Project is consistent with the South Carolina CZMA program. NOAA and USFWS – the involved federal trustee agencies - submitted that determination to the South Carolina Office of Ocean and Coastal Resource Management (OCRM) for review and concurrence via letter dated August 12, 2009. That determination is now final.

Endangered Species Act (ESA), 16 U.S.C. § 1531* et seq., *50 C.F.R. Parts 17, 222, & 224
The ESA requires all federal agencies to conserve endangered and threatened species and their habitats to the extent their authority allows. Under the ESA, the Department of Commerce (through NOAA) and the Department of the Interior (through USFWS) publish lists of endangered and threatened species. Section 7 of the Act requires federal agencies to consult with these departments to minimize the effects of federal actions on these listed species.

As summarized in subsection 6.1 above, the Trustees believe the actions selected in this Final RP/EA to restore estuarine marsh at the Project site are not likely to adversely affect threatened or endangered species or their designated critical habitats. Informal consultations with appropriate USFWS and National Marine Fisheries Service (NMFS) offices were initiated and both agencies have concurred in that determination. The records of this consultation are included in the Administrative Record.

***Fish and Wildlife Conservation Act, 16 U.S.C. § 2901* et seq.**
The planned restoration actions will either encourage the conservation of non-game fish and wildlife, or have no adverse effect.

***Fish and Wildlife Coordination Act (FWCA), 16 U.S.C. § 661* et seq.**
The FWCA requires that federal agencies consult with the USFWS, NOAA's National Marine Fisheries Service, and state wildlife agencies regarding activities that affect, control, or modify waters of any stream or bodies of water, in order to minimize the adverse impacts of such actions on fish and wildlife resources and habitat. The Trustees have coordinated with NOAA Fisheries, the USFWS, and the SCDNR (the appropriate state wildlife agency under FWCA). This coordination is also incorporated into compliance processes used to address the requirements of other applicable statutes, such as Section 404 of the CWA. The restoration actions described herein will have a positive effect on fish and wildlife resources.

***Magnuson-Stevens Fishery Conservation and Management Act, as amended and reauthorized by the Sustainable Fisheries Act (Public Law 104-297) (Magnuson-Stevens Act), 16 U.S.C. §§1801* et seq.**
The Magnuson-Stevens Act provides for the conservation and management of the Nation's fishery resources within the Exclusive Economic Zone (from the seaward boundary of every state to 200 miles from that baseline). The resource management goal is to achieve and maintain the optimum yield from U.S. marine fisheries. The Act also established a program to promote the protection of Essential Fish Habitat (EFH) in the review of projects conducted under federal permits, licenses, or other authorities that affect or have the potential to affect such habitat. After EFH has been described and identified in fishery management plans by the regional fishery management councils, federal agencies are obligated and other agencies are encouraged to consult with the Secretary of Commerce with respect to any action authorized, funded, or undertaken, or proposed to be authorized, funded, or undertaken by such agency that may adversely affect any EFH.

As summarized in subsection 6.2 above, the Trustees do not believe that the planned restoration actions will have a net adverse impact on EFH as designated under the Act. This finding was submitted to NMFS via letter dated December 1, 2009 and NMFS has concurred. The records of this consultation are included in the Administrative Record.

***Marine Mammal Protection Act, 16 U.S.C. § 1361* et seq.**
The Marine Mammal Protection Act provides for the long-term management of and research programs for marine mammals. It places a moratorium on the taking and importing of marine mammals and marine mammal products, with limited exceptions. The Department of Commerce is responsible for whales, porpoise, seals, and sea lions. The Department of the Interior is responsible for all other marine mammals. The planned restoration actions will not have an adverse effect on marine mammals.

***Migratory Bird Conservation Act, 16 U.S.C. § 715* et seq.**
The planned restoration actions will have no adverse effect on migratory birds. Migratory birds are likely to benefit from the re-establishment and enhancement of estuarine marsh that will be achieved through the planned restoration actions.

Migratory Bird Treaty Act, 16 U.S.C. § 703 – 712
The planned restoration actions will have no adverse impacts on migratory birds under the purview of this Act. No migratory birds will be pursued, hunted, taken, captured, killed, attempted to be taken, captured or killed, possessed, offered for sale, sold, offered to purchase, purchased, delivered for shipment, shipped, caused to be shipped, delivered for transportation, transported, caused to be transported, carried, or caused to be carried by any means whatever, received for shipment, transported or carried, or exported, at any time, or in any manner.

***National Historic Preservation Act, 16 U.S.C. § 470* et seq.**
Section 106 of the NHPA requires federal agencies, or federally funded entities, to consider the impacts of their projects on historic properties. NHPA regulations require that federal agencies take the lead in this process, and outline procedures to allow the Advisory Council on Historic Preservation to comment on any proposed federal action.

NOAA's compliance with the National Historic Preservation Act, 16 U.S.C. § 470 et seq. is summarized in subsection 6.1 above. The project was found to present an adverse effect on the Charleston Navy Yard Officers' Quarters district, which is listed in the National Register of Historic Places but that effect was determined to be minimal. Measures to address this effect were identified in consultation with the South Carolina State Historic Program Officer and shall be implemented at the site. NOAA also provided the opportunity for the Advisory Council on Historic Preservation to comment on the action.

Information Quality Guidelines Issued Pursuant to Public Law 106-554
Information disseminated by federal agencies to the public after October 1, 2002, is subject to information quality guidelines developed by each agency pursuant to Section 515 of Public Law 106-554 that are intended to ensure and maximize the quality of such information (i.e., the objectivity, utility and integrity of such information). This Final RP/EA is an information product covered by information quality guidelines established by NOAA and DOI for this purpose. The quality of the information contained herein is consistent with the applicable guidelines.

Executive Order 12898 (59 Fed. Reg. 7629) - Environmental Justice
This Executive Order requires each federal agency to identify and address, as appropriate, disproportionately high and adverse human health or environmental effects of its programs, policies, and activities on minority and low-income populations. EPA and the Council on Environmental Quality have emphasized the importance of incorporating environmental justice review in the analyses conducted by federal agencies under NEPA and of developing mitigation measures that avoid disproportionate environmental effects on minority and low-income populations. The restoration Project selected in this Final RP/EA has no potential to affect any low income or ethnic minority communities, therefore the Trustees have concluded that such communities would not be adversely affected by the planned restoration actions.

Executive Order Number 11514 (35 Fed. Reg. 8,693) – Protection and Enhancement of Environmental Quality
An Environmental Assessment is integrated within this RP/EA and environmental analyses and coordination have taken place as required by NEPA.

Executive Order Number 11988 (42 Fed. Reg. 26,951) – Floodplain Management
The planned restoration actions will directly or indirectly support development of the floodplain.

Executive Order Number 11990 (42 Fed. Reg. 26,961) - Protection of Wetlands
The planned restoration actions will not result in adverse effects on wetlands or the services they provide, but rather will provide for the enhancement of wetlands and wetland services.

Executive Order Number 12962 (60 Fed. Reg. 30,769) - Recreational Fisheries
The planned restoration actions will not result in adverse effects on recreational fisheries but will contribute to the enhancement of, and help support, such fisheries.

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Appendix A - Notice of Intent to Conduct Restoration Planning, *The Post and Courier, 11/25/03*.

USD Of Commerce, NOAA
9721 Executive Center Dr N. Koger Bldg., Ste 114
St. Petersburg FL 33702
Attn: Dolores Toscano

Number of Copies: 1

AFFIDAVIT OF PUBLICATION

The Post and Courier

State of South Carolina
County of Charleston

Personally appeared before me the undersigned advertising Clerk of the above indicated newspaper published in the City of Charleston, County and State aforesaid, who, being duly sworn, says that the advertisement of

(Copy attached)

appeared in the issues of said newspaper on the following day(s):

11/25/2003

at a cost of **$ 618.51**
Account# **H704225**
Order# **C250LA9F**
P.O. Number: **ever reach**

Subscribed and sworn to before me this 26th day of November A.D. 2003

Keisha Eddings
Advertising Clerk

Shelly Dulany
NOTARY PUBLIC, SC
My Commission expires
My Commission Expires 10/...

Form 3020

PUBLIC NOTICE

SOUTH CAROLINA DEPARTMENT OF NATURAL RESOURCES, THE OFFICE OF THE GOVERNOR OF SOUTH CAROLINA, THE SOUTH CAROLINA DEPARTMENT OF HEALTH & ENVIRONMENTAL CONTROL THE NATIONAL OCEANIC & ATMOSPHERIC ADMINISTRATION, THE UNITED STATES FISH & WILDLIFE SERVICE, and THE UNITED STATES NAVY

NOTICE OF INTENT TO CONDUCT RESTORATION PLANNING pursuant to 15 C.F.R. Section 990.44

M/V EVER REACH OIL SPILL of September 30, 2002

On or about September 30, 2002, #6 fuel oil was discharged or released into the waters of the Cooper River and Charleston Harbor, in South Carolina, from the containership M/V EVER REACH as that vessel entered, left or prepared to leave the river and harbor for its next port of call (hereinafter, generally referred to as "the oil spill"). The volume of oil discharged is not precisely known but has been estimated to be approximately 12,500 gallons. The distribution of oil was predominately concentrated along the western shore of the Cooper River between the Interstate 526 Bridge and the Cooper River Bridge, in the vicinity of the North Charleston Terminal and the Old Navy Base piers and docks; however, other shoreline areas were also exposed to varying degrees. These included tidal creeks and back water areas adjacent to James Island, Fort Johnson, Shutes Folly, Crab Bank, Morris Island, Folly Beach and Sullivan's Island. In all, the oil ranged over approximately 30 linear miles of shoreline comprised of a variety of shoreline types, including tidal flats, fringing marshes, intertidal oyster reefs, sandy beaches and manmade structures (i.e., docks, piers, bulkheads), and their associated sediments. The oil spill also resulted in the oiling of a number of shorebirds, a shellfish bed closure, and a temporary disruption to recreational shrimp baiting in area waters.

Evergreen International, S.A., the owner and/or operator of the M/V EVER REACH, was officially designated as the responsible party (RP) for the oil spill. Since the source of the oil was discovered, Evergreen International, S.A., has cooperated with relevant agencies in performing response and initial data collection activities, including activities to assist in determining whether injuries to natural resources likely occurred.

Form 3020 ... Expires 10/10

The South Carolina Department of Natural Resources (SCDNR), the Office of the Governor of South Carolina (SCOG), the South Carolina Department of Health and Environmental Control (SCDHEC), the National Oceanic and Atmospheric Administration (NOAA) of the United States Department of Commerce, the United States Fish and Wildlife Service (USFWS) of the United States Department of the Interior, and the United States Navy (USN) (collectively, "the Trustees") each have authority to seek damages for injuries to natural resources resulting from the oil spill under the Federal Water Pollution Control Act, 33 U.S.C. §§ 1251 et seq., the Oil Pollution Act of 1990 (OPA), 33 U.S.C. §§ 2701 et seq., and other applicable federal laws, including Subpart G of the National Oil and Hazardous Substances Pollution Contingency Plan, 40 C.F.R. Part 300.600 et seq. SCDNR, SCOG, and SCDHEC also have such authority under the South Carolina Pollution Control Act, S.C. Code Ann 48-1-10 et seq. (Supp. 2002), or other applicable State laws.

The Trustees have determined (as outlined below) that the Spill warrants conducting a natural resource damage assessment (NRDA). This assessment will be conducted in accordance with the NRDA regulations for oil spills at 15 C.F.R. Part 990 (NRDA Regulations). This Notice serves to inform the public that the Trustees are proceeding with natural resource injury assessment and restoration planning for the oil spill and, further, seeks early input from the public on the restoration alternatives which should be included for consideration in the development of that plan. The public will have a future opportunity to comment on a draft of the restoration plan before it is finalized by the Trustees.

TRUSTEE DETERMINATIONS

The decision to proceed with a NRDA for this oil spill is based on and supported by the following determinations of the Trustees, as specified in the NRDA regulations:

A. *Determination of Jurisdiction to Pursue Restoration*, 15 C.F.R. 990.41 - In accordance with 15 C.F.R. 990.41, the facts relating to this oil spill show:

1. The M/V EVER REACH is a "vessel", as that term is defined by Section 1001(37) of OPA, 33 U.S.C. 2701(37) and 15 C.F.R. 990.30.
2. The subject discharge of # 6 fuel oil from the M/V EVER REACH into the Cooper River and Charleston Harbor on or about September 30, 2002, constitutes an "Incident" as that term is defined by Section 1001(14) of OPA, 33 U.S.C. 2701(14) and 15 C.F.R. 990.30.
3. This Incident was not permitted under any Federal, State, or local law, nor did it involve either a public vessel as defined by OPA Section 1001(29), 33 U.S.C. 2701(29) or an onshore facility subject to the Trans-Alaska Pipeline Authority Act, 43 U.S.C. 1651, et seq.
4. Further, data and other information gathered during the response or collected pursuant to 15 C.F.R. 990.43 as part of pre-assessment phase activities indicate that natural resources under their trusteeship were injured as a result of the oil spill, including but not limited to estuarine habitats and birds. The oil spill, including necessary response actions, also disrupted recreational shrimp baiting and prompted the temporary closure of one shellfish bed to recreational harvest.

Accordingly, the Trustees have determined that they have jurisdiction to pursue natural resource restoration under OPA.

B. Determination to Conduct Restoration Planning, 15 C.F.R. 990.42 - The Trustees have also concluded that it is appropriate to proceed with restoration planning for this incident. This determination is based upon the data and other information (noted above) relating to this oil spill which indicates:

1. Natural resource injuries and resource service losses have resulted from the oil spill, including but not limited to injuries to estuarine habitats, birds and lost recreational use of area shrimp and shellfish resources.

2. Response actions have not adequately addressed, and are not expected to address, these injuries and losses. Response actions included actions such as protective booming, oil containment and partial removal from some shoreline areas (primarily, from beaches, man-made structures, and/or where pooling occurred); the capture, treatment and release of some oiled birds; protective closure of a shellfish bed, and the public dissemination of information or advisories intended to avoid or minimize the potential for human exposure. Oil could not be completely removed, however, from sensitive shoreline habitats such as marshes and tidal flats. Response actions could not wholly restore or rehabilitate any injured natural resources. Further, such actions do not compensate the public for resource service losses attributable to the oil spill, including the lost recreational use of area shrimp and shellfish resources.

3. Feasible restoration opportunities exist in the spill area for natural resources injured by the spill. Restoration planning will focus on the specific resource injuries and service losses caused by this oil spill, including those associated with affected salt marshes, tidal flats, shellfish beds, birds, and the lost recreational use of area shrimp and shellfish resources. Opportunities for restoration appropriate to address these injuries and losses may include but are not necessarily limited to alternatives such as monitored natural recovery, oyster reef restoration or creation, estuarine habitat preservation or enhancement, land acquisition, and establishment of upland buffers to protect estuarine areas.

NRDA COORDINATION

The Trustees are entering into a Memorandum of Agreement (MOA) to provide for ongoing coordination of this NRDA process by and among the Trustees. Further, by letter dated December 11, 2002, issued pursuant to 15 C.F.R. 990.14(c), the Trustees invited the RP to participate cooperatively in any NRDA initiated for this oil spill and the RP has officially confirmed its interest in participating in a cooperative NRDA. The Trustees may enter into a Memorandum of Agreement with the RP to provide for its participation in the NRDA process.

ADMINISTRATIVE RECORD

Concurrent with the issuance of this Notice, the Trustees have opened an Administrative Record (AR) to hold the information, records and other documents relied upon by the Trustees as they proceed with the NRDA for this oil spill. The AR is public. It is being maintained locally and is accessible by appointment during normal business hours at the offices of the United States Fish & Wildlife Service, Division of Ecological Services, 176 Croghan Spur Road, Charleston, S.C. Appointments to review the AR may be arranged by contacting Diane Duncan at that address, or by phone at 843-727-4704, ext. 29. The AR contains a copy of this Notice. The Trustees' MOA and other documents will be added as each is finalized or becomes available, including a planned Preassessment Data Report, a compilation of the preassessment data for this oil spill. The report, currently being developed, will include information and data that supports the Determinations of the Trustees set forth in this Notice. Today's Notice is intended to ensure that the public is aware that a coordinated assessment of natural resource damages for this oil spill is proceeding and to provide the public with an early opportunity to submit information to the Trustees on potential restoration opportunities in the spill area which might be appropriate to address natural resource injuries and losses caused by this oil spill. To submit such information on potential restoration alternatives, or for further information related to this Notice, contact: Tom Moore, NOAA Restoration Center, 9721 Executive Center Dr. N., Suite 114, St. Petersburg, FL 33702, by phone at 727-570-5716, by fax at 727-570-5390, or by email: Tom.Moore@noaa.gov.

Appendix B - *Final Modeling of Physical Fates and Biological Injuries Report,*

Executive Summary,2006.

FINAL

M/V Ever Reach Spill of 30 September 2002 in Charleston Harbor, SC: Restoration Scaling for Bird Injuries

by

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NOAA Contract: 50-DSNC-7-90032

ASA 03-084

November 13, 2006

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SUMMARY

The injury to birds caused by the 30 September 2002 spill into Charleston Harbor, SC, from the container ship *M/V Ever Reach* was estimated as 175 birds, including 89 seabirds (including 75 pelicans), 69 shorebirds, 16 wading birds, and less than the equivalent of one bird (as a probability) of others. Table 1-1 lists the injuries, as numbers killed, bird-years lost, and number of fledgling equivalents.

Estimates of the scale of restoration required to compensate for the injuries (with the project initialed in 2007) were made as summarized in Table S-1.

Table S-1. Summary of estimated scale of compensatory restoration required for injuries to birds.

Basis of Restoration Scaling	Injury Units	Injury Amount	Compensation
Food requirements to produce fledglings and trophic transfer modeling to the bird prey trophic level	# fledgling equivalents (in 2007)	789 fledglings	2.28 ha (5.64 acres) of saltmarsh

Trophic transfer modeling to the birds' trophic level could underestimate the saltmarsh area that would be compensatory if there are more trophic levels between the benthic invertebrate level and the birds injured than that assumed in modeling, and that some of the prey production is not consumed by the target (injured) species of birds. Thus, the method used was to estimate food requirements to produce fledglings and use trophic transfer modeling to the bird prey trophic level. An assumed rate of trophic transfer from prey to bird is not needed, and instead food requirements and fledgling production were modeled in detail. This method does assume the saltmarsh provides food that would be consumed by the target species of birds or their prey, a reasonable assumption for the present case.

1. INTRODUCTION

Oil spill fates and biological effects modeling was performed for the 30 September 2002 spill into Charleston Harbor, SC, from the container ship *M/V Ever Reach*. The injury caused by the spill was evaluated for birds, marine mammals, sea turtles, and subtidal fish and invertebrates. The report "M/V Ever Reach Spill of 30 September 2002 in Charleston Harbor, SC: Modeling of Physical Fates and Biological Injuries" contains the description of the modeling and injury quantification (French McCay et al., 2005). Table 1-1 contains the injury estimates for the birds. Injuries to marine mammals, sea turtles, and subtidal fish and invertebrates were estimated as negligible.

Table 1-1. Summary of estimated injuries to birds. The model estimate is a probability, and thus may be a fraction of an animal.

Group Totals	Birds Killed (#)	Dominant Species	Interim Loss (#-years)	# Fledgling Equivalents (in 2002)	# Fledgling Equivalents (in 2007)
Waterfowl	0.06	Canada goose	0.1	0.1	0.1
Seabirds	89.2	Brown pelican	556	384	446
Wading birds	16.4	Egrets, herons	31	36	41
Shorebirds	68.8	Ruddy turnstone	531	260	301
Raptors	0.14	Osprey	1.0	0.5	0.6
Total birds	**174.6**	**-**	**1120**	**681**	**789**

2. SCALE OF COMPENSATORY HABITAT RESTORATION

Food web modeling and Habitat Equivalency Analysis (HEA) calculations were performed to estimate the amount of saltmarsh that would be compensatory to the bird injury, following the methods in French McCay and Rowe (2003) and with some additional methods to be described below. This was a two step process:

1. Use trophic transfer modeling to estimate compensatory bird food production rate per unit of salt marsh created.
2. Determine the food required to produce additional fledglings and then use the compensatory (bird) food production rate per unit of salt marsh created to calculate the area of marsh required.

The scaling of the compensatory restoration uses methods currently in practice by NOAA and state trustees, i.e., Habitat Equivalency Analysis (HEA). Scaling methods used here were initially developed for use in the *North Cape* case, as described in French McCay and Rowe (2003). These methods have also been used in several other cases, as well as in successful claims for 23 cases submitted by the Florida Department of Environmental Protection to the US Coast Guard, National Pollution Fund Center (French McCay et al., 2003a).

Restoration should provide equivalent quality biota to compensate for the losses. Equivalent quality implies same or similar species with equivalent ecological role and value for human uses. The equivalent production or replacement should be discounted to present-day values to account for the interim loss between the time of the injury and the time restoration provides equivalent ecological and human services.

Habitat creation or preservation projects have been used to compensate for injuries of wildlife, fish and invertebrates. The concept is that the restored habitat leads to a net gain in wildlife, fish and invertebrate production over and above that produced by the location before the restoration. The size of the habitat (acreage) is scaled to just compensate for the injury (interim loss).

In the model used here, the habitat may be seagrass bed, saltmarsh, oyster reef or other structural habitats that provide such ecological services as food, shelter, and nursery habitat and are more productive than open bottom habitats. The injuries are scaled to the new primary (plant) or secondary (e.g., benthic) production produced by the created habitat, as the entire food web benefits from this production. A preservation project that would avoid the loss of habitat could also be scaled to the production preserved. The latter method would only be of net gain if the habitat is otherwise destined to be destroyed.

One approach is to use primary production to measure the benefits of the restoration project. The total injuries in kg are translated into equivalent plant (angiosperm) production as follows. Plant biomass passes primarily through the detrital food web via detritivores consuming the plant material and attached microbial communities. When macrophytes are consumed by detritivores, the ecological efficiency is low because of the high percentage of structural material produced by the plant, which must be broken down by microorganisms before it can be used by the detritivore. Each species group is assigned a trophic level relative to that of the detritivores. If the species group is at the same trophic level, it is assumed 100% equivalent, as the resource injured would presumably have the same ecological value in the food web as the detritivores. If the injured resource preys on detritivores or that trophic level occupied by the detritivores, the ecological efficiency is that for trophic transfer from the prey to the predator. Values for production of predator per unit production of prey (i.e., ecological efficiency) are taken from the ecological literature, as reviewed by French McCay and Rowe (2003).

Alternatively, the habitat requirements may be scaled using secondary (e.g., benthic invertebrate) production instead of primary production. Scaling to primary production assumes that all the benefits to animals are generated by the additional plant production as food. However, the habitat provides other ecological services to animals, such as supplying shelter, nursery areas, refuge from predators, etc. Benthic invertebrate production gains are calculated as the difference between production in shallow unvegetated habitats and in vegetated or otherwise structured habitat. Similarly, scaling could be based on differences in nekton production (before and after restoration). The animal production in the habitat is typically larger than that which can be accounted for by additional primary (plant) production. Using benthic (or other animal) production for scaling implicitly includes these habitat services gained.

Equivalent compensatory angiosperm (plant) or secondary (benthic) production of the restored resource is calculated as kg of injury divided by ecological efficiency. For primary production, the ecological efficiency is the product of the efficiency of transfer from angiosperm to invertebrate detritivore and efficiency from detritivore to the injured resource. For secondary production, the ecological efficiency is the product of the efficiency of transfer for each step up the food chain from the secondary level to the trophic level of concern. Discounting at 3% per year is included for delays in production because of development of the habitat, and delays between the time of the injury and when the production is realized in the restored habitat. The equations and assumptions may be found in French McCay and Rowe (2003).

The needed data for the scaling calculations are:

- number of years for development of full function;
- annual primary or secondary production rate per unit area (P) of restored habitat at full function;
- delay before restoration project begins; and
- project lifetime (years).

In South Carolina, it is most likely that saltmarsh restoration would be undertaken as restoration for bird injuries. Oyster reef restoration is also an option. However, this requires good water quality and appropriate environmental conditions to be successful.

HEA calculations for saltmarsh are performed here, following the methods in French McCay and Rowe (2003). It is assumed that the saltmarsh requires 15 years to recover (based on French et al., 1996a) ultimately reaching 80% of full function, the restoration begins 5 years after the spill, and the project lifetime is 50 years. Above-ground primary production rates of saltmarsh cord grasses in the southeast US (Georgia marshes) have been estimated as 1290 g dry weight m^{-2} yr^{-1} (Teal, 1962) and 2,555-4,526 g dry weight m^{-2} yr^{-1} (Dai and Wiegert, 1996). The annual primary production rate used in these analyses is the mean for the two studies, 2,415 g dry weight m^{-2}. In addition, saltmarsh benthic microalgal production provides another 40% (966 g dry weight m^{-2}; Currin et al., 1995). Thus, estimated primary production rates in southeast US (Georgia) saltmarshes total 3381 g dry weight m^{-2} yr^{-1}. Rates of secondary production are not available.

2.1 Trophic Transfer Modeling

It is assumed that creation of saltmarsh that increases invertebrate and fish production will be of direct benefit to the bird species where restoration is required, i.e., the additional production will be appropriate bird food (i.e., additional prey biomass). The amount of saltmarsh required in compensation for the quantified bird injuries was estimated using trophic transfer efficiencies for each step in the food web from benthic invertebrates to the prey of each of the bird categories. No correction is made for the possibility that the target species of birds will not obtain that food. If correction for availability were made, the scale of the project would increase proportionately.

Pelicans feed primarily on young menhaden, which consume primarily pelagic and benthic invertebrates. Thus, the pelican's prey is at the trophic level of small fish feeding on plankton and benthic invertebrates. The ecological efficiency of small fish preying on benthic invertebrate detritivores is 20% (French McCay and Rowe, 2003). Similar assumptions are made for the other groups based on their trophic level (Table 2-1). These efficiencies are used to translate the compensatory bird prey production requirements to saltmarsh area (as described above). Calculations were made per 1000 kg of bird food required, as shown in Table 2-1. To the extent that there are more trophic levels between the benthic invertebrate level and the prey of the birds injured, and/or some of the prey production is not consumed by those species of birds, this compensatory scale is a low estimate.

Table 2-1. Scaling of compensatory restoration (if project begun in 2007) per unit of required bird food (of 1000 kg) for saltmarsh based on primary production as the measurement of net gain.

Species Category	Unit Requirement (kg)	Trophic Level	Production Yield Relative to Benthic Detritivores (%)	Compen-satory Produc-tion (kg wet wt) per Unit Require-ment	Habitat Area (m^2) per Unit Require-ment	Habitat Area (acres) per Unit Require-ment
Benthic invertebrates	1000	detritivores	100	5,083	111	0.027
Small fish and decapods	1000	bottom feeders	20	25,416	556	0.137
Large fish	1000	piscivores	4	127,079	2781	0.687

2.2 Food Requirements to Produce Fledglings

The scaling was performed using the food web model and trophic efficiencies described in French McCay and Rowe (2003) and described above, up to the step of the prey of the bird species groups involved. The amount of saltmarsh required in compensation was then estimated by developing an estimate of food requirements to rear an additional fledgling, multiplied by the number of fledgling equivalents to the interim loss (from Table 1-1). Thus, this method evaluates in more detail the benefits of food production to the bird species injured than a full trophic transfer model. The assumption is that food is limiting to bird production.

The majority and most significant injuries were to pelicans. Hingtgen et al. (1985) reviewed the life history of eastern brown pelicans, stating that the major limitation to fledgling production was the ability of the adults to obtain sufficient food for rearing. Thus, provision of additional food (fish) should increase fledgling production of the remaining pelican population in the area of the spill.

Hingtgen et al. (1985) state that pelican chicks require 57 kg of fish between hatching and fledging. Breeding adult pelicans require 90 kg of fish for themselves during this period. However, if the adult were not breeding, it would require some lesser amount of fish over that period than the 90 kg. Thus, the net amount of fish to rear a chick to fledging is 57 + 90 kg, minus the amount required for non-breeding adult birds in the same time period.

Furness and Cooper (1982) describe a bioenergetics model for seabirds (and other aquatic birds) where food requirements can be estimated from body weight (W). The calculation begins with an estimate of basal metabolic needs (EE, kJ/g/day), a function of temperature. These equations were used, assuming a summer-time temperature of 30^{o}C:

$$\text{At } 30^{o}\text{C: } EE = 4.472 * W^{0.6637}$$

To account for normal daily activities, total daily energy needs are 2.444 times the basal rate (Furness and Cooper, 1982). Assuming a digestive efficiency of 80% (Furness, 1978), the daily ration required is 2.444*EE/0.8. Conversion from kJ to g wet weight was made assuming 5.33 kJ/g (Gremillet et al., 2003). The daily ration was converted to the mass of food required by non-breeders over the time from hatching to fledging (using the data in the injury quantification report, French McCay et al., 2004, Tables 3-8 to 3-12).

For pelicans, the breeding-period ration for a non-breeder was subtracted from the total of 57 + 90 kg required by a breeding bird to rear a chick to estimate the amount of fish required to rear an additional chick. Similar data of food needs to rear chicks of the other species were not available. Thus, the ratio of food need for rearing a pelican chick divided by the ration for a non-breeding pelican was used to estimate the food needs to rear extra chicks of the other species. The results of the calculations of food requirements are in Table 2-2.

Using the trophic transfer model, it is assumed that creation of saltmarsh that increases invertebrate and fish production will be of direct benefit to the bird species where restoration is required. No correction is made for the possibility that breeding birds will not obtain that food. If correction for availability were made, the scale of the project would increase proportionately. Thus, food requirements to rear a fledgling are used to scale the saltmarsh area.

Pelicans feed primarily on young menhaden, which consume primarily pelagic and benthic invertebrates. Thus, the pelican’s prey is at the trophic level of small fish feeding on plankton and benthic invertebrates. The ecological efficiency relative to benthic invertebrate detritivores is that for the prey, 20%. Similar assumptions are made for the other groups based on their trophic level (Table 2-2). This efficiency is used to translate the compensatory food requirements to saltmarsh area (as described above).

Table 2-2. Estimated food needs for metabolism and rearing chicks and compensatory wetland areas (if project begins in 2007).

	Waterfowl	Seabirds	Wading Birds	Shorebirds	Raptors
Body weight (g)	5000	3500	1300	30	1900
Daily ration of a non-breeder (g/day)	730.7	576.7	298.9	24.5	384.5
Ration of a non-breeder during rearing period (kg)	43.9	44.4	17.9	0.73	23.1
Ration for rearing an additional fledgling (kg)	101.3	102.6	41.4	1.7	53.3
Total food required to compensate for injuries (kg wet weight)	13	39,439	1,482	442	29
Production yield of prey relative to benthic detritivores (%)	100	20	20	100	20
Saltmarsh area required (m^2)	1	21,936	825	49	16
Saltmarsh area required (acres)	0.0003	5.42	0.204	0.012	0.004

The results of the calculations of food requirements and the scale of compensatory restoration (assuming saltmarsh creation begins in 2007) are in Table 2-2. The total area required is 2.28 ha (5.64 acres). To the extent that there are more trophic levels between the benthic invertebrate level and prey the injured birds would consume, and that some of the prey production is not consumed by those species of birds, this compensatory area is a low estimate.

The inferred small fish production via trophic transfer from primary production using this trophic transfer model is 3.2 g dry weight/m^2/yr. Small fish production in Delaware marshes has been estimated as about 10 g dry weight/m^2/yr (Kneib, 2000). If the higher small fish production rate were used, the required acreage would be about 1/3 that in Table 2.2. However, given that all the small fish production would not be consumed by pelicans and other injured bird species, the estimates based on the 3.2 g dry weight/m^2/yr are reasonable.

The suggestion was made that acreage requirements might be based on feeding the restored fledglings for their entire lifespan. However, the scaling calculations were made translating the older bird injuries to units of equivalent fledglings lost. Thus, replacement of the required number of fledglings would compensate for the injury. This does implicitly assume that once the fledglings are produced they will survive at the same rates as the injured birds before the spill. While there is evidence that the production of new birds (i.e., fledglings) is food-limited, mortality of older birds is from a mix of causes and not specifically starvation. Thus, the assumption that post-fledgling survival will be similar to that for the same species before the spill without providing additional food resources is a reasonable approximation.

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Appendix C - *Final Report on Restoration Scaling for Bird Injuries*, November 13, 2006.

FINAL

M/V Ever Reach Spill of 30 September 2002 in Charleston Harbor, SC: Modeling of Physical Fates and Biological Injuries

by

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SUMMARY

Oil spill modeling was performed for the 30 September 2002 spill into Charleston Harbor, SC, from the container ship *M/V Ever Reach*. Figure S-1 is a map of the spill-affected area with the ship's path and observed shoreline oiling. The objectives were to provide (1) an assessment of the pathways and fate of the oil, and thus estimate exposure to the water surface, shoreline and other habitats, water column, and sediments; and (2) an estimate of injuries to wildlife (birds, marine mammals, sea turtles) and subtidal aquatic organisms (water column and benthic biota, exposed by the water pathway and subtidal sediment contamination) that can be used to scale compensatory restoration. Observations and data collected during and after the spill were used as much as possible as input to and to calibrate the model. Where data from the event were not available, historical information was used to make the assessment as site-specific as possible.

The analysis was performed using the model system SIMAP (Spill Impact Model Analysis Package). The physical fates model in SIMAP estimates the distribution of oil (as mass and concentrations) on the water surface, on shorelines, in the water column and in the sediments, accounting for spreading, evaporation, transport, dispersion, emulsification, entrainment, dissolution, volatilization, partitioning, sedimentation, and degradation. The biological effects model estimates short-term (acute) exposure of biota of various behavior types to floating oil and subsurface contamination (in water and subtidal sediments), resulting percent mortality, and sublethal effects on production (somatic growth). For each wildlife behavior group, a portion of the animals in the area swept by surface oil over a threshold thickness (10 g/m^2) is assumed to die, based on probability of encounter with the oil on the water surface multiplied by the probability of mortality once oiled. Toxicity to aquatic biota in the water column and subtidal sediments is estimated from dissolved aromatic concentrations and exposure duration, using laboratory-based bioassay data for oil hydrocarbon mixtures. Losses are estimated by species or species group for fish, invertebrates and wildlife by multiplying percent loss by abundance. The model has been validated using simulations of over 20 spill events where data are available for comparison.

The model uses incident specific wind data, current data, and transport and weathering algorithms to calculate mass balance in various environmental compartments (water surface, shoreline, water column, atmosphere, sediments, etc.), surface oil distribution over time (trajectory), and concentrations of the oil components in water and sediments. Geographical data (habitat mapping and shoreline location, Figure S-2) were obtained from existing Geographical Information System (GIS) databases based on Environmental Sensitivity Indices (ESI). Water depth is available from National Oceanic and Atmospheric Administration (NOAA) National Ocean Service (NOS) soundings databases. Hourly wind speed and direction data during and after the spill was obtained from a nearby meteorological station. Tidal and other currents were modeled based on known water heights, using a hydrodynamic model based on physical laws, and that conserves mass and momentum.

Specifications for the scenario (date, timing, amount, duration of release, etc.) were based on information obtained and distributed during the response by NOAA HAZMAT, the US Coast Guard, state responders and trustees, and the Responsible Party (RP). The spill was 12,500 gal (= 46.4 MT) of intermediate fuel oil (IFO 380). It appears to have been caused by grounding on a submerged dredge pipe in the Cooper River, which occurred as the vessel came into port early on 30 September 2002. Based on the distribution of oil observed (Figure S-1) after the spill and modeling results, the release must have been protracted: as the ship was traveling from the grounding site (32^{o} 51.167' N, 79^{o} 56.195' W) into Berth 1 NC Terminal (05:35 to 07:18 hours), and again as the ship left the harbor later the same day (left berth at 19:00 hours, passed harbor entrance about 20:30 hours, path in Figure S-1). Oiling in the harbor and outside along Morris and Folly Islands cannot be accounted for assuming oil was released only at or up-river of the submerged dredge site. Considerable oil must have been released in the lower harbor and outside in offshore waters. The leak apparently stopped while the ship was at the berth, as the U.S. Coast Guard did not observe any oil around the ship while in port. (Hydrostatic pressure would retain oil in the hull while the ship was stationary, but when the ship moved, lower pressure over the hull surface and turbulence would draw oil out of the ship.)

The surface oil trajectory agreed with observations from over-flights, mapping of shoreline oil (from SCAT surveys and other observations), and other field records, and was thus considered the best simulation of the event. The model replicates well the overall movement of the oil. The model conserves oil mass, estimates losses to evaporation, and so the surface oil area estimates are realistic estimates of the oil mass on the water at any given time.

A total of 18-23 brown pelicans were observed in the field as moderately or heavily oiled, with 30 other pelicans showing spots or oil stain. Tri-State treated 21 of the oiled pelicans (1 adult and 20 juveniles) and released them. Other oiled birds observed were: 1 great blue heron, several egrets, 1 double-crested cormorant, and 15 ruddy turnstones. Aquatic bird injuries were estimated using the model from the area swept by enough surface oil to oil a bird above a threshold dose level for effects. Tables S-1 and S-2 list the model-estimated direct kill of wildlife for the best fates model simulation, along with the observed oiled birds. The estimated numbers are probabilities, and thus may be fractions of an animal. The model estimate of the total birds oiled is 175, including 75 brown pelicans, 7.3 black skimmers, 3.4 terns, 3.3 gulls, 16.4 wading birds, 69 shorebirds, and fractions of waterfowl and raptors (estimated as probabilities). The estimate numbers of sea turtles and dolphins oiled were insignificant, and the injury assumed zero. The number of oiled pelicans estimated by the model is 75, as opposed to the 18-23 observed as significantly oiled. This difference is in part accounted for in that the model estimates injuries to pelicans that are distributed around the harbor and in the rivers, and not just those concentrated in areas of heavy oiling at Crab Bank (which were the ones observed). The colony at Crab Bank was explicitly modeled, and 70 birds were estimated oiled there, in addition to 5 pelicans distributed around the area. Oiled skimmers, terns, and shorebirds would be unlikely to be observed or captured for cleaning. Note that if the pre-spill abundance were, for example, a factor two different, the model kill estimate would change by that same factor. Thus, the model estimates and the field data agree within the uncertainty of both estimates.

Table S-2 also lists the total injury interim loss, which is the sum (annually) of the numbers killed that would still be alive each year after the spill, as #-years, using standard demographic modeling and discounting the future losses at 3% annually. The interim loss includes the direct kill of birds and the first generation of their progeny. To express the injury in units that could be used to scale restoration, which is likely to be based on increased production of fledglings, the interim loss of mixed ages is divided by the bird-years gained per fledgling to estimate the number of fledglings required in compensation. The interim loss was translated to the equivalent number of age 0 animals (fledglings) at the time of the spill (2002) and if they were to be replaced in the year 2006 (i.e., discounted for 4 years of delay before restoration, a possible time-frame for restoration to be implemented). Scaling for restoration accomplished in other years than 2006 can be easily calculated by discounting the 2002 fledgling equivalents by 3% each year of delay after 2002. The majority of the injury is due to seabirds (mostly pelicans) and shorebirds, with a smaller loss of waders. The raptor and waterfowl injuries would be compensated by less than one fledgling each (in 2006).

The best estimate of total injury to subtidal fish and invertebrates is 0 kg. Subsurface concentrations of oil hydrocarbons and dissolved aromatics did not exceed 1 ppb in any water volume >140 m^3 (the resolution of the model grid for the subsurface plume) at any time after the spill. Thus, the exposure to water column and bottom-dwelling organisms in subtidal habitats was not significantly toxic and no significant impacts to these organisms from acute exposure to oil would be expected.

Injuries to intertidal biota other than birds were not included in the modeling assessment. The field-collected data (sediment and oyster tissue samples) from intertidal areas contaminated by the spill may be used to evaluate potential injuries there from exposure to oil hydrocarbons. Table S-3 lists the areas of intertidal habitat oiled to varying degrees in the (best) model simulation. The threshold 0.1 mm (~100 g/m^2) is the minimum (dose) in the model for impact to waders and shorebirds in the intertidal areas. Mortality of the vegetation in marshes occurs above about 14 mm of oil, according to literature reviewed in French et al. (1996a). In the model simulations, none of the wetlands exceeded 14 mm thick oil. Figure S-3 shows the areas oiled. Over-laid on the map are locations of intertidal oyster reefs along the Cooper River, in Charleston Harbor, and near Folly Beach. When the majority of the oil mass came ashore, 95% of the PAHs remained in the oil. Thus, the PAH content of the shoreline oil was about 2%, inferring 1 g/m^2 of total hydrocarbons (THC) is equivalent to about 0.02 g PAH/m^2. Assuming the oil was mixed into the top 1 cm of sediment, a sediment porosity of 40%, and a sediment dry weight of 2.6 g/cm^3, 1 g THC/m^2 is equivalent to 64 μg THC/g of dry sediment (64 ppm). The PAH concentration in dry sediment that is equivalent to 1 g THC/m^2 is 1.3 μg PAH/g dry sediment (1.3 ppm). The intertidal contamination predicted by the model can be broadly compared to observations based on sampling. However, detailed comparisons to sample stations are inappropriate, as the model's resolution does not address the patchy nature of the actual contamination on shore.

The accuracy of the biological injury assessment depends primarily on the accuracy of (1) the fates model results, (2) the assumed toxicity values, and (3) the biological abundance data input to the model. Since the wind and current data input to the model are reasonably accurate, the fates model simulation agrees well with observations after the spill and uncertainty associated with the fates model assumptions is relatively low. With more accurate wind data (more spatial detail), the fates model and bird mortality results would be more accurate, but the estimated losses would change by much less than an order of magnitude. Because species and life stages vary considerably in their sensitivity to aromatics in oil, the injury was quantified for the range of possible toxicity values, including for sensitive species. Even for the most sensitive species where bioassay data are available, subtidal fish and invertebrate injury from acute exposure is not indicated or likely, given the spill scenario and environmental conditions after the spill. For birds, the biomass losses are directly proportional to the pre-spill abundance assumed in the model inputs. Thus, a change (or uncertainty) in abundance is directly translated to a proportional change (uncertainty) in the quantified injury.

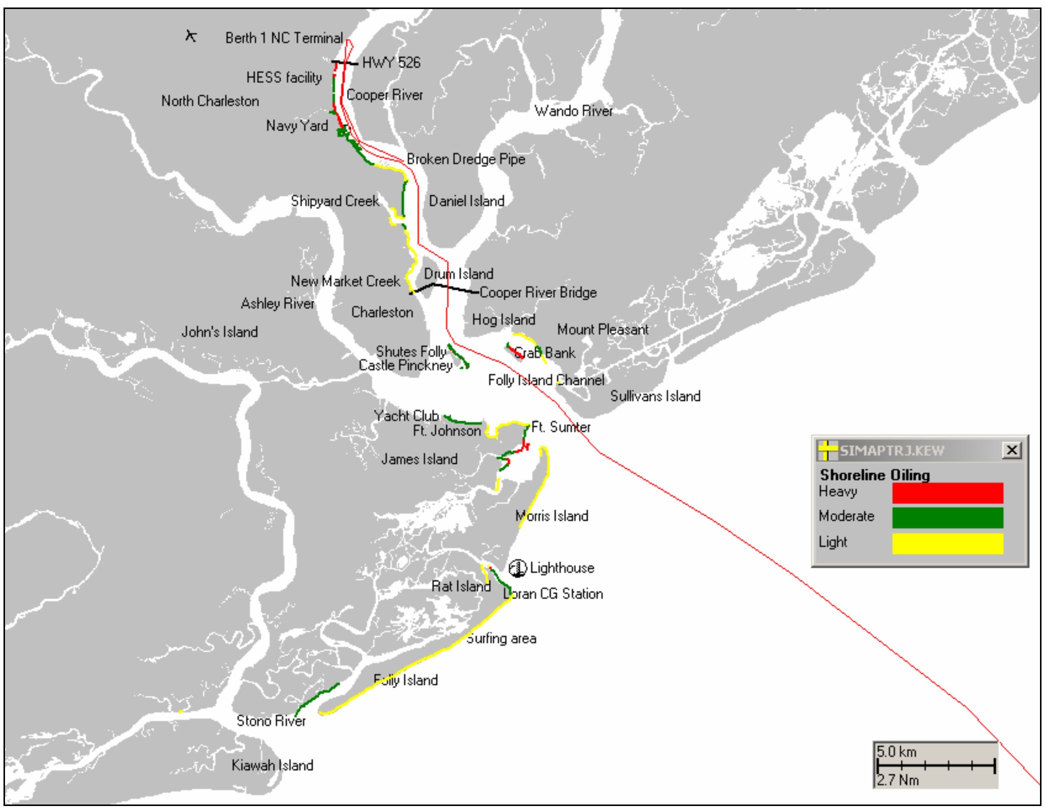

Figure S-1. Map of Charleston Harbor area, the *Ever Reach*'s path and observed shoreline oiling after the spill.

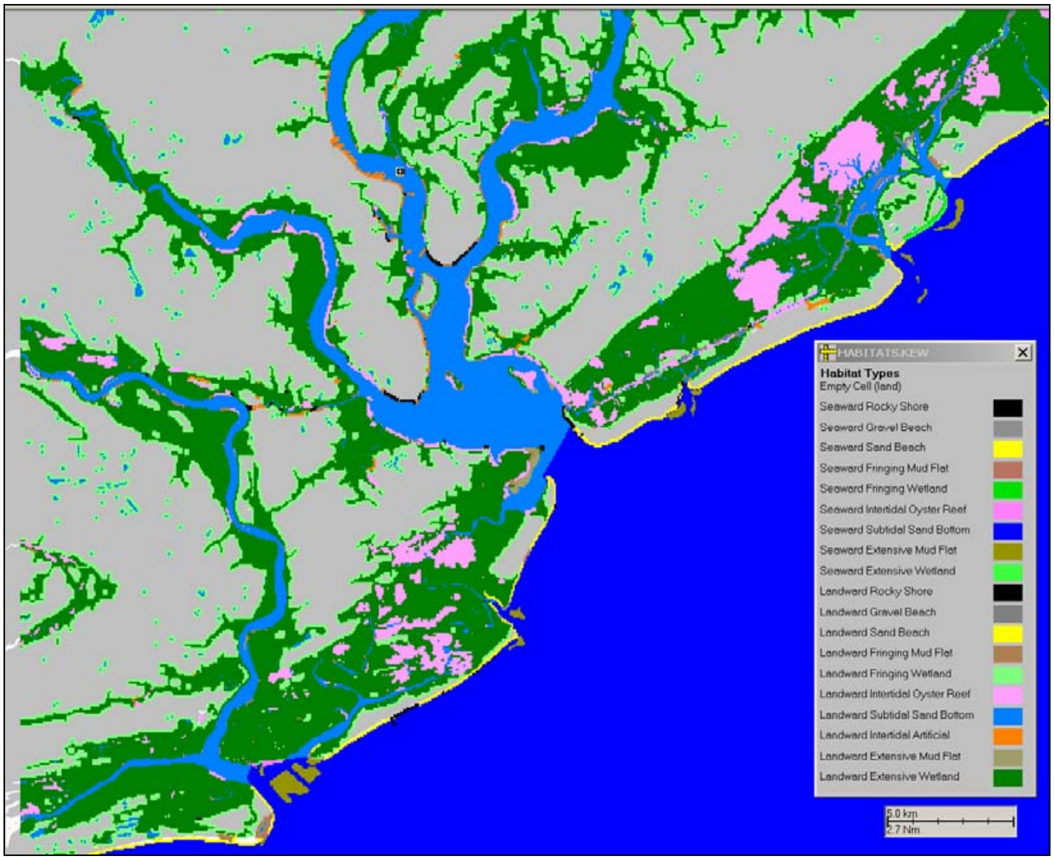

Figure S-2. Habitat grid used in modeling in the area affected by the spill.

Table S-1. Estimated injuries to birds, marine mammals and sea turtles for the best simulation of the spill. The model estimate is a probability, and thus may be a fraction of an animal. Observations of oiled birds are also listed for comparison.

Species	**Model (#)**	**Observed (#)**
Waterfowl (ducks, geese)	0.06	
Black skimmer	7.28	
Black tern	0.61	
Bonaparte's gull	0.00	
Brown pelican	75.20	48-53
Caspian tern	0.16	
Common tern	2.04	
Double-crested cormorant	1.07	1
Forster's tern	0.04	
Gull-billed tern	0.47	
Herring gull	0.10	
Laughing gull	0.56	
Least tern	0.04	
Ring-billed gull	2.60	
Royal tern	0.05	
Sandwich tern	0.01	
Black-crowned night-heron	0.02	
Clapper rail	0.05	
Great egret	12.0	several
Great blue heron	4.0	1
Green heron	0.16	
Little blue heron	0.01	
Tricolored heron	0.07	
Snowy egret	0.05	
Wood stork	0.03	
American oystercatcher	0.91	
Black-bellied plover	0.35	
Dunlin	0.99	
Greater yellowlegs	0.02	
Marbled godwit	0.37	
Ruddy turnstone	60.0	15
Semipalmated plover	2.44	
Short-billed dowitcher	2.99	
Willet	0.71	
Bald eagle	0.01	
Osprey	0.13	
Loggerhead turtle	-	

Table S-2. Summary of estimated injuries to birds, marine mammals and sea turtles for the best simulation of the spill. The model estimate is a probability, and thus may be a fraction of an animal. Observations of oiled birds are also listed for comparison.

Group Totals	Model (#)	Observed (#)	Interim Loss (# -years)	# Fledgling Equivalents (in 2002)	# Fledgling Equivalents (in 2006)
Waterfowl	0.06	-	0.1	0.1	0.1
Seabirds	89.2	49-54	556	384	433
Wading birds	16.4	approx. 4	31	36	40
Shorebirds	68.8	15	531	260	293
Raptors	0.14	-	1.0	0.5	0.6
Marine mammals (dolphins)	0	-	0	-	-
Sea turtles	0	-	0	-	-
Total birds	**174.6**	**68-73**	**1120**	**681**	**766**

Table S-3. Area (m2) of intertidal zone, by shore type, contaminated by oil of various thicknesses (1 mm thick oil ~ 1000 g/m^2 ~64 ppm total hydrocarbons, THC, ~ 1300 ppm of PAH) in the best model simulation.

Total Hydrocarbons	**>1000 g/m^2**	**>100 g/m^2**	**>10 g/m^2**	**> 1 g/m^2**	**>0.1 g/m^2**
Oil Thickness	**>1 mm**	**>0.1 mm**	**>0.01 mm**	**>0.001 mm**	**>0.0001 mm**
THC concentration (µg TPH/g dry sediment)	**> 64 mg/g**	**> 6400 µg/g**	**> 640 µg/g**	**> 64. µg/g**	**> 6.4 µg/m^2**
PAH concentration (ppm)	**> 1300 ppm**	**> 130 ppm**	**> 13 ppm**	**> 1.3 ppm**	**> 0.13 ppm**
PAH concentration (µg PAH/g dry sediment)	**> 1300 µg/g**	**> 130 µg/g**	**> 13 µg/g**	**> 1.3 µg/g**	**> 0.13 µg/m^2**
Shore Type:					
Rocky shoreline	140	2,737	2,737	2,737	2,737
Gravel beach	211	772	772	772	772
Sand beach	702	6,317	6,317	6,317	6,317
Mud flat	702	2,456	2,456	2,456	2,456
Wetland	772	2,737	2,737	2,737	2,737
Oyster reef	0	2,035	2,035	2,035	2,035
Artificial shoreline	2,527	6,387	6,387	6,387	6,387
Total	5,053	23,442	23,442	23,442	23,442

Table S-4. Area (acres) of intertidal zone, by shore type, contaminated by oil of various thicknesses (1 mm thick oil ~ 1000 g/m2 ~64 ppm total hydrocarbons, THC, ~ 1300 ppm of PAH) in the best model simulation.

Total Hydrocarbons	**>1000 g/m^2**	**>100 g/m^2**	**>10 g/m^2**	**> 1 g/m^2**	**>0.1 g/m^2**
Oil Thickness	**>1 mm**	**>0.1 mm**	**>0.01 mm**	**>0.001 mm**	**>0.0001 mm**
THC concentration (µg TPH/g dry sediment)	**> 64 mg/g**	**> 6400 µg/g**	**> 640 µg/g**	**> 64. µg/g**	**> 6.4 µg/m^2**
PAH concentration (ppm)	**> 1300 ppm**	**> 130 ppm**	**> 13 ppm**	**> 1.3 ppm**	**> 0.13 ppm**
PAH concentration (µg PAH/g dry sediment)	**> 1300 µg/g**	**> 130 µg/g**	**> 13 µg/g**	**> 1.3 µg/g**	**> 0.13 µg/m^2**
Shore Type:					
Rocky shoreline	0.03	0.68	0.68	0.68	0.68
Gravel beach	0.05	0.19	0.19	0.19	0.19
Sand beach	0.17	1.56	1.56	1.56	1.56
Mud flat	0.17	0.61	0.61	0.61	0.61
Wetland	0.19	0.68	0.68	0.68	0.68
Oyster reef	0.00	0.50	0.50	0.50	0.50
Artificial shoreline	0.62	1.58	1.58	1.58	1.58
Total	1.25	5.79	5.79	5.79	5.79

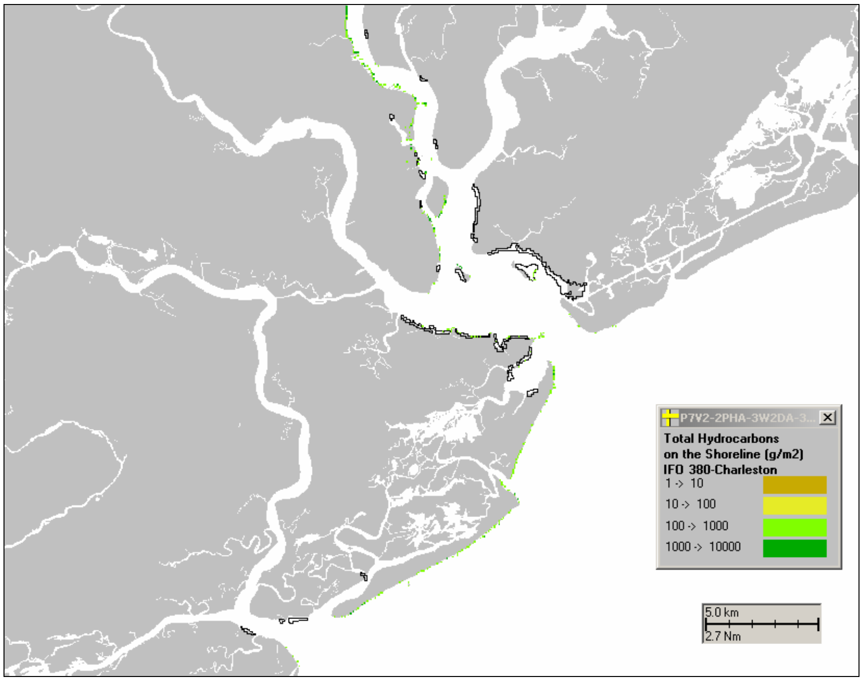

Figure S-3. Total hydrocarbons on shorelines predicted by the (best) model simulation. The polygons over-laid on the map are locations of oyster reefs that are along the shore of the Cooper River, in Charleston Harbor, and near Folly Beach, i.e., that were oiled or near areas oiled in the model simulation. (Note: Figure S-2 shows the location of all oyster reefs in the model grid.)

1. INTRODUCTION

Oil spill modeling was performed for the 30 September 2002 spill into Charleston Harbor, SC, from the container ship *M/V Ever Reach*. The modeling provides (1) an assessment of the pathways and fate of the oil, and thus estimate exposure to the water surface, shoreline and other habitats, water column, and sediments; and (2) an estimate of injuries to wildlife (birds, mammals, sea turtles) and subtidal aquatic organisms (i.e., water column and benthic biota, exposed by the water pathway and subtidal sediment contamination). This report describes the data inputs for and results of the modeling. Inputs include habitat and depth mapping, winds, currents, other environmental conditions, chemical composition and properties of the source oil, specifications of the release (amount, timing, etc.), toxicity parameters, and biological abundance. Some inputs have significant influence on the modeling results. Sensitivity analysis was performed by varying critical input data.

Model results are displayed by a Windows graphical user interface (SIMAP Viewer) that animates the trajectory and concentrations over time. The model simulation outputs are provided with the SIMAP Viewer so that the details may be examined at any scale (zoom window). The figures included here (in the appendices) are selected snapshots taken from that output. Appendix A.1 shows the spill location and nearby areas. Place names on the map are used in this report to describe observations and model results. Appendices A.2 and A.3 show the shoreline and habitat types, and water depths in the model domain.

The spill was 12,500 gal (= 46.4 MT) of intermediate fuel oil (IFO 380). It appears to have been caused by grounding on a submerged dredge pipe in the Cooper River, which occurred as the vessel came into port early on 30 September 2002. Based on the distribution of oil observed after the spill and modeling results, the release must have been protracted: as the ship was traveling from the grounding site (79^{o} 56.195' W, 32^{o} 51.167' N) into Berth 1 NC Terminal (05:35 to 07:18 hours), and again as the ship left the harbor later the same day (left berth at 19:00 hours, passed harbor entrance about 20:30 hours). Oiling in the harbor and outside along Morris and Folly Islands cannot be accounted for assuming oil was released only at or up-river of the submerged dredge site. Considerable oil must have been released in the lower harbor and outside in offshore waters. The leak apparently stopped while the ship was at the berth, as the U.S. Coast Guard did not observe any oil around the ship while in port. (Hydrostatic pressure would retain oil in the hull while the ship was stationary, but when the ship moved, lower pressure over the hull surface and turbulence would draw oil out of the ship.)

Figures in Appendix B show observations made on oil movements and the extent of oil contamination. From an over-flight done between 07:30 and 09:00 on 2 October 2003, the shoreline of the Navy pier was heavily oiled, as was the eastern coastlines of Shutes Folly and Crab Bank (Figure B.1-1). This oiling was still observed on the mornings of 3 October and 4 October (Figures B.1-2 and B.1-3). The SCAT observations from 2 October are similar to those from the over-flight on that same day, however, with some more oiling on the shore side of Mount Pleasant, heavy oiling along Ft. Johnson, and some light oiling on Morris Island (Figure B.2-1). On the morning of 3 October, the

SCAT team observed small tar balls (approximately 2 cm in diameter) in the wrack line and estimated 1% oil coverage on North Folly Beach. As the SCAT team moved south on Folly Beach, they noticed an increase in the size of tar balls (up to the size of a quarter) and estimated oil coverage to be 10% (Figure B.2-2; Situation Update, http://spills.incidentnews.gov). These observations were used to calibrate the fates model to the spill conditions.

Section 2 describes the physical fates and biological effects model used for this analysis. Section 3 describes the model input data and assumptions. Results of the physical fates model are described in Section 4. Section 5 describes the biological impacts and injury quantification results. References cited are in Section 6. Appendices provide input data and model results, in tables, maps and other figures.

2. MODEL DESCRIPTION

The analysis was performed using the model system developed by Applied Science Associates (ASA) called SIMAP (Spill Impact Model Analysis Package). SIMAP includes (1) an oil physical fates model, (2) interfacing to a hydrodynamics model for simulation of currents, (3) a biological effects model, (4) an oil physical, chemical and toxicological database, (5) environmental databases (winds, currents, salinity, temperature), (6) geographical data (in a GIS), (7) a biological database, (8) a response module to analyze effects of response activities, (9) graphical visualization tools for outputs, and (10) exporting tools to produce text format output.

SIMAP originated from the oil fates and biological effects submodels in the Natural Resource Damage Assessment Model for Coastal and Marine Environments (NRDAM/CME), which ASA developed in the early 1990s for the US Department of the Interior for use in Natural Resource Damage Assessment (NRDA) regulations under the Comprehensive Environmental Response, Compensation and Liability Act of 1980 (CERCLA). The NRDAM/CME (Version 2.4, April 1996) was published as part of the CERCLA type A NRDA Final Rule (Federal Register, May 7, 1996, Vol. 61, No. 89, p. 20559-20614). The technical documentation for the NRDAM/CME is in French et al. (1996a,b,c). This technical development involved several in-depth peer reviews, as described in the Final Rule.

SIMAP has undergone considerable development since completion of the NRDAM/CME. Additions and modifications to prepare SIMAP were made to increase model resolution, allow modification and site-specificity of input data, allow incorporation of temporally varying current data, evaluate subsurface releases and movements of subsurface oil, track multiple chemical components of the oil, enable stochastic modeling, and facilitate analysis of results. The consideration of the impacts of subsurface oil is important, particularly in the evaluation of impacts on aquatic organisms. Surface floating oil primarily impacts wildlife and intertidal biota, and not aquatic biota in subtidal habitats. At higher wind speeds than about 12 knots, oil will entrain into the water column, unless it has become too viscous to do so after weathering and the formation of mousse. Once oil is entrained in the water in the form of small droplets, monoaromatics (MAHs) and polynuclear aromatic hydrocarbons (PAHs) dissolve into the water column. The dissolved MAHs and PAHs are the most bioavailable and toxic portion of the oil. The dissolution rate is very sensitive to the droplet size (because it involves mass transfer across the surface area of the droplet), and the amount of hydrocarbon mass dissolved is a function of the mass entrained and droplet size distribution. These are in turn a function of soluble hydrocarbon content of the oil, the amount of evaporation of these components before entrainment, oil viscosity (which increases as the oil weathers and emulsifies), oil surface tension (which may be reduced by surfactant dispersants), and the energy in the system (the higher the energy the smaller the droplets). Large droplets (greater than a few hundred microns in diameter) resurface rapidly, and so dissolution from those is also inconsequential.

Thus, the fate of MAHs and PAHs in surface oil is primarily volatilization to the atmosphere, rather than to the water. If wind speeds exceed 12 knots, entrainment of the surface oil into the water becomes significant. If oil is entrained before it has weathered and lost the lower molecular weight aromatics to the atmosphere, dissolved MAHs and PAHs in the water can reach concentrations where they can affect water column organisms or bottom communities (French McCay and Payne, 2001).

Below are brief descriptions of the fates and effects models implemented in SIMAP. Detailed descriptions of the algorithms and assumptions in the model are in published papers (French McCay 2002, 2003, 2004). The model has been validated with more than 20 case histories, including the *Exxon Valdez* and other large spills (French and Rines, 1997; French McCay, 2003, 2004; French McCay and Rowe, 2004) as well as test spills designed to verify the model (French et al., 1997).

2.1 Physical Fates Model

The three-dimensional physical fates model estimates distribution (as mass and concentrations) of whole oil and oil components on the water surface, on shorelines, in the water column, and in sediments. Oil fate processes included are spreading (gravitational and by shearing), evaporation from slicks, transport, randomized dispersion, emulsification, entrainment (natural and facilitated by dispersant), dissolution, volatilization of dissolved hydrocarbons from the surface water, adherence of oil droplets to suspended sediments, adsorption of soluble and semi-soluble aromatics to suspended sediments, sedimentation, and degradation.

Oil is a mixture of hydrocarbons of varying physical, chemical, and toxicological characteristics. Thus, oil hydrocarbons have varying fates and impacts on organisms. In the model, oil is represented by component categories, and the fate of each tracked separately. The "pseudo-component" approach (Payne et al., 1984, 1987; French et al., 1996a; Jones 1997; Lehr et al. 2000) is used, where chemicals in the oil mixture are grouped by physical-chemical properties, and the resulting component category behaves as if it were a single chemical with characteristics typical of the chemical group.

The most toxic components of oil to aquatic organisms are low molecular weight aromatic compounds (monoaromatic and polynuclear aromatic hydrocarbons, MAHs and PAHs), which are both volatile and soluble in water. Their acute toxic effects are by narcosis, where toxicity is related to the octanol-water partition coefficient (K_{ow}), a measure of hydrophobicity. The more hydrophobic the compound, the more toxic, but the less soluble and so the less exposure there is to aquatic organisms. Compounds of $\log(K_{ow})>5.6$ are considered insoluble and so unavailable to aquatic biota (French McCay, 2002). Thus, impact is the result of a balance between bioavailability (exposure) and toxicity once exposed. French McCay (2002) contains a full description of the oil toxicity model in SIMAP.

Because of these considerations, the SIMAP fates model focuses on tracking the lower molecular weight aromatic components divided into chemical groups based on volatility, solubility, and hydrophobicity. In the model, the oil is treated as eight components (defined in Table 2-1). Six of the components (all but the two non-volatile residual components) evaporate at rates specific to the pseudo-component. Solubility is strongly correlated with volatility, and the solubility of aromatics is higher than aliphatics of the same volatility, with the MAHs the most soluble, the 2-ring PAHs semi-soluble, and the 3-ring PAHs slightly soluble Mackay et al. (1992a,b,c,d). Both the solubility and toxicity of the non-aromatic hydrocarbons are much less than for the aromatics and dissolution (and water concentrations) of non-aromatics is safely ignored. Thus, dissolved concentrations are calculated only for each of the three soluble aromatic pseudo-components.

This number of components provides sufficient accuracy for the evaporation and dissolution calculations, particularly given the time frame (minutes) over which dissolution occurs from small droplets and the rapid resurfacing of large droplets (see discussion above). The alternative of treating oil as a single compound with empirically-derived rates (e.g., Mackay et al, 1980; Stiver and Mackay, 1984) does not provide sufficient accuracy for impact analyses because the impacts to water column organisms are caused by MAHs and PAHs, which have specific properties that differ from the other volatile and soluble compounds. Use of more pseudo components does not improve accuracy, as the major constituents of concern are well characterized (sufficiently similar in properties within the pseudo-component group of chemicals) by the modelled component properties used in SIMAP. The model has been validated both in predicting dissolved concentrations and resulting toxic effects, supporting the adequacy of the use of this number of pseudo-components (French McCay, 2003).

Table 2-1. Definition of four distillation cuts and the eight pseudo-components in the model (monoaromatic hydrocarbons, MAHs; benzene + toluene + ethybenzene + xylene, BTEX; polynuclear aromatic hydrocarbons, PAHs).

Characteristic	**Volatile and and Highly Soluble**	**Semi-volatile and Soluble**	**Low Volatility and Slightly Soluble**	**Residual (non-volatile and insoluble)**
Distillation cut	1	2	3	4
Boiling Point (^{o}C)	< 180	180 - 265	265 - 380	>380
Molecular Weight	50 - 125	125 - 168	152 - 215	> 215
Log(K_{ow})	2.1-3.7	3.7-4.4	3.9-5.6	>5.6
Aliphatic pseudo-components: Number of Carbons	volatile aliphatics: C4 – C10	semi-volatile aliphatics: C10 – C15	low-volatility aliphatics: C15 – C20	non-volatile aliphatics: > C20
Aromatic pseudo-component name: included compounds	MAHs: BTEX, MAHs to C3-benzenes	2 ring PAHs: C4-benzenes, naphthalene, C1-, C2-naphthalenes	3 ring PAHs: C3-, C4-naphthalenes, 3-4 ring PAHs with log(K_{ow}) < 5.6	$\geq$4 ring aromatics: PAHs with log(K_{ow}) > 5.6 (insoluble)

The lower molecular weight aromatics dissolve from the whole oil and are partitioned in the water column and sediments according to equilibrium partitioning theory (French et al., 1996a; French McCay 2004). The residual fractions in the model are composed on non-volatile and insoluble compounds that remain in the "whole oil" that spreads, is transported on the water surface, strands on shorelines, and disperses into the water column as oil droplets or remains on the surface as tar balls. This is the fraction that composes black oil, mousse, and sheen.

The schematic in Figure 2-1 shows oil fate processes simulated in the model in open water. The algorithms are described in French McCay (2004). Lagrangian elements (spillets) are used to simulate the movements of oil components in three dimensions over time. Surface floating oil, subsurface droplets, and dissolved components are tracked in separate spillets. Transport is the sum of advective velocities by currents input to the model, surface wind drift, vertical movement according to buoyancy, and randomized turbulent diffusive velocities in three dimensions. The vertical diffusion coefficient is computed as a function of wind speed in the wave-mixed layer. The horizontal and deeper water vertical diffusion coefficients are model inputs.

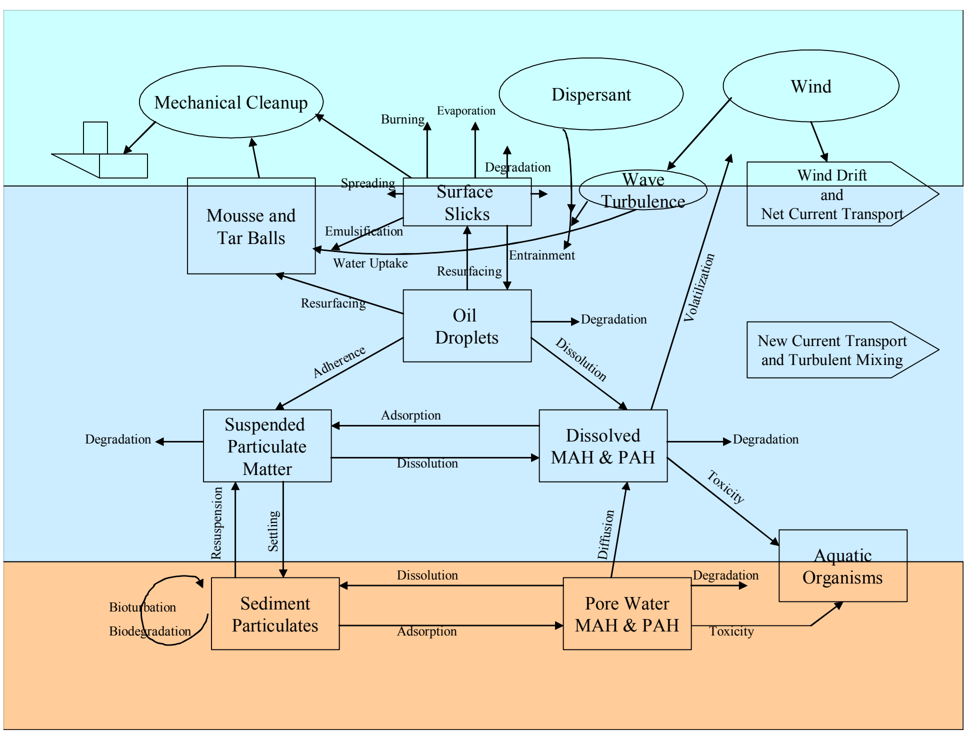

Figure 2-1. Simulated oil fates processes in open water

The oil (whole and as pseudo-components) separates into different phases or parts of the environment, i.e., surface slicks; emulsified oil (mousse) and tar balls; oil droplets suspended in the water column; dissolved lower molecular weight components (MAHs and PAHs) in the water column; oil droplets adhered and hydrocarbons adsorbed to suspended particulate matter in the water; hydrocarbons on and in the sediments; dissolved MAHs and PAHs in the sediment pore water; and hydrocarbons on and in the shoreline sediments and surfaces. The physical fates model creates output files recording the distribution of a spilled substance in three-dimensional space and time. The quantities recorded are:

- area covered by oil and thickness on the water surface ("swept area");
- volumes in the water column at various concentrations of dissolved aromatics;
- volumes in the water column at various concentrations of total hydrocarbons in suspended droplets;
- total hydrocarbon concentrations and dissolved aromatic concentrations in surface sediment;
- lengths and locations of shoreline impacted and volume of oil ashore in each segment.

The dissolved aromatic hydrocarbon concentration in the water column is calculated from the mass in the Lagrangian elements, as follows. Concentration is contoured on a three-dimensional Lagrangian grid system. This grid (of 200 X 200 cells in the horizontal and 5 vertical layers) is scaled each time step to just cover the volume occupied by aromatic particles, including the dispersion around each particle center. This maximizes the resolution of the contour map at each time step and reduces error caused by averaging mass over large cell volumes. Distribution of mass around the particle center is described as Gaussian in three dimensions, with one standard deviation equal to twice the diffusive distance ($2D_xt$ in the horizontal, $2D_zt$ in the vertical, where D_x is the horizontal and D_z is the vertical diffusion coefficient, and t is particle age). The plume grid edges are set at one standard deviation out from the outer-most particle. These data are used by the biological effects model to evaluate exposure, toxicity and impacts.

2.2 Biological Effects Model

The biological exposure model estimates the area, volume or portion of a stock or population affected by surface oil, concentrations of oil components in the water, and sediment contamination. The biological effects model estimates losses resulting from acute exposure after a spill (i.e., losses at the time of the spill and while acutely toxic concentrations remain in the environment) in terms of direct mortality and lost production because of direct exposure or the loss of food resources from the food web. Losses are estimated by species or species group for fish, invertebrates (i.e., shellfish and non-fished species) and wildlife (birds, mammals, sea turtles). Lost production of aquatic plants (microalgae and macrophytes) and lower trophic levels of animals are also estimated.

The area potentially affected by the spill is represented by a rectangular grid with each grid cell coded as to habitat type. The habitat grid is also used by the physical fates model to define the shoreline location and type, as well as habitat and sediment type. A habitat is an area of essentially uniform physical and biological characteristics that is occupied by a group of organisms that are distributed throughout that area. A contiguous grouping of habitat grid cells with the same habitat code represents an ecosystem in the biological model. The density of fish, invertebrates and wildlife, and rates of lower trophic level productivity, are assumed constant for the duration of the spill simulation and evenly distributed across an ecosystem. While biological distributions are known to be highly variable in time and space, data are generally not sufficient to characterize this patchiness. Oil is also patchy in distribution. The patchiness is assumed to be on the same scale so that the intersection of the oil and biota is equivalent to overlays of spatial mean distributions.

Mobile fish, invertebrates and wildlife are assumed to move at random within each ecosystem during the simulation period. This is a reasonable assumption for the period of the simulation (generally a few weeks). Benthic organisms may also remain stationary on or in the bottom. Planktonic stages, such as pelagic fish eggs, larvae, and juveniles (i.e., young-of-the-year during their pelagic stage(s)), move with the currents.

Habitats include open water, oyster reef, wetland, sea grass, and shoreline environments. Habitat types are defined by depth, proximity to shoreline(s), bottom/shore type, dominant vegetation type, and the presence of invertebrate reefs. With respect to proximity to shoreline(s), habitats are designated as landward or seaward. Landward portions are the harbor, rivers, and inlets. The seaward portion is the open ocean (coastal continental shelf). This designation allows different biological abundances to be simulated in landward and seaward zones of the same habitat type (e.g., open water with sand bottom).

2.2.1 Wildlife

In the model, surface slicks (or other floating forms such as tar balls) of oils and petroleum products impact wildlife (birds, marine mammals, sea turtles). For each of a series of surface spillets, the physical fates model calculates the location and size (radius of circular spreading spillet) as a function of time. The area swept by a surface spillet in a given time step is calculated as the quadrilateral area defined by the path swept by the spillet diameter. This area is summed over all time steps for the time period the spillet is present on the water surface and separately for each habitat type where the oil passes. Spillets sweeping the same area of water surface at the same time are superimposed. The total area swept over a threshold thickness by habitat type is multiplied by the probability that a species uses that habitat (0 or 1, depending upon its behavior) and a combined probability of oiling and mortality. This calculation is made for each surface-floating spillet and each habitat for the duration of the model simulation.

A portion of the wildlife in the area swept by the slick over a threshold thickness is assumed to die, based on probability of encounter with the slick multiplied by the probability of mortality once oiled. The probability of encounter with the slick is related to the percentage of the time an animal spends on the water or shoreline surface. The probability of mortality once oiled is nearly 100% for birds and fur-covered mammals (assuming they are not successfully treated) and much lower for other wildlife. The products of the two probabilities for various wildlife behavior groups are in Table 2-2. Estimates for the probabilities are derived from information on behavior and field observations of mortality after spills (reviewed in French et al., 1996a). The threshold is

10 micron (~10g/m^2) thick oil, based on data and calculations in French et al. (1996a). The wildlife mortality model has been validated with more than 20 case histories, including the *Exxon Valdez* and other large spills, verifying that these values are reasonable (French and Rines, 1997; French McCay 2003, 2004; French McCay and Rowe, 2004).

Area swept is calculated for the habitats occupied by each of the behavior groups of wildlife listed in Table 2-2. Species or species groups are assigned to behavior groups to evaluate their loss. Wildlife mortality is directly proportional to abundance per unit area and the percent mortalities in Table 2-2.

Table 2-2. Combined probability of encounter with the slick and mortality once oiled, if present in the area swept by a slick exceeding a threshold thickness. Area swept is calculated for the habitats occupied.

Wildlife Group	Probability	Habitats Occupied
Dabbling waterfowl	99%	Intertidal and landward subtidal
Nearshore aerial divers	35%	Intertidal and landward subtidal
Surface seabirds	99%	All intertidal and subtidal
Aerial seabirds	5%	All intertidal and subtidal
Wetland wildlife (waders and shorebirds)	35%	Wetlands, shorelines, seagrass beds
Cetaceans	0.1%	Seaward subtidal
Sea turtles	1%	All intertidal and subtidal
Surface birds in seaward only	99%	All seaward intertidal and subtidal
Surface diving birds in seaward only	35%	All seaward intertidal and subtidal
Aerial divers in seaward only	5%	All seaward intertidal and subtidal
Surface birds in landward only	99%	All landward intertidal and subtidal
Surface diving birds in landward only	35%	All landward intertidal and subtidal
Aerial divers in landward only	5%	All landward intertidal and subtidal
Surface diving birds in water only	35%	All subtidal
Aerial divers in water only	5%	All subtidal

2.2.2 Fish and Invertebrates

In the model, aquatic biota (e.g., fish, invertebrates) are affected by dissolved aromatic concentrations in the water or sediment. This rationale is supported by the fact that soluble aromatics are the most toxic constituents of oil (Neff *et al.*, 1976; Rice *et al.*, 1977; Tatem *et al.*, 1978; Neff and Anderson, 1981; Malins and Hodgins, 1981; National Research Council, 1985, 2002; Anderson, 1985; French McCay 2002). Exposures in the water column are short in duration. Therefore, effects there are the result of acute toxicity. In the sediments, exposure may be both acute and chronic, as the concentrations may remain elevated for longer periods of time.

The model evaluates mortality and sublethal effects of dissolved aromatic concentrations in the water or sediment. Mortality is a function of duration of exposure – the longer the duration of exposure, the lower the effects concentration (see review in French McCay, 2002). At a given concentration after a certain period of time, all individuals which will die have done so. The LC50 is the lethal concentration to 50% of exposed organisms. The incipient LC50 ($LC50_{\infty}$) is the asymptotic LC50 reached after infinite exposure time (or long enough that that level is approached, Figure 2-2). Percent mortality is a log-normal function of concentration, with the LC50 the center of the distribution.

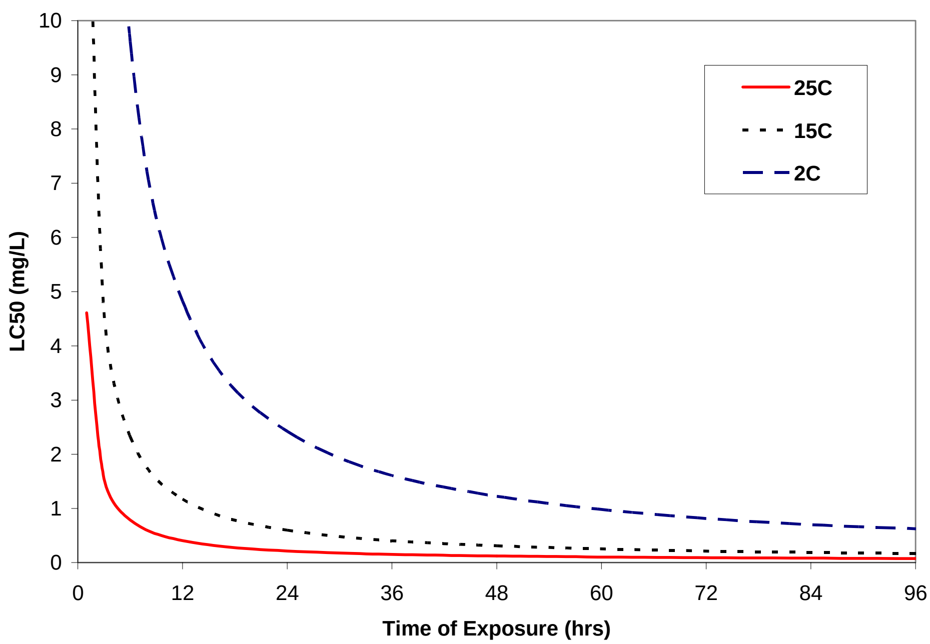

Figure 2-2. LC50 of dissolved PAH mixtures from oil, as a function of exposure duration and temperature.

The oil toxicity model in SIMAP utilizes the accepted toxic units approach for organic compounds whose primary acute effect is narcosis, which include MAHs and PAHs. The acute toxic effects of narcotic chemicals are additive (Swartz et al., 1995; French et al., 1996a; DiToro et al., 2000; DiToro and McGrath, 2000; French McCay, 2002). The approach is being used by the US Environmental Protection Agency (EPA) in the development of PAH water and sediment quality criteria (DiToro et al., 2000; DiToro and McGrath, 2000). French McCay (2002) provides estimates of $LC50_\infty$ for MAH and PAH mixtures in fuel and crude oils for spills under different environmental conditions. Figure 2-2 plots LC50s for total dissolved PAHs for species of average sensitivity under turbulent conditions ($LC50_\infty$ = 50 µg/L) for a range of exposure durations and temperatures. The $LC50_\infty$ for 95% of species fall in the range 6-400 µg/L (ppb). This oil toxicity model has been validated using laboratory oil bioassay data (French McCay, 2002).

In SIMAP, $LC50_\infty$ for the dissolved aromatic mixture of the spilled oil is input to the model. For each of a series of aquatic biota behavior groups, the model evaluates exposure duration, and corrects the LC50 for time of exposure and temperature to calculate mortality (Figure 2-2). The oil toxicity model is described in detail in French McCay (2002).

Movements of biota, either active or by current transport, are accounted for in determining time and concentration of exposure. Lagrangian elements are used to represent schools or groups of animals. The elements move or remain stationary according to the behavior of the animal type, and concentration and duration of exposure are recorded. Exposures are integrated over space and time by habitat type (open water, reef, or wetland in offshore or nearshore waters) to calculate a total percentage killed. The behavior groups, representing species or stages within species, are:

1) planktonic (move with currents),
2) demersal and stationary (on the bottom exposed to near bottom water),
3) benthic (in the sediments and stationary),
4) demersal fish and invertebrates (on the bottom exposed to near bottom (within 1 m) water and moving slowly),
5) small pelagic fish and invertebrates (moving randomly and slowly in the water column), and
6) large pelagic fish and invertebrates (moving randomly and rapidly in the water column).

Mortality is calculated as percent loss in specified areas. The percent mortality of the exposure group is multiplied by abundance at the time exposed and in the habitat type to calculate the species' mortality as numbers or biomass (kg).

Lost production of lower trophic level plants and animals (not explicitly modeled as individual species) is also integrated in space and over time using EC50s, the effective concentration to reduce growth to 50% of normal, to parameterize a log-normal function of the same form as the mortality function. Total production loss (g dry weight) is summed over time and space. Production losses of lower trophic levels are typically very small because of their short generation times and quick recovery after a spill. They have not been measured in the field because the impact is less than natural variability.

2.3 Validation of the Biological Effects Model

The biological effect model has been validated using simulations of over 20 spill events where data are available for comparison (French and Rines, 1997; French McCay, 2003, 2004; French and Rowe, 2004). In most cases (French and Rines, 1997; French McCay, 2004; French and Rowe, 2004) only the wildlife impacts could be verified because of limitations of the available observational data. However, in the *North Cape* spill simulations, both wildlife and water column impacts (lobsters) could be verified (French McCay, 2003).

2.4 Quantification of Fish and Invertebrate Injury as Lost Production

The biomass (kg) of animals killed represents biomass that had been produced before the spill. In addition to this injury, if the spill had not occurred, the killed organisms would have continued to grow until they died naturally or to fishing. This lost future (somatic) production is estimated and added to the direct kill injury. The total injury is the total production foregone. The loss is expressed in present day (i.e., present year) values using a 3% annual discount rate for future losses. Restoration should compensate for this loss. The scale of restoration needed is equivalent to production lost when both are expressed in values indexed to the same year, i.e., the present year.

Interim losses are injuries sustained in future years (pending recovery to baseline abundance) resulting from the direct kill at the time of the spill. Interim losses potentially include:

- Lost future uses (ecological and human services) of the killed organisms themselves;
- Lost future (somatic) growth of the killed organisms (i.e., production foregone, which provides additional services);
- Lost future reproduction, which would otherwise recruit to the next generation.

The approach here is that the injury includes the direct kill and its future services, plus the lost somatic growth of the killed organisms, which would have provided additional services. Because the impact on each species, while locally significant, is relatively small compared to the scale of the total population in the area, it is assumed that density-dependent changes in survival rate are negligible, i.e., changes in natural and fishing mortality of surviving animals do not compensate for the killed animals during the natural life span of the animals killed.

It is also assumed that the injuries were not large enough to significantly affect future reproduction and recruitment in the long term. It is assumed that sufficient eggs will be produced to replace the lost animals in the next generation. The numbers of organisms affected, while locally significant, are relatively small portions of the total reproductive stock. Given the reproductive strategy of the species involved to produce large numbers of eggs, of which only a few survive, it is assumed that density-dependent compensation for lost reproduction occurs naturally.

The services provided by the injured organisms are measured in terms of production, i.e., biomass (kg wet weight) directly lost or not produced. Among other factors, services of biological systems are related to the productivity of the resources, i.e., to the amount of food produced, the usage of other resources (as food and nutrients), the production and recycling of wastes, etc. Particularly in aquatic ecosystems, the rate of turnover (production) is a better measure of ecological services than standing biomass (Odum, 1971). Thus, the sum of the standing stock killed (which resulted from production previous to the spill) plus lost future production is a more appropriate scaler, as opposed to standing stock alone (as number or kg), for measuring ecological services.

This injury estimation method was developed and used previously in the injury quantification for the *North Cape* spill of January 1996 (French McCay et al., 2003). The method makes use of the population model in the NRDAM/CME and SIMAP. Injuries are calculated in three steps:

1. The direct kill is quantified by age class using a standard population model used by fisheries scientists.
2. The net (somatic) growth normally to be expected of the killed organisms is computed and summed over the remainder of their life spans (termed lifetime production).
3. Future interim losses are calculated in present day values using discounting at a 3% annual rate.

The normal (natural in local waters) survival rates per year and length-weight by age relationships are used to construct a life table of numbers and kg for each annual age class. Lifetime production is estimated as the sum of the net (somatic) growth normally to be expected of the killed individual over the remainder of its life span. The age-class specific weight gain per year times percent expected to be left alive by the end of that year is summed over all years to calculate total lifetime production. Growth in future years is discounted 3% annually. Equations for these calculations are in French McCay et al. (2003).

It should be noted that compensation is needed for lost production of each of the individual species injured, and that losses are additive. Restoration for a prey species killed will compensate for that prey killed and all the services that prey would have provided in the future to its predators and other resources. The predators that would eat that prey but were directly killed were produced before the spill from *different* prey individuals as food. Thus, the predator's production loss must be compensated in addition to the prey animals directly killed. This may be accomplished by providing additional prey production to compensate for the direct predator loss.

Discounting at 3% per year is included to translate losses in future years (interim loss) to present-day values. The discounting multiplier for translating value n years after the spill to present value is calculated as $(1+d)^{-n} = 1/(1+d)^n$, where d=0.03. Thus, the losses in future years have a discounted value in the present. In this report, all discounting is calculated based on the number of years from the year of the spill. The present day is considered the year of the spill.

2.5 Quantification of Wildlife Injury (Interim Loss)

The interim loss of wildlife (in this case, birds) is calculated from the number of oil-killed birds using standard demographic modeling. The interim loss includes the direct loss, expressed as the number of bird-years lost that is attributable to the killed birds themselves, and the loss of fledgling production those birds would have produced. The lost fledglings are also translated to number of bird-years lost using the same demographic model. One generation of fledglings is assumed lost because of the spill's effects.

The direct loss is the sum over all years into the future of the number of birds that would have otherwise been alive each year following the spill, counting each year of life as one bird-year, until all animals would have died in the absence of the spill. The calculation is based on the following, using annual age classes. The number reaching age *t* in years (N_t) is the number at the previous annual age class (N_{t-1}) times the annual survival rate for that age class:

$$N_t = N_{t-1}\, e^{(-Z_t)}$$

where Z_t is the age-specific annual instantaneous natural mortality rate, which is related to the annual survival rate for age *t* (S_t) by the following:

$$S_t = e^{(-Z_t)}$$

The equations used to calculate the direct interim loss in bird-years (D_L) are:

$$D_L = \sum_i \sum_y \left(N_{i,y}\, S_{i+y} \right) / (1+d)^y$$

$$N_{i+1,y+1} = N_{i,y}\, S_{i+y} = N_{i,y}\, e^{[-(Z_{i+y})]}$$

where $N_{i,y}$ is the number of age class i expected to have remained alive at the beginning of year y after the spill, S_{i+y} is the expected portion of age class i surviving from age i+y to i+y+1, W_{i+y} is the weight per individual for age class i at y years after the spill, Z_{i+y} is instantaneous annual mortality rate (for age i+y), and *d* is the discount rate ($d = 0.03$: NOAA 1997). For first year birds, S_1 is corrected for the age of the bird at the spill date, i.e., survival rate is assumed constant from the date of fledging to their first birthday after hatching.

The equations used to calculate the interim loss for fledglings the kill birds would have otherwise produced, in bird-years (F_L) are:

$$F_L = \sum_i \sum_y \left(N_{i,y}\, S_{i+y}\, R_{i+y}\, F_{i+y} \right) / (1+d)^y$$

where R_{i+y} is the number of fledglings produced per bird at age $i+y$ and F_{i+y} is the number of bird-years per fledgling discounted by the number of years after the spill when they would have been produced, $i+y$. F_{i+y} is calculated as:

$$F_{i+y} = \sum_{n=i+y}^{\infty} \left(S_{i+y} \right) / (1+d)^n$$

The total interim loss (T_L), in bird-years, is the sum of the direct loss and the lost fledgling production:

$$T_L = D_L + F_L$$

These bird-years (T_L) are of mixed age classes. The interim loss T_L is translated to the equivalent number of fledglings (F_P) needed in compensation, as a likely restoration objective would be to produce additional fledglings to add to the population. The calculation of F_P is as follows:

$$F_P = T_L / F_G$$

where F_G is the number of bird-years per fledgling produced, calculated as:

$$F_G = \sum_i \left(S_i \right) / (1+d)^i$$

Thus, the injury is quantified as lost bird-years of mixed age classes (T_L) and translated to the number of fledglings that would produce that same number of bird-years (F_P). Replacement of F_P birds at the age of fledging would compensate for the injury resulting from the oil-induced mortality of all ages of birds and their fledgling production foregone.

3. MODEL INPUT DATA

3.1 Geographical and Model Grid

For geographical reference, SIMAP uses a rectilinear grid to designate the location of the shoreline, the water depth (bathymetry), and the shore or habitat type. The grid is generated from a digital coastline using the ESRI Arc/Info compatible Spatial Analyst program. The cells are then coded for depth and habitat type. Note that the model identifies the shoreline using this grid. Thus, in model outputs, the coastline map is only used for visual reference; it is the habitat grid that defines the actual location of the shoreline in the model.

The digital shoreline, shore type, and habitat mapping were obtained from the Environmental Sensitivity Index (ESI) Atlas database compiled for the area by Research Planning, Inc. (RPI). These data are distributed by NOAA Hazmat (Seattle, WA). GIS data for intertidal oyster reefs were complied from ESI data and ground-truthed data from the 1980's (Michael Yianopoulos, SCDNR, pers. comm., December 2003). The oyster reef data were also compared to a map of SCDNR GIS coverages of oyster beds in the Charleston Harbor area from 1995 provided by Tom Moore (NOAA) and Howard Schnabolk (NOAA RC in Charleston). In some locations, oyster reefs were present one survey and not in the others, but all surveys were included in the mapping of the habitat grid. The gridded habitat type data are shown in Appendix A.2. The grid scale resolution is indicated in Table A.2-1 of Appendix A.2.

As noted above, within a grid, habitats are designated as landward or seaward. Landward portions are the harbor, rivers, and inlets. The seaward portion is the open ocean (coastal continental shelf). This designation allows different biological abundances to be simulated in landward and seaward zones of the same habitat type (e.g., open water with sand bottom). The biological database is coded to landward or seaward by species (see French et al., 1996a, c).

Ecological habitat types (Table 3-1) are broadly categorized into two zones: intertidal and subtidal. Intertidal habitats are those above spring low water tide level, with subtidal being all water areas below that level. Intertidal areas may be extensive, such that they are wide enough to be represented by an entire grid cell at the resolution of the grid. These are typically either mud flats or wetlands, and are coded 20 (seaward mudflat), 21 (seaward wetland), 50 (landward mudflat) or 51 (landward wetland). All other intertidal habitats are typically much narrower than the size of a grid cell. Thus, these fringing intertidal types (indicated by F in Table 3-1) have typical (for the region, French et al., 1996a) widths associated with them in the model. Boundaries between land and water are fringing intertidal habitat types. On the waterside of fringing intertidal grid cells, there may be extensive intertidal grid cells if the intertidal zone is extensive. Otherwise, subtidal habitats border the fringing intertidal.

Table 3-1. Classification of habitats. Seaward (Swd) and landward (Lwd) system codes are listed. (Fringing types indicated by (F) are only as wide as the intertidal zone in that province. Others (W = water) are a full grid cell wide and must have a fringing type on the land side.)

Habitat Code (Swd, lwd)	Zone	Ecological Habitat	F or W
1,31	Intertidal	Rocky Shore	F
2,32		Gravel Beach	F
3,33		Sand Beach	F
4,34		Fringing Mud Flat	F
5,35		Fringing Wetland (Saltmarsh)	F
6,36		Macrophyte Bed	F
7,37		Mollusk Reef	F
8,38		Coral Reef	F
9,39	Subtidal	Rock Bottom	W
10,40		Gravel Bottom	W
11,41		Sand Bottom	W
12,42		Silt-mud Bottom	W
13,43		Wetland (Subtidal of Saltmarsh)	W
14,44		Macroalgal (Kelp) Bed	W
15,45		Mollusk Reef	W
16,46		Coral Reef	W
17,47		Seagrass Bed	W
18,48	Intertidal	Man-made, Artificial	F
19,49		Ice Edge	F
20,50		Extensive Mud Flat	W
21,51		Extensive Wetland (Saltmarsh)	W

The intertidal habitats were assigned based on the shore types in digital Environmental Sensitivity Index (ESI) maps distributed by NOAA HAZMAT (CD-ROM). This data was gridded using the ESRI Arc/Info compatible Spatial Analyst program. Open water areas were defaulted to sand bottom, as open water bottom type has no influence on the model results. Where data are missing, shore types are defaulted as in Table 3-2. Habitats inside Charleston Harbor, the rivers, and other coastal inlets were designated as landward, and open coastal water as seaward.

Table 3-2. Default fringing intertidal habitat type, given adjacent subtidal or extensive intertidal habitat type.

Subtidal or Extensive Intertidal Habitat	Fringing Intertidal Habitat
Seagrass Bed (47)	Sand Beach (33)
Subtidal Sand Bottom (41)	Sand Beach (33)
Extensive Mudflat (50)	Fringing Mudflat (34)
Extensive Wetland (51)	Fringing wetland (35)

Depth data were obtained from Hydrographic Survey Data supplied on CD-ROM by the U.S. Department of Commerce, National Oceanic and Atmospheric Administration, National Geophysical Data Center. Hydrographic survey data consist of large numbers of individual depth soundings. The depth soundings were gridded using the ESRI Arc/Info compatible Spatial Analyst program. The gridded depth data are shown in Appendix A.3.

3.2 Environmental Data

The model uses hourly wind speed and direction for the time of the spill and simulation. The model can use multiple wind files, spatially interpolating between them to determine local wind speed and direction. Two wind data sets are available for the area and time of the spill. Standard meteorological data were acquired from the National Data Buoy Center (http://www.ndbc.noaa.gov/station_page.phtml?station=fbis1), "Station FBIS1 - Folly Beach, SC" (32.68^{o}N, 79.89^{o}W). Wind data were also obtained for Charleston International Airport (32.9 ^{o} N, 80.033^o W). Hourly mean wind speed and direction for 30 September to October 31 2002 were compiled in the SIMAP model input file format. Wind speed and direction data are in Appendix C.

Surface water temperature was 23^{o}C during the week after the spill (NOAA CO-OPS, http://co-ops.nos.noaa.gov). The same temperature is assumed for both the water surface and the air immediately above the water. Water temperature affects evaporation rate, and so surface oil volume, but not the trajectory of the spill. The effect of water temperature within the range of a few degrees Celsius is insignificant.

Salinity is assumed to be the mean value for South Carolina inlets, based on data compiled in French et al. (1996b). The salinity value assumed in the model runs has little influence on the fate of the oil, as salinity is used to calculate water density (along with temperature), which is used to calculate buoyancy, and none of the oils evaluated have densities near that of the water.

Suspended sediment is assumed 11.7 mg/L, based on Department of Health and Environmental Control (SCDHEC) data (David Graves, pers. comm., January 2004). A concentration of 10 mg/L is typical for coastal waters (Kullenberg, 1982). The sedimentation rate is set at 1 m/day. The low suspended sediment concentration indicates little adsorption and settling of oil occurred and so the sinking rate has no significant affect on the model trajectory. Sedimentation of oil and PAHs becomes significant at about 100 mg/L suspended sediment concentration. There is no evidence that high suspended sediment concentrations occurred during the spill.

The horizontal diffusion (randomized mixing) coefficient is assumed as 1 m^2/sec, and the range from 0.1-10 m^2/sec was examined in sensitivity analyses. The vertical diffusion (randomized mixing) coefficient is assumed 0.0001 m^2/sec. These are reasonable values for coastal waters based on empirical data (Okubo and Ozmidov, 1970; Okubo, 1971) and modeling experience. The vertical diffusion coefficient used kept the relatively shallow water column well mixed, and so variation of this parameter had no significant impact on the results. Thus, only variation of the horizontal diffusion coefficient was examined.

3.3 Currents

3.3.1 Tidal and Other Currents

Currents have significant influence on the trajectory and oil fate, and are critical data inputs. Wind-driven, tidal and background (river flow) currents were included in the modeling analysis. The local surface wind drift is calculated within the oil spill model (as described in the next section). The tidal currents and river-flow currents are input to the oil fates and biological effects models from a current file that is prepared for this purpose.

Current data were generated using ASA's boundary fitted coordinate hydrodynamic model (BFHYDRO) which produces applicable hydrodynamic data sets suitable for use in the SIMAP model system. The hydrodynamic model's governing equations and validation are described in detail in Spaulding (1984), Muin (1993), Muin and Spaulding (1997a, b), Spaulding et al. (1999a), and Sankaranarayanan and Spaulding (2003). The boundary-fitted grid is a mesh of quadrilateral cells of varying size and included angles, which is capable of handling variable geometry and flow regimes. The boundary fitted coordinate system in BFHYDRO uses general curvilinear coordinates to map the model grid to the shoreline of the water body being studied. It also allows enormous versatility in grid sizing so that many of the smaller features may be resolved, along with the larger, without being penalized by an excessive grid size (number of cells).

The boundary-fitted method uses a set of coupled quasi-linear elliptic transformation equations to map an arbitrary horizontal multi-connected region from physical space to a rectangular mesh structure in the transformed horizontal plane. The 3-dimensional conservation of mass and momentum equations, with approximations suitable for estuaries (Muin and Spaulding, 1997a, b) that form the basis of the model, are then solved in this transformed space. In addition, an algebraic transformation is used in the vertical to map the free surface and bottom onto coordinate surfaces. The resulting equations are solved using an efficient semi-implicit finite difference algorithm.

The hydrodynamic model (BFHYDRO) has been validated in numerous applications, including in Muin and Spaulding (1997a, b), Spaulding et al. (1999a), and Sankaranarayanan and Spaulding (2003) where the governing equations are described. Applications that have been validated include: for San Francisco Bay (Sankaranarayanan and French McCay, 2003a); for the Narragansett Bay system (Swanson et al., 1998; Spaulding et al., 1999b; Kim and Swanson, 2001); for Bay of Fundy (Sankaranarayanan and French McCay, 2003b); the Savannah River (Mendelsohn et al., 1999), and Charleston Harbor, SC (Peene et al., 1997; Yassuda et al., 2000a,b; Mendelsohn et al., 2001).

In that Charleston Harbor and nearby coastal waters are highly energetic and predominantly well-mixed, BFHYDRO was applied in the two-dimensional mode, thus providing vertically-averaged currents. Known physical conditions were input to the model grid at the edges, termed “open boundaries”. These inputs are described as “forcing factors”. The forcing factors used were water height, available from tidal height data, and river flow. Salinity driven (i.e., density driven) flows, were not considered for the present analysis. Forcing factors due to wind stress on the water surface were included in the wind drift calculation in the oil fates model.

Tidal currents are driven by a mix of forces with semi-diurnal and diurnal periodicity, causing the elevations of successive high and low tides to be unequal. The major 6 constituents are M2, S2, N2, K1, O1, and P1, where the letter and number codes for the tidal constituents are standard terminology based on harmonic analysis of tidal height data (Defant, 1961), with the number indicating the approximate frequency of the sinusoidal cycle per day (1 is diurnal and 2 is semi-diurnal). The letter indicates the sinusoidal periodicities included in the component. M2 and S2 are pure lunar and solar components, respectively. All the others are mixtures of signals resulting from various periodic changes in the position of the sun and moon relative to the earth. For more information, see Defant (1961) or similar oceanographic text book.

The model grid is shown in Appendix D.1 (Figure D.1-1). Tidal forcing was accomplished by defining the water height over time at the model grid boundaries. The forcing was specified for each tidal constituent. The current vectors for each constituent were computed for each model grid cell and time step based on physical laws (conservation of mass and momentum). Current vectors for non-tidal flows (i.e., river) were computed in an analogous manner. In the oil spill model, the various tidal constituent and non-tidal current vectors were summed to determine the actual transport of oil components and plankton in the particular grid cell and time step of interest.

Appendix D.2 contains current vector plots for selected representative times after the spill. An animation of the current vectors, as well as current speed contour maps, may be seen using the SIMAP Viewer.

3.3.2 Wind-driven Surface Currents

Local wind-driven surface currents are calculated within the SIMAP fates model, based on local wind speed and direction. Surface wind drift of oil has been observed in the field to be 1-6% (average 3-4%) of wind speed in a direction 0-30 degrees to the right (in the northern hemisphere) of the down-wind direction (ASCE, 1996). In restricted waters with little fetch, such as in the spill area, the angle tends to be near zero, while in open waters the angle develops to be 20^o-30^o to the right of down wind.

Wind drift speed and angle were studied in detail by Youssef and Spaulding (Youssef, 1993; Youssef and Spaulding, 1993, 1994). Wind drift speed is a percentage of wind speed over the water, highest at low wind speed and decreasing as wind speed increases. The range of drift speed for winds up to 20 kts (averaged over time) is 2-4% of wind speed. At 10 kts or less, which prevailed during the spill event, the percent of wind speed is about 3.5-4% at the water surface, decreasing to 2% at 0.1m below the surface. The angle to the right of down wind is highest at low wind speed, on the water surface ranging from about 20^o-30^o at 10 kts or less. The drift speed decreases, and the drift angle increases, deeper into the water column.

Youssef and Spaulding (Youssef, 1993; Youssef and Spaulding, 1993, 1994) developed a set of equations to describe the percent of wind speed and angle as functions of wind speed and depth in the water. This algorithm has been incorporated into SIMAP. The wind drift is applied to the upper 5 meters of the water column. The SIMAP algorithm was validated with observations of the drift of floating fuel and bitumen in open ocean surface water after an intentional (test) Orimulsion spill (French et al., 1997). This Youssef and Spaulding algorithm was used in some model runs for surface wind drift. However, the best fit to the shoreline oiling observations was obtained assuming a constant 3.5% of wind speed and 0^o angle (see results, below).

3.4 Oil Properties and Toxicity

The spilled oil consisted of Intermediate Fuel Oil (IFO 380), a heavy fuel oil. Physical and chemical data were taken from the Environment Canada catalogue of crude oil and oil product properties (Whiticar et al., 1992; Jokuty et al, 1996), except as available from measurements on the source oil (provided by the responsible party, measured by Battelle). Fuel density was assumed 0.98 g/cm^3 (API = 12.888), which is lighter than seawater water, and so the (pure) fuel floated. The viscosity (40,470 cp) of typical heavy fuel is high, which slows entrainment into the water column to a very low rate. Variation of these two parameters within the typical range for heavy fuels would have no significant effect on the results. Surface tension was assumed 32.6 dyne/cm. Minimum oil slick thickness for spreading oil was assumed 1mm, based on McAuliffe (1987).

PAH concentrations were measured in the source oil by Battelle. MAH concentrations were based on data in Wang et al. (1995). For heavy fuel oil spills, MAHs do not have a significant impact on aquatic organisms for the following reasons. MAH concentrations are <3% in fresh fuel oils. MAHs are soluble, and so some becomes bioavailable (dissolved). MAH compounds are also very volatile, and will volatilize (from the water surface and water column) very quickly after a spill. The threshold for toxic effects for these compounds is about 500 ppb for sensitive species (French McCay, 2002). MAHs evaporate faster than they dissolve, such that toxic concentrations are not reached. The small concentrations of MAHs in the water will quickly be diluted to levels well below toxic thresholds immediately after a spill. Thus, while the assumed values for MAHs are approximate, this has little influence on model results.

The percentage of PAHs in the oil has a significant influence on the model results. Thus, the LC50s assumed were for PAH concentrations in the water. French McCay (2002) estimated an LC50 for PAH mixtures of 50 ppb for typical heavy fuels at infinite exposure time and for the average species. Ninety-five percent of species have LC50s between 6 and 400 μg/L (ppb). In the assessment, a worst case was evaluated to determine if injuries in subtidal habitats would be expected for any species. Thus, all species were assumed to be of high sensitivity to dissolved hydrocarbons, i.e., LC50 = 6 ppb. The model corrected this LC50 to temperature and duration of exposure for each group of organisms exposed.

From analysis of the source oil by Battelle, the total PAH content is 1.64% (mean of two source oil sample measurements). Of the total, 1.38% is of 2 to 3-ring PAHs with log(Kow)≤5.6, which are the acutely toxic components. Table E-3 of Appendix E lists the fraction of the oil represented by each pseudocomponent used in the model runs.

3.5 Shoreline Oil Retention

Retention of oil on a shoreline depends on the shoreline type, width and angle of the shoreline, viscosity of the oil, the tidal amplitude, and the wave energy. In the NRDAM/CME (French et al., 1996a,b), shore holding capacity was based on observations from the *Amoco Cadiz* spill in France and the *Exxon Valdez* spill in Alaska (based on Gundlach (1987) and later work summarized in French et al., 1996a). These data are used here (Table 3-3). The shore width (intertidal zone width where oiling would occur) was assumed 1 m.

Table 3-3. Maximum surface oil thicknesses for various beach types as a function of oil viscosity (from French et al., 1996a, based on Gundlach, 1987).

	Oil Thickness (mm) by Oil Type		
Shore Type	Light (<30 cSt)	Medium (30-2000 cSt)	Heavy (>2000 cSt)
Rocky shore	1	5	10
Gravel beach	2	9	15
Sand beach	4	17	25
Mud flat	6	30	40
Wetland	6	30	40
Artificial	1	2	2

3.6 Scenario

The spill was estimated as involving 12,500 gal (= 46.4 MT) of intermediate fuel oil (IFO 380). It appears to have begun after the ship grounded on a submerged dredge pipe in the Cooper River, which occurred as the vessel came into port early on 30 September 2002. The ship reached the dredge pipe (32 ^{o} 51.167' N, 79^{o} 56.195' W) at 05:35 AM on 30 September. Based on the distribution of oil observed after the spill and modeling results, the release must have been protracted: as the ship was traveling from the grounding site into Berth 1 NC Terminal (05:35 to 07:18 hours), and again as the ship left the harbor later the same day (left berth at 19:00 hours, passed harbor entrance about 20:30 hours). Oiling in the harbor and outside along Morris and Folly Islands cannot be accounted for assuming oil was released only at or up-river of the submerged dredge site (see results). The leak apparently stopped while the ship was at the berth, as the US Coast Guard (USCG) did not observe any leaking while the *Ever Reach* was docked. The oil apparently leaked again as the ship was underway leaving the harbor. Hydrostatic pressure would retain oil in the hull while the ship was stationary, but when the ship moved, lower pressure over the hull surface and turbulence would draw oil out of the ship.

The ship's log and the responsible party provided waypoints and times for the ship's movements, as listed in Table E-2 of Appendix E. Figures E-1 and E-2 plot the path of the ship inbound and outbound, respectively. The path of the ship between waypoints was assumed to follow the harbor channel, and the times between known points were interpolated assuming constant speed between waypoints.

The oil was assumed to be released from the water surface. While the crack in the hull was underwater, the oil is buoyant in seawater and so floats to the surface rapidly. The volume spilled was assumed to released evenly in time during the inbound trip (30% of the volume from 05:35 to 07:18 hours) and the outbound trip (70% from 19:00 to 22:19 hours), with no leakage while docked at the berth. Appendix E contains tables of model inputs for the SIMAP physical fates model.

The model simulations did not include accounting for on-water or shoreline oil removal activities. While these activities did occur, estimates of the actual amount of oil removed are not available. Removal of oil from shorelines would not affect the magnitude of injuries calculated by the model because cleanup occurred after the birds were exposed (in the model). Removal of oil from the water surface would not have a significant affect the injuries calculated, because most of this skimming activity occurred in the area of the Navy base where little oiling of birds occurred.

3.7 Biological Abundances

Wildlife species include aquatic birds, marine mammals and sea turtles. The model inputs may include two types of abundance data: (1) distributed average densities (#/km^2) in appropriate habitats, and (2) total number at specific locations located in the GIS database (e.g., at colony sites). Section 2.2 describes the assignment of each species to a set of habitats that it uses and that are assumed for the distributed densities. Those densities are assumed uniformly distributed across its preferred habitats. Thus, the habitat grid defines the habitat map, and so the distributed density of each species. Added to this are the total number of animals at specific point locations (colonies).

Fish and invertebrates are also input as average density by species (or group) per unit area in assigned habitats. The NRDAM/CME (French et al., 1996c) contains mean seasonal or monthly densities for 77 biological provinces in US coastal and marine waters. Data for province 21, for South Carolina coastal waters, were used (summarized in Appendix G). Fish and invertebrate density varies by landward open water, seaward open water, and structured habitat (i.e., wetlands, oyster reefs, Table 3-1). In the NRDAM/CME (French et al., 1996c), the abundances are for fished stocks and the biomass includes those animals greater than the age of recruitment to fishing. In the biological effects model the age/size distribution is computed from fishery modeling parameters (natural and fishing instantaneous mortality rates, length as a function of age, and weight-length relationships), such that the mortality is calculated for all age classes from age 1 year up (and assuming the various age classes live in the same habitat in that age structure).

Young-of-the-year mortality is quantified separately. The biological database includes number of age 1-year (365 day old) individuals per km^2. The young-of-the-year abundances in the NRDAM/CME (French et al., 1996c) were calculated from the spawning stock and life history information as to where those animals would live for each month of their first year of life. The numbers are those needed to recruit to the stock at age one year in order to maintain a stable population size. Thus, young-of-the-year mortality is for only those that would have survived their first year if not for the spill. Assumed densities of young-of-the-year are in Appendix G.

3.7.1 Wildlife Densities

Data for the distributed bird densities were derived from various surveys that occurred in the Charleston Harbor area. The four main data sources included 1) USGS Breeding Bird Survey (BBS) for sites near Charleston Harbor (Sauer et al. 2003); 2) 2002-2003 nesting bird counts from Tom Murphy (South Carolina Department of Natural Resources) for Crab Bank and Castle Pinckney on Shutes Folly; 3) 2000-2002 International Shorebird Survey (Brian Harrington, Manomet Center for Conservation Sciences), and 4) existing data in the NRDAM/CME (French et al. 1996c) from Portnoy et al. 1981, Haney and McGillivery (1985), and Johnsgard (1990). Table 3-4 summarizes the distributed bird density estimates and assumptions of species seasonality and presence that were used in modeling.

The USGS Breeding Bird Survey (BBS) is a roadside survey conducted during the peak nesting season (Sauer et al. 1997), which is primarily during June, although for some southern states it occurs during May as the breeding season is earlier than other areas of the US. Each route is 24.5 miles (39.4 km) with a total of fifty stops located at 0.5 mile (0.8 km) intervals. At each stop, the observer records all birds heard or seen within 0.25

miles (0.4 km). The Kiawah Island route (SC-801, funded by the town of Kiawah, South Carolina) was used to estimate the abundance of seabirds, waders and raptors that would be present at the time of the spill (September-October 2002). GIS was used to calculate the area of habitat for each species that was within 0.4 km of every stop along the route. This area, the ratio of breeders to non-breeders estimated by French et al. (1996c), and the assumption that the resident and breeding species would still be present in September-early October were used to calculate the density of seabirds, waders and raptors that would be in the spill area during the fall.

The John's Island BBS route (SC-001) was used to estimate the density of waterfowl, as no waterfowl species were counted in the Kiawah route (SC-801). Unlike with the Kiawah Island survey, the exact route for John's Island was not available. Therefore, the suitable habitat area (water or wetlands) was assumed to be ½ of the survey route, as a maximum possible area (assuming the road used for the survey follows the shores of water bodies, with terrestrial habitat on the opposite side of the road). This leads to density estimates for waterfowl species that are minimum estimates. Using the same area estimate, the densities of waterfowl for two other BBS surveys (Walterboro and Adam's Run), show that there is little variability in waterfowl abundance between sites (Table 3-5). The assumed habitat area for John's Island and the ratio of breeders to non-breeders (French et al. 1996) were used to calculate the density of waterfowl that would be in the spill area during the fall.

Nest count data for 2002-2003 at Crab Bank and Castle Pinckney (on Shutes Folly, Tom Murphy, pers. comm., Sept. 2003) were used to estimate osprey and brown pelican abundance within the lower Charleston Harbor. There are about 15 pairs of osprey observed to nest in the lower harbor. They nest in the spring (March-April), and migrate out in October (Tom Murphy, pers. comm., Sept. 2003). In 2002-2003, a mean of 430 pairs of pelicans nested in the harbor area (at Crab Bank and Castle Pinckney). Multiplying these estimates by the estimated ratio of total birds per breeding pair (from French et al., 1996), there were an estimated 42 osprey and 1672 pelicans in the population associated with the lower harbor area. While those birds would have been concentrated at the nest sites during nesting season, they would have been more dispersed but still within the local area by September 30. As both species prefer estuarine waters, it is assumed they remained primarily in the lower harbor. The area of the lower harbor estimated using GIS (72.7 km^2) was used to calculate a (distributed) density of osprey and pelicans that would be present during the time of the spill.

Considerable uncertainty exists with the distributed density estimates, primarily in the calculation of area these species use as habitat. For instance, the estimate for brown pelican in the lower harbor from Tom Murphy's data (Tom Murphy, pers. comm., Sept. 2003), is greater than that of brown pelican on Kiawah Island in the BBS Survey (Sauer et al. 2003) by a factor of two (Table 3-6), although this difference is likely attributable to differences in habitat. For osprey, the abundance estimate from the BBS Kiawah Island survey is a factor of eight greater than that calculated from Tom Murphy's data (Table 3-6). Because of this variability, we have used the lower harbor density estimates for species where sufficient data were available, using the Kiahah Island densities for other species.

In addition to pelicans distributed in the general area of Charleston Harbor, Tri-State observed 200 pelicans concentrated on Crab Bank and 10 on nearby Hog Island (Figure A.1-1) during the week following the spill. The concentration of pelicans at the colony sites were input to the model, along with the distributed density derived as described above, but with 210 pelicans subtracted from the 1672 in the local population before calculating the distributed density. The model evaluated whether each colony site was hit, and calculated the percentage of the pelicans oiled based on the probability described in Section 2.2.1 (35%, Table 2-2, which amounts to 70 birds if the Crab Bank area was oiled in the simulation and 3.5 birds if the Hog Island area was oiled).

The International Shorebird Survey (ISS), specifically the Pitt Street, Mount Pleasant site (on Shem Creek just north of Crab Bank in the lower harbor) for September to November 2000-2002 (Brian Harrington, Manomet Center for Conservation Sciences, pers. comm., April 13, 2004), was used to calculate the distributed density of shorebirds that would be present at the time of the spill. From an aerial photo of the Pitt Street vicinity, the area surveyed was estimated as 0.30 km^2. Table 3-7 is a comparison of the Pitt Street site with the smaller Folly Road, James Island site (0.07 km^2). This comparison shows the high level of variability between sites. The Pitt Street was chosen as a more accurate representation of shorebirds that would be present in Charleston Harbor during the period of the spill.

3.7.2 Wildlife Life History Data

Wildlife life history parameters are required to calculate the interim loss for the injury quantification. Tables 3-8 to 3-12 list the population parameters used and their sources. The most abundant species present in each group was used to estimate the interim losses, and so the population parameters were for those species. The number of fledglings produced per adult (greater than the age of first reproduction) per year is based on the age distribution indicated by the survivorship schedule and the assumption that all mature adults nest each year.

The data for pelicans were primarily based on a life history review by Hingtgen et al. (1985), which was used to develop a Habitat Suitability Index (HSI) model to the eastern brown pelican. The average number of brown pelican fledglings produced per nest in SC from 1970 to 1982 was 1.1 (observed in nest counts by Wilkinson, 1982), and half this was used as the fledging rate per adult ($\geq$ 4 yrs old) in the population.

For the other species groups, the data in French et al. (1996c) were used. These values were developed to be generally applicable to spills throughout the US, and were based on literature review for each species or species group using information for populations throughout North America. The notes in Table 3-13, from French et al. (1996c), describe the sources of the data.

Table 3-4. Summary of the distributed density data used for waterfowl, seabirds, waders, shorebirds and raptors.

Species Name	#/km^2 for fall	Species seasonality from Forsythe (1998)	Presence Basis	Source
Mallard	0.001	Winter Visitor	Observed in BBS survey in summer	BBS Survey for Johns Island (1982-1996)
Canada goose	0.02	Winter Visitor	Observed in BBS survey in summer	BBS Survey for Johns Island (1982-1996)
Hooded merganser	0.00	Winter Visitor	Observed in BBS survey in summer	BBS Survey for Johns Island (1982-1996)
Pied-billed grebe	0.00	Permanent Resident	Not observed in survey	BBS Survey for Kiawah Island (1966-2002)
Double-crested cormorant, seaward	0.00	Permanent Resident	Observed in fall in survey	NRDAMCME: Haney and McGillivery (1985)
Double-crested cormorant, landward	2.00	Permanent Resident	Assume same density all year	BBS Survey for Kiawah Island (1966-2002)
Herring gull	0.11	Summer Visitor	Observed in fall in survey	NRDAMCME: Haney and McGillivery (1985)
Ring-billed gull	2.78	Summer Visitor	Assumed still present in fall	Forsythe 1972
Laughing gull, seaward	0.27	Summer Resident	Observed in fall in survey	NRDAMCME: Haney and McGillivery (1985)
Laughing gull, landward	12.07	Summer Resident	Assumed still present in fall	BBS Survey for Kiawah Island (1966-2002)
Bonaparte's gull	0.00	Winter Visitor		NRDAMCME: Haney and McGillivery (1985)
Wilson's phalarope	present	Transients	Not observed in fall surveys	Forsythe (pers. obs.)
Black skimmer, seaward	1.08	Permanent Resident	Observed in fall in survey	NRDAMCME: Haney and McGillivery (1985)
Black skimmer, landward	2.51	Permanent Resident	Assume same density all year	BBS Survey for Kiawah Island (1966-2002)
Least tern, seaward	0.00	Summer Resident	Not observed in fall survey	NRDAMCME: Haney and McGillivery (1985)
Least tern, landward	1.33	Summer Resident	Assumed still present in fall	BBS Survey for Kiawah Island (1966-2002)
Common tern	2.18	Transient	Uncommon	NRDAMCME: Haney and McGillivery (1985)
Forster's tern, seaward	0.01	Permanent Resident	Observed in fall in survey	NRDAMCME: Haney and McGillivery (1985)
Forster's tern, landward	1.16	Permanent Resident	Assume same density all year	BBS Survey for Kiawah Island
Royal tern, seaward	0.01	Permanent Resident	Observed in fall in survey	NRDAMCME: Haney and McGillivery (1985)
Royal tern, landward	1.49	Permanent Resident	Assume same density all year	BBS Survey for Kiawah Island (1966-2002)
Caspian tern	0.17	Permanent Resident	Assume same density all year	BBS Survey for Kiawah Island (1966-2002)

Species Name	$\#/km^2$ for fall	Species seasonality from Forsythe (1998)	Presence Basis	Source
Black tern	0.65	Transient	Common in Aug-Sept	NRDAMCME: Haney and McGillivery (1985)
Sandwich tern, seaward	0.01	Summer Resident	Observed in fall in survey	NRDAMCME: Haney and McGillivery (1985)
Sandwich tern, landward	0.00	Summer Resident	Not observed in survey	BBS Survey for Kiawah Island (1966-2002)
Gull-billed tern	0.50	Summer Resident	Assumed still present in fall	BBS Survey for Kiawah Island (1966-2002)
Brown pelican, seaward	0.22	Permanent Resident	Observed in fall in survey	NRDAMCME: Portnoy et al. 1981
Brown pelican, landward	20.25	Permanent Resident	Assume same density all year	Tom Murphy counts, pers com Sept 2003
Great blue heron	1.04	Permanent Resident	Assume same density all year	BBS Survey for Kiawah Island (1966-2002)
Tricolored heron	1.56	Permanent Resident	Assume same density all year	BBS Survey for Kiawah Island (1966-2002)
Little blue heron	0.17	Permanent Resident	Assume same density all year	BBS Survey for Kiawah Island (1966-2002)
Green heron	3.73	Summer Resident	Assumed still present in fall	BBS Survey for Kiawah Island (1966-2002)
Black-crowned night-heron	0.43	Permanent Resident	Assume same density all year	BBS Survey for Kiawah Island (1966-2002)
Yellow-crowned night-heron	0.09	Summer Resident	Assumed still present in fall	BBS Survey for Kiawah Island (1966-2002)
Great egret	4.59	Permanent Resident	Assume same density all year	BBS Survey for Kiawah Island (1966-2002)
Snowy egret	1.30	Permanent Resident	Assume same density all year	BBS Survey for Kiawah Island (1966-2002)
Clapper rail	1.22	Permanent Resident	Assume same density all year	BBS Survey for Kiawah Island (1966-2002)
Wood stork	0.61	Summer Resident	Assumed still present in fall	BBS Survey for Kiawah Island (1966-2002)
Willet	17.01	Permanent Resident	Assume same density all year	International Shorebird Survey, 2000-2002
Killdeer	0.00	Permanent Resident	Assume same density all year	International Shorebird Survey, 2000-2002
American Oystercatcher	21.73	Permanent Resident	area for Pitt Street, Mt Pleasant	International Shorebird Survey, 2000-2002
Black-bellied Plover	8.50	Winter Visitor	area for Pitt Street, Mt Pleasant	International Shorebird Survey, 2000-2002

Species Name	#/km² for fall	Species seasonality from Forsythe (1998)	Presence Basis	Source
Semipalmated Plover	58.58	Winter Visitor	area for Pitt Street, Mt Pleasant	International Shorebird Survey, 2000-2002
Piping plover	0.00	Winter Visitor	Not observed in Manomet survey	International Shorebird Survey, 2000-2002
Wilson's Plover	present	Summer Resident	Not observed in fall surveys	International Shorebird Survey, 2000-2002
Greater Yellowlegs	0.47	Winter Visitor	area for Pitt Street, Mt Pleasant	International Shorebird Survey, 2000-2002
Spotted Sandpiper	0.00	Transient, winter visitor	area for Pitt Street, Mt Pleasant	International Shorebird Survey, 2000-2002
Whimbrel	0.00	Transient, winter visitor	area for Pitt Street, Mt Pleasant	International Shorebird Survey, 2000-2002
Marbled Godwit	8.98	Winter Visitor	area for Pitt Street, Mt Pleasant	International Shorebird Survey, 2000-2002
Ruddy Turnstone	4.72	Winter Visitor	area for Pitt Street, Mt Pleasant	International Shorebird Survey, 2000-2002
Semipalmated Sandpiper	0.00	Transient	area for Pitt Street, Mt Pleasant	International Shorebird Survey, 2000-2002
Western Sandpiper	0.00	Winter Visitor	area for Pitt Street, Mt Pleasant	International Shorebird Survey, 2000-2002
Least Sandpiper	0.00	Winter Visitor	area for Pitt Street, Mt Pleasant	International Shorebird Survey, 2000-2002
Dunlin	23.62	Winter Visitor	area for Pitt Street, Mt Pleasant	International Shorebird Survey, 2000-2002
Short-billed Dowitcher	71.81	Winter Visitor	area for Pitt Street, Mt Pleasant	International Shorebird Survey, 2000-2002
Osprey	0.57	Summer Resident	Assumed still present in fall	Tom Murphy counts, pers com Sept 2003
Bald eagle	0.05	Permanent Resident	Assume same density all year	NRDAMCME: Johnsgard (1990)
Marsh wren	present	Permanent Resident	Not observed in fall surveys	Forsythe (pers. obs.)

Table 3-5. Comparison of waterfowl density estimates based on data for three sites in BBS Survey that are located in relatively close proximity to Charleston Harbor. Data for John's Island was used for modeling.

Species Name	USGS BBS, Adam's Run (1966 – 2002) $\#/km^2$	USGS BBS, Walterboro (1966 – 2002) $\#/km^2$	USGS BBS, Johns Island (1982 – 1996) $\#/km^2$
Mallard	0.000	0.002	0.001
Canada goose	0.047	0.075	0.022
Hooded merganser	0.005	0.002	0.002

Table 3-6. Comparison of seabird, wader and raptor distributed density estimates based on data from 2 data sources [Tom Murphy, SCDNR (pers. comm. Sept. 2003) and USGS BBS Survey for Kiawah Island (Sauer et al. 2003)].

Species Name	Tom Murphy (SCDNR), per comm., Sept 2003 $\#/km^2$	USGS BBS, Kiawah Island, 1966-2002 monthly mean $\#/km^2$
Pied-billed grebe		0.00
Double-crested cormorant, landward		2.00
Laughing gull, landward		12.06
Black skimmer, landward		2.51
Least tern, landward		1.33
Forster's tern, landward		1.16
Royal tern, landward		1.50
Sandwich tern, landward		0.00
Gull-billed tern		0.50
Brown pelican, landward	20.25	10.27
Great blue heron		1.04
Tricolored heron		1.56
Little blue heron		0.17
Green heron		3.73
Black-crowned night-heron		0.43
Yellow-crowned night-heron		0.09
Great egret		4.59
Snowy egret		1.30
Clapper rail		1.21
Willet		0.16
Killdeer		0.05
Osprey	0.57	4.42

Table 3-7. Comparison of shorebird data for two sites in International Shorebird Survey. Density estimates (#/km^2) for Pitt Street, Mount Pleasant were used in modeling.

Species	Pitt Street, Mt. Pleasant 2000-2002	Pitt Street, Mt. Pleasant 2000-2002	Folly Rd, James Island 2000-2002	Folly Rd, James Island 2000-2002
Units	**Mean Count**	**#/km^2**	**Mean Count**	**#/km^2**
Black-bellied Plover	2.57	8.50	27.07	348.35
Wilson's Plover	0.00	0.00	0.00	0.00
Semipalmated Plover	17.71	58.58	43.33	557.70
Piping Plover	0.00	0.00	0.00	0.00
American Oystercatcher	6.57	21.73	0.00	0.00
Greater Yellowlegs	0.14	0.47	0.07	0.86
Lesser Yellowlegs	0.00	0.00	0.00	0.00
Spotted Sandpiper	0.00	0.00	0.20	2.57
Whimbrel	0.00	0.00	0.13	1.72
Marbled Godwit	2.71	8.98	0.00	0.00
Ruddy Turnstone	1.43	4.72	2.07	26.60
Red Knot	0.00	0.00	0.00	0.00
Sanderling	0.00	0.00	0.00	0.00
Semipalmated Sandpiper	0.00	0.00	3.93	50.62
Western Sandpiper	0.00	0.00	18.27	235.09
Least Sandpiper	0.00	0.00	11.67	150.15
Dunlin	7.14	23.62	0.33	4.29
Short-billed Dowitcher	21.71	71.81	20.27	260.83
Long-billed Dowitcher	0.00	0.00	0.00	0.00
Wilson's Snipe	0.00	0.00	0.00	0.00
Willet	5.14	17.01	6.27	80.65
Killdeer	0.00	0.00	0.07	0.86

Table 3-8. Life history parameters assumed for waterfowl based on Canada goose (the most abundant species).

Parameter	Value	Reference
Survival: fledging to age 1 year	0.239	French et al. (1996c)
Month of year when hatch	6	French et al. (1996c)
Months age at fledging	2	French et al. (1996c)
Age of young-of-the-year (yr) at spill date	0.333	(calculated)
Survival spill to age 1	0.318	(calculated)
Annual survival (>1 yr)	0.546	French et al. (1996c)
# Fledglings /adult /yr	1.4	French et al. (1996c)
Age first reproduce (yrs)	3	French et al. (1996c)
Weight (kg/bird)	5	French et al. (1996c)

Table 3-9. Life history parameters assumed for seabirds based on eastern brown pelican (the most abundant species).

Parameter	Value	Reference
Survival: fledging to age 1 year	0.275	Hingtgen et al. (1985); Schreiber and Mock, 1988
Month of year when hatch	5	Hingtgen et al. (1985)
Months age at fledging	3	Hingtgen et al. (1985)
Age of young-of-the-year (yr) at spill date	0.417	(calculated)
Survival spill to age 1	0.366	(calculated)
Annual survival (>1 yr)	0.840	Hingtgen et al. (1985)
# Fledglings /adult /yr	0.55	Wilkinson (1982)
Age first reproduce (yrs)	4	Hingtgen et al. (1985)
Weight (kg/bird)	3.5	Hingtgen et al. (1985)

Table 3-10. Life history parameters assumed for wading birds based on herons and egrets, generally (as described in French et al., 1996c).

Parameter	Value	Reference
Survival: fledging to age 1 year	0.320	French et al. (1996c)
Month of year when hatch	5	French et al. (1996c)
Months age at fledging	2	French et al. (1996c)
Age of young-of-the-year (yr) at spill date	0.417	(calculated)
Survival spill to age 1	0.450	(calculated)
Annual survival (>1 yr)	0.660	French et al. (1996c)
# Fledglings /adult /yr	0.84	French et al. (1996c)
Age first reproduce (yrs)	2	French et al. (1996c)
Weight (kg/bird)	1.3	French et al. (1996c)

Table 3-11. Life history parameters assumed for shorebirds based on sandpipers, generally (as described in French et al., 1996c).

Parameter	Value	Reference
Survival: fledging to age 1 year	0.470	French et al. (1996c)
Month of year when hatch	5	French et al. (1996c)
Months age at fledging	1	French et al. (1996c)
Age of young-of-the-year (yr) at spill date	0.417	(calculated)
Survival spill to age 1	0.618	(calculated)
Annual survival (>1 yr)	0.800	French et al. (1996c)
# Fledglings /adult /yr	0.87	French et al. (1996c)
Age first reproduce (yrs)	1	French et al. (1996c)
Weight (kg/bird)	0.03	French et al. (1996c)

Table 3-12. Life history parameters assumed for raptors based on osprey (the most abundant species).

Parameter	Value	Reference
Survival: fledging to age 1 year	0.380	French et al. (1996c)
Month of year when hatch	5	French et al. (1996c)
Months age at fledging	2	French et al. (1996c)
Age of young-of-the-year (yr) at spill date	0.417	(calculated)
Survival spill to age 1	0.508	(calculated)
Annual survival (>1 yr)	0.820	French et al. (1996c)
# Fledglings /adult /yr	0.76	French et al. (1996c)
Age first reproduce (yrs)	3	French et al. (1996c)
Weight (kg/bird)	1.9	French et al. (1996c)

Table 3-13. Sources for life history parameters assumed.

Species Group	Notes on Sources
Geese	Annual survival rates are means of data provided by Ogilvie (1978) and Bellrose (1980), including for Canada and snow geese. Hunting mortalities, hatchlings per adult, fledglings per adult, and age of reproduction are from Bellrose (1980) for Canada geese. Month hatched, age fledged and maximum age are from Ogilvie (1978). Mean weight is a mean of data for Canadian geese from Johnsgard (1978) and Bellrose (1980)
Herons and egrets	Values are means of available data for herons and egrets. Survival is from Ryder (1978). Hatchlings per adult is from English (1978). Fledglings per adult is a mean from English (1978), Konerman et al. (1978) and Frederick and Collopy (1989). Month hatched is from Bayer (1978) and English (1978). Age fledged is from Ehrlich et al. (1988). Age of reproduction is from Bayer (1978). Maximum age is from Ryder (1978). Mean weight for great blue herons, great egrets and black-crowned night-herons is from Hoffman (1978)
Sandpipers and plovers	First year survival is from Boyd (1962), Jacobs (1986) and Evans and Pienkowski (1984). Adult survival is from these sources plus Evans (1991). Hatchings per adult is from Evans and Pienkowski (1984). Fledglings per adult is from Safriel (1975). Month hatched is from Bent (1962). Age fledged is from Ehrlich et al. (1988). Age of reproduction and maximum age are from Oring et al. (1983). Mean weight is from Page et al. (1979)
Osprey	Survival rates and mean weight are from Newton (1979) and Henney (1986). Hatchlings per adult is from the Audubon Society of RI (1990). Fledglings per adult is from the Audubon Society of RI (1990), Newton (1979) and Henney (1986). Month hatched is from Bent (1937) and age fledged is from Bent (1937) and Ehrlich et al. (1988). Age of reproduction is from Bent (1937) and Henney (1986). Maximum age is from Newton (1979)

4. FATES MODEL RESULTS

The SIMAP model quantifies, in space and over time:

- The spatial distribution of oil mass and volume on water surface over time
- Oil mass, volume and thickness on shorelines over time
- Subsurface oil droplet concentration, as total hydrocarbons, in three dimensions over time
- Dissolved aromatic concentration (which causes most aquatic toxicity) in three dimensions over time
- Total hydrocarbons and aromatics in the sediments over time

The fates model output at each time step includes:

- oil thickness (microns or g/m^2) on water surface,
- oil thickness (microns or g/m^2) on shorelines,
- subsurface oil droplet concentration (ppb), as total hydrocarbons,
- dissolved aromatic concentration in water (ppb),
- total hydrocarbon loading on sediments (g/m^2), and
- dissolved aromatics concentration in sediment pore water (ppb).

Model results are displayed by a Windows graphical user interface that animates the trajectory and concentrations over time. The figures included in the appendices are summaries of that output. The full model outputs of all model runs are available on CD and may be viewed with the SIMAP Viewer software, which is the model interface that displays the output data.

With the SIMAP Viewer, one can view the model results for all times steps of the model simulations. The maps show total hydrocarbons on and in the water, and dissolved aromatic concentrations in the water, after the spill. Concentrations in the water are calculated for a grid (200 X 200 cells horizontally, 5 layers vertically) sized to just cover the plume at the time of the output. The Viewer provides animated maps showing the vertical maximum concentration, the vertical mean concentration, or the concentrations in a selected layer. The Viewer also produces cross-sections showing subsurface concentrations. The user's manual for the SIMAP Viewer provides instructions on the use of the software.

Modeling of the trajectory and fate of the oil was performed using SIMAP, varying uncertain parameters to evaluate sensitivity to those assumptions. The calculations were made with a time step of 5 min. The model was run for 10 days, during which time all the oil came ashore or dispersed at sea. The following model inputs were varied to determine which provided the best fit to the observations.

- The horizontal turbulent diffusion coefficient (0.1, 1, 5, or 10 m^2/sec)
- Wind drift was either 3.5% of wind speed and angle = 0^o, or calculated using the model (see section 3.3.2)

- The spill was assumed instantaneous from one location, the location of the submerged dredge, or along the path and with the timing described in Section 3.6.

The fates model results of surface oil were visually compared to observed surface oil locations (e.g., from over-flights), scat reports, and other field data, as available. Surface oil distribution from over-flights and other observations are summarized in Appendix B. Quantitative observations of the surface oil distribution in the field are not available. Thus, quantitative comparisons to the model simulations could not be made. The model conserves oil mass, estimates losses to evaporation, and so the surface oil area estimates are realistic estimates of the oil mass on the water at any given time.

Appendix F contains figures for the best simulation (base case), i.e., that simulation best agreeing with observed oil locations and shoreline oiling. Appendix F.1 shows the mass balance of oil. The graph shows, as a function of time since the release start, percent of total mass spilled on the water surface, in the water column, on shorelines, in the sediment, in the atmosphere, and degraded. Initially all of the oil is on the surface. After 3 hours the majority of the surface oil from the 30 September morning's release (during the inbound trip) has come ashore (85.5%). Also at this time 14% of the oil has evaporated, no oil is entrained in the water column and 0.1% of the oil has degraded. Just after the second phase of the release during the outbound trip (at 17 hours after the spill start), 46% of the oil is floating and 46% is ashore. By 48 hours (05:35 on 2 October), 19% remains floating, 62% is ashore, and 13% has evaporated. The remaining floating oil is mainly at sea at this time, and over the next week it disperses.

Quantitative measurements of mass cleaned up are not available. Thus, cleanup was not included in the model simulations. Inclusion of shoreline cleanup would have no effect on the biological model results, as birds are exposed to oil as it comes ashore in the model. The model does not include effects of oiling that might have occurred at a later time (e.g., weeks after the spill).

Appendix F.2 shows the model trajectory, i.e., the path of the oil and locations where shorelines were oiled to some degree. The model replicates well the overall movement and timing of the oil from the spill path to the Navy piers, Crab Bank, Shutes Folly and Folly Beach. Once the majority of the spill was outside the harbor, it traveled in a westerly direction towards Folly Beach. Close to the source of the release, oil would have appeared as dark brown sheen with occasional patches of thicker oil. As the oil approached the Folly Beach area, the oil spread out and weathered. Very little would have been visible on the water as it would be tar balls and sheen by the time it reached shore.

Appendix F.3 shows the amount of oil accumulated on shorelines and sediments for the (base case) simulation, as mass of total hydrocarbons per unit area (averaged in each habitat grid cell). The area of shoreline that was oiled with greater than 100 g/m^2 (1mm) is estimate in the model simulation as 2,316 m^2 for rocky shore; 772 m^2 for gravel beach; 6,527 m^2 for sand beach; 2,597 m^2 for mud flat; 2,737 m^2 for wetland; 2,106 m^2 for oyster reef, and 6,387 for artificial/man made shoreline. No shoreline cleanup was simulated in the model. Thus, oil simply accumulates and remains on the shore.

Appendix F.3 also summarizes the sensitivity analysis results for oil contamination. The shoreline oiled by each simulation is plotted. The variation of the horizontal diffusion coefficient affected the amount of shoreline oiled; more shoreline was oiled if the value was higher. However, if too much horizontal diffusion was assumed, the result was too much oiling on the left descending bank of the Cooper River, which was not observed. Use of the model drift algorithm did not result in the correct distribution of oiling on Folley's Island. The assumption of 3.5% of wind speed and 0^o angle provided the best overall fit to the shoreline oiling observations.

The case where all the oil was assumed released instantaneously at the submerged dredge site does not fit the observations at all (Figure F.3-7). The river currents are not sufficiently strong to move the oil down into the harbor and to outside coastal areas by the time it was observed there. A similar pattern (absence of oil in the lower harbor and offshore) would result if oil were released only at and up-river of the submerged dredge in the model.

Appendix F.4 shows the surface distribution of oil. For slicks on the water surface, 1 μm ~ 1 g/m^2. Table 4-1 gives approximate thickness ranges for surface oil of varying appearance. Dull brown sheens are about 1 g/m^2 thick. Rainbow sheen is about 200-800 mg/m^2 and silver sheens are 50-800 mg/m^2 thick (NRC, 1985). Crude and heavy fuel oil > 1mm thick appears as black oil. Floating oil will not always have these appearances, however, as weathered oil would be in the form of scattered floating tar balls and tar mats where currents converge.

Table 4-1. Oil thickness (microns ~ g/m^2) and appearance on water (NRC, 1985).

Minimum	Maximum	Appearance
0.05	0.2	Colorless and silver sheen
0.2	0.8	Rainbow sheen
1	4	Dull brown sheen
10	100	Dark brown sheen
1000	10000	Black oil

Figure F.4-1 shows the maximum amount of surface oil (g/m^2) passing through each model grid cell at any time after the spill, averaged over the area of the grid cell. As indicated in Section 2.2, the threshold for impacts to wildlife is 10 μm (10 g/m^2). Note that the evaluation of surface oil impacts is made using the output of the fates model that retains the patchy and time-varying oil distribution information. The map of mean g/m^2 of floating oil in each grid cell (Figure F.4-1) only provides a summary of the path of the oil for illustrative purposes.

Subsurface concentrations of oil hydrocarbons and dissolved aromatics did not exceed 1 ppb in any water volume >140 m^3 (the resolution of the model grid for the subsurface plume) at any time after the spill. Focused runs with this high resolution were made to evaluate the potential for toxic concentrations to occur in the top 1m of the water column. The thinnest layer examined was the top 0.2m of the water column, just under the floating oil. No concentrations exceeding 1 ppb were estimated for any cell of horizontal dimension 20m by 35m. The mass balance (Table F-2 in Appendix F.1) shows that the amount of soluble aromatics dissolved during the spill was very small, much less than 1% of the total soluble (and volatile) aromatic fraction. Most of the soluble/volatile aromatics evaporated from the floating oil on the water surface and off the oiled shorelines. Thus, the exposure to water column and bottom-dwelling organisms in subtidal habitats was not significant and no acute toxicity induced impacts to these organisms would be expected.

5. ASSESSMENT OF INJURIES

5.1 Wildlife

Appendix B.4 contains a table summarizing the oiled birds observed in the field after the spill. A total of 18-23 brown pelicans were observed moderately or heavily oiled, with 30 other pelicans showing spots or oil stain. Tri-State treated 21 of the oiled pelicans (1 adult and 20 juveniles) and released them. Other oiled birds observed were: 1 great blue heron, several egrets, 1 double-crested cormorant, and 15 ruddy turnstones.

Table 5-1 lists the model-estimated impacts to wildlife for the best fates model simulation, along with the observed oiled birds. The estimated numbers are probabilities, and thus may be fractions of an animal. The majority of the 99 estimated killed birds are brown pelicans (75) and black skimmers (7). Others estimated oiled are 3.4 terns, 3.3 gulls, 1 cormorant, 1 wading bird, 9 shorebirds and 0.1 osprey. The number of oiled pelicans estimated by the model is 75, as opposed to the 48-53 observed. This difference is in part accounted for in that the model estimates injuries to pelicans that are distributed around the harbor and in the rivers, and not just those concentrated in areas of heavy oiling at Crab Bank (which were the ones observed). The colony at Crab Bank was explicitly modeled, and 70 birds were estimated oiled there, in addition to 5 pelicans distributed around the area. Oiled skimmers, terns, and shorebirds would be unlikely to be observed or captured for cleaning. Note that if the pre-spill abundance were, for example, a factor two different, the model kill estimate would change by that same factor. Thus, the model estimates and the field data agree within the uncertainty of both estimates.

The estimate of sea turtle injury is 0.12 adult (loggerhead) turtles, and is therefore not significant. Sea turtles of any age group would be very unlikely to be impacted by a spill in this location and no oiled sea turtles were observed.

Cetaceans (dolphins), while in the area impacted by the spill, were estimated to have a very low probability of oiling in the model simulations. The model results include <0.005 dolphin. This result is a probability and as no marine mammals were observed affected by the spill, the injury to marine mammals is assumed zero.

Tables 5-2 and 5-3 list the model results for all the scenarios run. It may be seen that the seabird and osprey (0.1 bird) injuries are not sensitive to the variation in the horizontal diffusion coefficient. However, the amount of shoreline oiling and the resulting wader and shorebird injuries vary with the horizontal diffusion coefficient. As the value used for the best simulation gives agreement with the observed shoreline oiling, the results in Table 5-1 are the best estimates. The injuries are somewhat sensitive to the model drift, but again, the best simulation is that that best fits the shore oiling observations.

After performing the modeling, it was recognized that 1 great blue heron, 3 great egrets and 15 ruddy turnstones were observed oiled, but the model estimates were much lower than this (Tables 5-1 to 5-3), likely due to underestimation of the pre-spill abundance. Thus, the actual injury was at least these values. In recognition that not all oiled birds would have been observed after the spill, the likely number of birds of these species oiled was higher. We assume a multiplier of 4 times the observed oiled birds to estimate total oiled birds of these species. Thus, the final injury estimates of great blue heron, great egrets, and ruddy turnstones are 4, 12, and 60, respectively, as reflected in Tables S-1 and S-2 of the summary section. Thus, the estimated numbers of birds oiled in the spill are as listed in Tables S-1 and S-2. The results in Table S-2 are repeated in Table 5-4, along with the estimates of the interim loss.

The interim loss was estimated using the methods described in Section 2.5. The direct loss, indirect loss of fledglings, and total interim loss, as bird-years per bird killed, are discounted in future years at 3% annually and represent mixed age classes. The total lost bird years of mixed ages is the bird-years per bird killed times the number killed. The number of fledgling equivalents are calculated in order to express the injury in a single age class, that most likely to be used to scale the restoration. The number of fledglings needed for compensation of the spill's injuries is given in year 2002 numbers (assuming restoration were to occur in that year of the spill) and in year 2006 numbers (the appropriate number if the restoration were in 2006. The appropriate number to use in the scaling is that used as the units for the restoration scale calculation.

Table 5-1. Estimated injuries to birds, marine mammals and sea turtles for the best simulation of the spill. The model estimate is a probability, and thus may be a fraction of an animal. Observations of oiled birds are also listed for comparison.

Species	**Model (#)**	**Observed (#)**
Canada goose	0.01	
Hooded merganser	0.05	
Mallard	0	
Black skimmer	7.28	
Black tern	0.61	
Bonaparte's gull	0.00	
Brown pelican	75.20	48-53
Caspian tern	0.16	
Common tern	2.04	
Double-crested cormorant	1.07	1
Forster's tern	0.04	
Gull-billed tern	0.47	
Herring gull	0.10	
Laughing gull	0.56	
Least tern	0.04	
Ring-billed gull	2.60	
Royal tern	0.05	
Sandwich tern	0.01	
Black-crowned night-heron	0.02	
Clapper rails	0.05	
Great egret	0.19	Several (3)
Great blue heron	0.04	1
Green heron	0.16	
Little blue heron	0.01	
Tricolored heron	0.07	
Snowy egret	0.05	
Wood stork	0.03	
Yellow-crowned night-heron	0.00	
Am. oystercatcher	0.91	
Black-bellied plover	0.35	
Dunlin	0.99	
Greater yellowlegs	0.02	
Marbled godwit	0.37	
Piping plover	0.00	
Ruddy turnstone	0.20	15
Semipalm. sandpiper	0.00	
Semipalmated plover	2.44	
Short-billed dowitcher	2.99	
Willet	0.71	

Species	Model (#)	Observed (#)
Bald eagle	0.01	
Osprey	0.13	
Bottlenose Dolphin	0.00	
Striped dolphin	0.00	
Loggerhead turtle	0.12	
Ridley turtle	0.00	
Group Totals:		
Waterfowl	0.06	-
Seabirds	89.24	49-54
Wading birds	0.61	approx. 4
Shorebirds	8.98	15
Raptors	0.14	-
Marine mammals (dolphins)	0	-
Sea turtles	0.12	-
Total birds	**99.15**	**68-73**

Table 5-2. Total oiled wildlife (#) by category in alternate scenario runs performed in the sensitivity analysis. The best simulation is that with 3.5% of wind speed, 0^o angle, and horizontal diffusion of 1.0 m^2/sec.

Wind Drift	**3.5%, 0^o**	**3.5%, 0^o**	**3.5%, 0^o**	**3.5%, 0^o**	**Model calculated**	**Model calculated**
Horizontal Diffusion	**1.0 m^2/s**	**10.0 m^2/s**	**5.0 m^2/s**	**0.1 m^2/s**	**1.0 m^2/s**	**10.0 m^2/s**
Waterfowl	0.06	0.06	0.06	0.06	0.05	0.05
Seabirds	89.24	89.96	90.65	90.15	87.61	86.80
Wading birds	0.61	0.86	0.90	0.40	0.75	0.88
Shorebirds	8.98	12.62	13.13	5.85	10.95	12.8
Raptors	0.14	0.14	0.14	0.12	0.15	0.14
Cetaceans	0.00	0.00	0.00	0.00	0.00	0.00
Sea turtles	0.12	0.12	0.12	0.12	0.09	0.09

Table 5-3. Estimated oiled wildlife (#) by species in alternate scenario runs performed in the sensitivity analysis. The best simulation is that with 3.5% of wind speed, 0° angle, and horizontal diffusion of 1.0 m^2/sec. [In the species name, lwd indicates the landward density, and swd indicates the seaward density.]

Wind Drift	3.5%, 0°	3.5%, 0°	3.5%, 0°	3.5%, 0°	Model calculated	Model calculated
Horizontal Diffusion	**1.0 m^2/s**	**10.0 m^2/s**	**5.0 m^2/s**	**0.1 m^2/s**	**1.0 m^2/s**	**10.0 m^2/s**
Canada goose	0.01	0.01	0.02	0.01	0.02	0.01
Hooded merganser	0.05	0.05	0.05	0.05	0.04	0.04
Mallard	0.00	0.00	0.00	0.00	0.00	0.00
Black skimmer, lwd	0.47	0.47	0.50	0.46	0.53	0.46
Black skimmer, swd	6.81	6.68	6.86	6.82	5.20	5.25
Black tern	0.61	0.60	0.61	0.61	0.47	0.47
Bonaparte’s gull	0.00	0.00	0.00	0.00	0.00	0.00
Brown pelican, Crab Bank	70.00	70.00	70.00	70.00	70.00	70.00
Brown pelican, lwd	3.81	3.80	4.00	3.74	4.29	3.70
Brown pelican, swd	1.39	1.36	1.40	1.39	1.06	1.07
Caspian tern	0.16	0.15	0.16	0.16	0.12	0.12
Common tern	2.04	2.01	2.06	2.04	1.58	1.59
Double-crested cormorant lwd	1.06	1.06	1.12	1.04	1.20	1.03
Double-crested cormorant swd	0.01	0.01	0.01	0.01	0.01	0.01
Forster's tern, lwd	0.03	0.03	0.03	0.03	0.04	0.03
Forster's tern, swd	0.01	0.01	0.01	0.01	0.01	0.01
Gull-billed tern	0.47	0.46	0.47	0.47	0.36	0.36
Herring gull	0.1	0.10	0.10	0.10	0.08	0.08
Laughing gull, lwd	0.32	0.32	0.34	0.32	0.37	0.31
Laughing gull, swd	0.24	0.24	0.25	0.24	0.19	0.19
Least tern, lwd	0.04	0.04	0.04	0.04	0.04	0.03
Ring-billed gull	2.6	2.56	2.63	2.60	2.02	2.03
Royal tern, lwd	0.04	0.04	0.04	0.04	0.05	0.04
Royal tern, swd	0.01	0.01	0.01	0.01	0.01	0.01
Sandwich tern, swd	0.01	0.01	0.01	0.01	0.01	0.01
Black-crowned night-heron	0.02	0.03	0.03	0.01	0.02	0.03

Wind Drift	3.5%, 0°	3.5%, 0°	3.5%, 0°	3.5%, 0°	Model calculated	Model calculated
Horizontal Diffusion	**1.0 m^2/s**	**10.0 m^2/s**	**5.0 m^2/s**	**0.1 m^2/s**	**1.0 m^2/s**	**10.0 m^2/s**
Clapper rails	0.05	0.07	0.07	0.03	0.06	0.07
Great egret	0.19	0.27	0.28	0.12	0.23	0.27
Great blue heron	0.04	0.06	0.06	0.03	0.05	0.06
Green heron	0.16	0.22	0.23	0.10	0.19	0.22
Little blue heron	0.01	0.01	0.01	0.00	0.01	0.01
Tricolored heron	0.07	0.09	0.10	0.04	0.08	0.09
Snowy egret	0.05	0.08	0.08	0.04	0.07	0.08
Wood stork	0.03	0.04	0.04	0.02	0.03	0.04
Yellow-crowned night-heron	0	0.01	0.01	0.00	0.00	0.01
Am. oystercatcher	0.91	1.27	1.32	0.59	1.10	1.29
Black-bellied plover	0.35	0.50	0.52	0.23	0.43	0.51
Dunlin	0.99	1.38	1.44	0.64	1.20	1.40
Greater yellowlegs	0.02	0.03	0.03	0.01	0.02	0.03
Marbled godwit	0.37	0.53	0.55	0.24	0.46	0.53
Piping plover	0	0.00	0.00	0.00	0.00	0.00
Ruddy turnstone	0.2	0.28	0.29	0.13	0.24	0.28
Semipalm. sandpiper	0	0.00	0.00	0.00	0.00	0.00
Semipalmated plover	2.44	3.43	3.57	1.59	2.98	3.48
Short-billed dowitcher	2.99	4.21	4.38	1.95	3.65	4.27
Willet	0.71	1.00	1.04	0.46	0.86	1.01
Bald eagle	0.01	0.01	0.01	0.01	0.01	0.01
Osprey	0.13	0.13	0.14	0.12	0.14	0.13
Bottlenose Dolphin	0	0.00	0.00	0.00	0.00	0.00
Striped dolphin	0	0.00	0.00	0.00	0.00	0.00
Loggerhead turtle	0.12	0.12	0.12	0.12	0.09	0.09
Ridley turtle	0	0.00	0.00	0.00	0.00	0.00

Table 5-4. Estimated total birds killed by oil and interim loss calculations (based on the methods described in Section 2.5).

Measure of Interim Loss	Waterfowl	Seabirds	Wading Birds	Shorebirds	Raptors
Direct kill by oiling (#)	0.06	89.24	16.38	68.78	0.14
Direct loss of bird-years/bird killed (discounted) (D_L/ $N_{i,0}$)	0.91	4.01	1.59	3.32	3.63
Lost fledgling production: Bird-years/bird killed (discounted) (F_L/ $N_{i,0}$)	0.11	2.23	0.30	4.41	3.36
Total bird-years/bird killed (of mixed ages, discounted) (T_L/ $N_{i,0}$)	1.02	6.23	1.89	7.72	6.99
Bird-years/fledgling (discounted) (F_G)	0.49	1.45	0.86	2.04	1.81
Number of fledglings to restore per bird killed (fledgling equivalents of a killed bird) (F_P/ $N_{i,0}$)	2.07	4.31	2.18	3.78	3.86
Total lost bird-years (of mixed ages) (T_L)	0.06	556	30.9	531	2.4
Number of fledgling equivalents (F_P, # fledglings to be restored, assumed in 2002)	0.12	384	35.8	260	1.3
Number of fledgling equivalents (# of fledglings to be restored, assumed in 2006)	0.14	433	40.3	293	1.5

5.2 Fish and Invertebrates in Subtidal Habitats

Table 5-5 lists the losses of fish and invertebrates for the best, as well as alternate, simulation(s) of the spill. Losses include the direct kill plus the calculated production foregone, which is the future growth of the killed animals, had there not been a spill. In the simulation for this case, the concentrations of toxic aromatics in the water and sediments did not exceed thresholds for effects. Thus, there are no fish or invertebrate injuries.

Table 5-5. Estimate of injury to fish and invertebrates.

Fishery species	Kill (#)	Kill (kg)	Production Forgone (kg)	Total Injury (kg)
Total small pelagic fish	0	0	0	0
Total large pelagic fish	0	0	0	0
Total demersal fish	0	0	0	0
Total demersal invertebrates	0	0	0	0
Total mollusks	0	0	0	0
Total all species	0	0	0	0

5.3 Intertidal Habitats

Tables 5-6 and 5-7 list the areas of intertidal habitat oiled to varying degrees in the (best) model simulation. The threshold 0.1 mm (~100 g/m^2) is the minimum (dose) in the model for impact to waders and shorebirds in the intertidal areas. Mortality of the vegetation in marshes occurs above about 14 mm of oil, according to literature reviewed in French et al. (1996a). In the model simulation, none of the wetlands exceeded 14 mm thick oil. Figure 5-1 shows the areas oiled. Over-laid on the map are locations of oyster reefs along the Cooper River, in Charleston Harbor, and near Folly Beach.

When the majority of the oil mass came ashore, 95% of the PAHs remained in the oil. Thus, the PAH content of the shoreline oil was about 2% of total hydrocarbons. This infers 1 g/m^2 of total hydrocarbons on the shoreline is equivalent to about 20 mg PAH/m^2. Assuming the oil was mixed into the top 1 cm of sediment, 1 g/m^2 of total hydrocarbons (THC) on the shoreline is equivalent to 10^{-4} g THC/cm^3 of wet sediment. Assuming a sediment porosity of 40% (i.e., 40% water and 60% sediment) and a sediment dry weight of 2.6 g/cm^3, 1 cm^3 of wet sediment contains 1.56 g dry sediment. Thus, 1 g THC/m^2 is equivalent to 64 μg THC/g of dry sediment (64 ppm). The PAH concentration in dry sediment that is equivalent to 1 g THC/m^2 is 1.3 μg PAH/g dry sediment (1.3 ppm). The intertidal contamination predicted by the model can be broadly compared to observations based on sampling. However, detailed comparisons to sample stations are inappropriate, as the model's resolution does not address the patchy nature of the actual contamination on shore.

Table 5-6. Area (m^2) of intertidal zone, by shore type, contaminated by oil of various thicknesses (1 mm thick oil ~ 1000 g/m^2 ~64 ppm total hydrocarbons, THC, ~ 1300 ppm of PAH) in the best model simulation.

Total Hydrocarbons	**>1000 g/m^2**	**>100 g/m^2**	**>10 g/m^2**	**> 1 g/m^2**	**>0.1 g/m^2**
Oil Thickness	**>1 mm**	**>0.1 mm**	**>0.01 mm**	**>0.001 mm**	**>0.0001 mm**
THC concentration (µg TPH/g dry sediment)	**> 64 mg/g**	**> 6400 µg/g**	**> 640 µg/g**	**> 64. µg/g**	**> 6.4 µg/m^2**
PAH concentration (ppm)	**> 1300 ppm**	**> 130 ppm**	**> 13 ppm**	**> 1.3 ppm**	**> 0.13 ppm**
PAH concentration (µg PAH/g dry sediment)	**> 1300 µg/g**	**> 130 µg/g**	**> 13 µg/g**	**> 1.3 µg/g**	**> 0.13 µg/m^2**
Shore Type:					
Rocky shoreline	140	2,737	2,737	2,737	2,737
Gravel beach	211	772	772	772	772
Sand beach	702	6,317	6,317	6,317	6,317
Mud flat	702	2,456	2,456	2,456	2,456
Wetland	772	2,737	2,737	2,737	2,737
Oyster reef	0	2,035	2,035	2,035	2,035
Artificial shoreline	2,527	6,387	6,387	6,387	6,387
Total	5,053	23,442	23,442	23,442	23,442

Table 5-6. Area (acres) of intertidal zone, by shore type, contaminated by oil of various thicknesses (1 mm thick oil ~ 1000 g/m^2 ~64 ppm total hydrocarbons, THC, ~ 1300 ppm of PAH) in the best model simulation.

Total Hydrocarbons	**>1000 g/m^2**	**>100 g/m^2**	**>10 g/m^2**	**> 1 g/m^2**	**>0.1 g/m^2**
Oil Thickness	**>1 mm**	**>0.1 mm**	**>0.01 mm**	**>0.001 mm**	**>0.0001 mm**
THC concentration (μg TPH/g dry sediment)	**> 64 mg/g**	**> 6400 μg/g**	**> 640 μg/g**	**> 64. μg/g**	**> 6.4 $\mu g/m^2$**
PAH concentration (ppm)	**> 1300 ppm**	**> 130 ppm**	**> 13 ppm**	**> 1.3 ppm**	**> 0.13 ppm**
PAH concentration (μg PAH/g dry sediment)	**> 1300 μg/g**	**> 130 μg/g**	**> 13 μg/g**	**> 1.3 μg/g**	**> 0.13 $\mu g/m^2$**
Shore Type:					
Rocky shoreline	0.03	0.68	0.68	0.68	0.68
Gravel beach	0.05	0.19	0.19	0.19	0.19
Sand beach	0.17	1.56	1.56	1.56	1.56
Mud flat	0.17	0.61	0.61	0.61	0.61
Wetland	0.19	0.68	0.68	0.68	0.68
Oyster reef	0.00	0.50	0.50	0.50	0.50
Artificial shoreline	0.62	1.58	1.58	1.58	1.58
Total	1.25	5.79	5.79	5.79	5.79

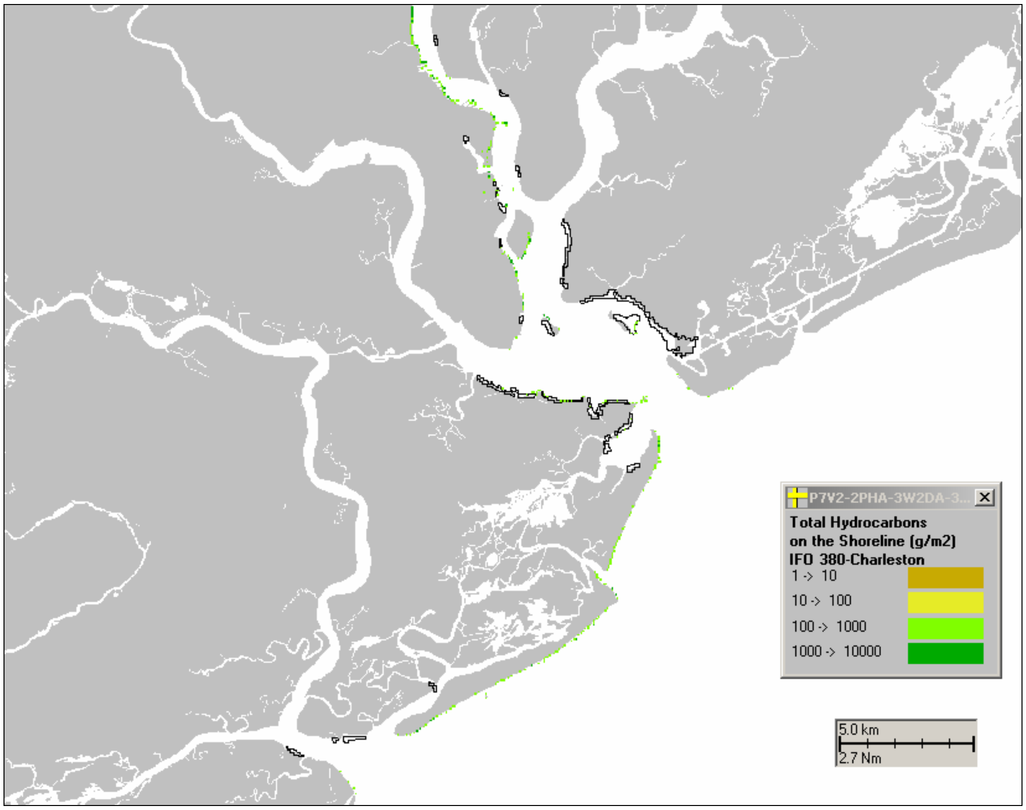

Figure 5-1. Total hydrocarbons on shorelines predicted by the (best) model simulation. The polygons over-laid on the map are locations of oyster reefs along the Cooper River, in Charleston Harbor, and near Folly Beach.

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APPENDIX A: GEOGRAPHICAL DATA AND MAPS

This appendix contains maps of the areas affected by the spill and the model habitat and depth grids used in the simulations.

A.1 Maps of the Vicinity of the Spill

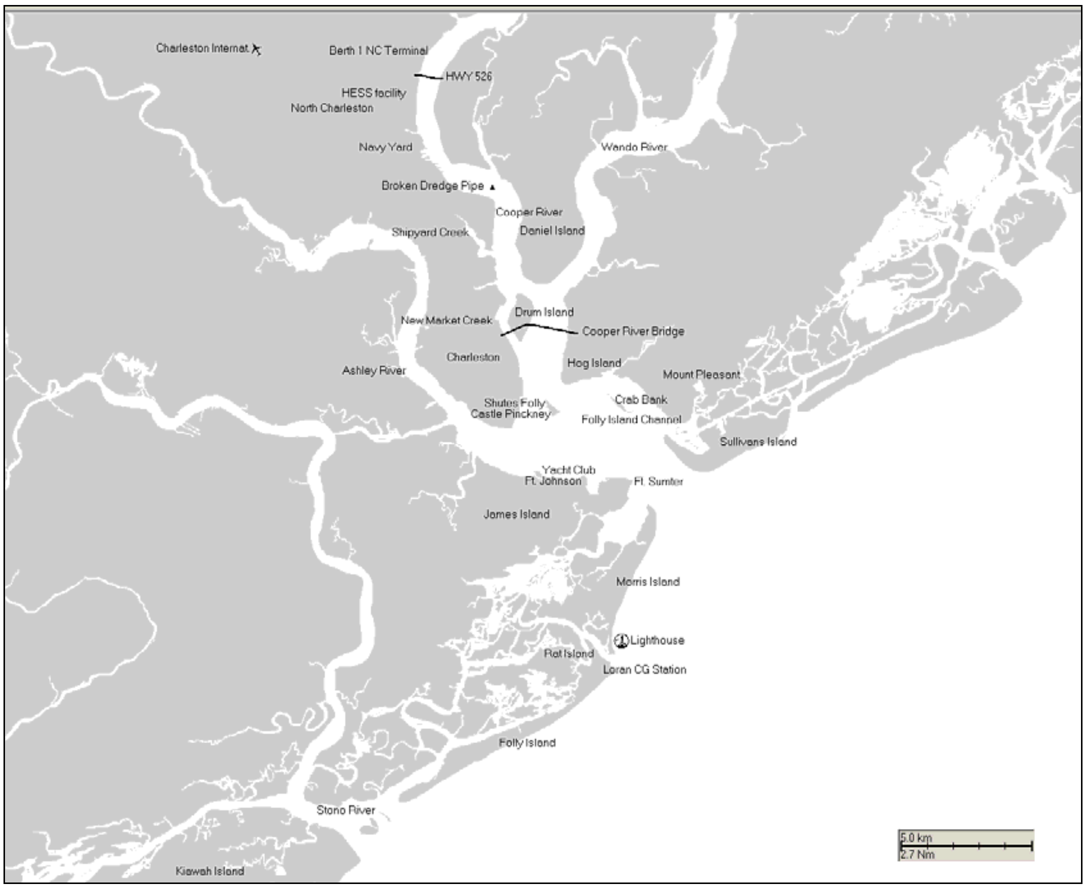

Figure A.1-1. Map of Charleston Harbor and its surrounding vicinity.

Figure A.1-2. Closer view of Charleston Harbor including areas that were impacted by the spill.

A.2 Gridded Habitat Mapping

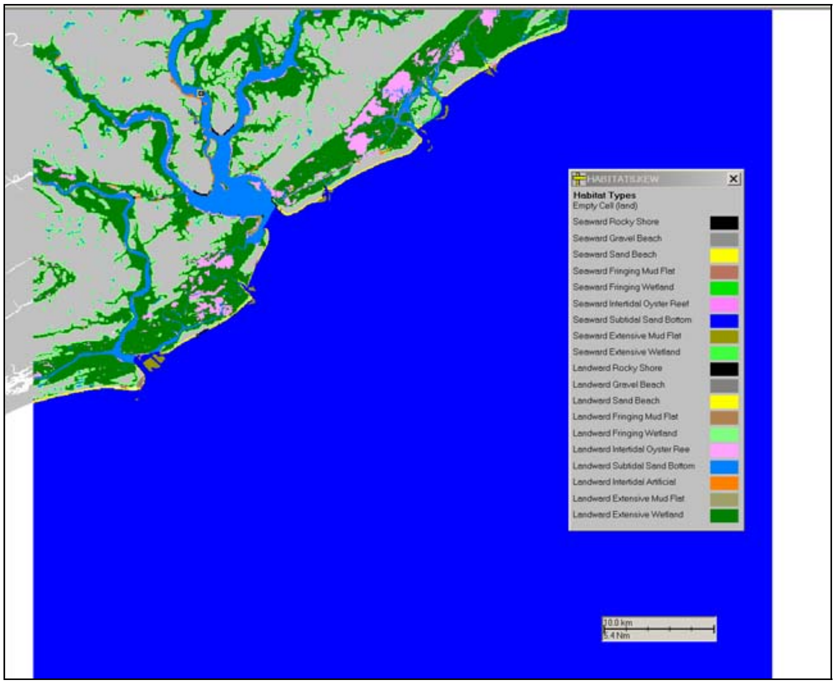

Figure A.2-1. Habitat grid used in modeling (full view).

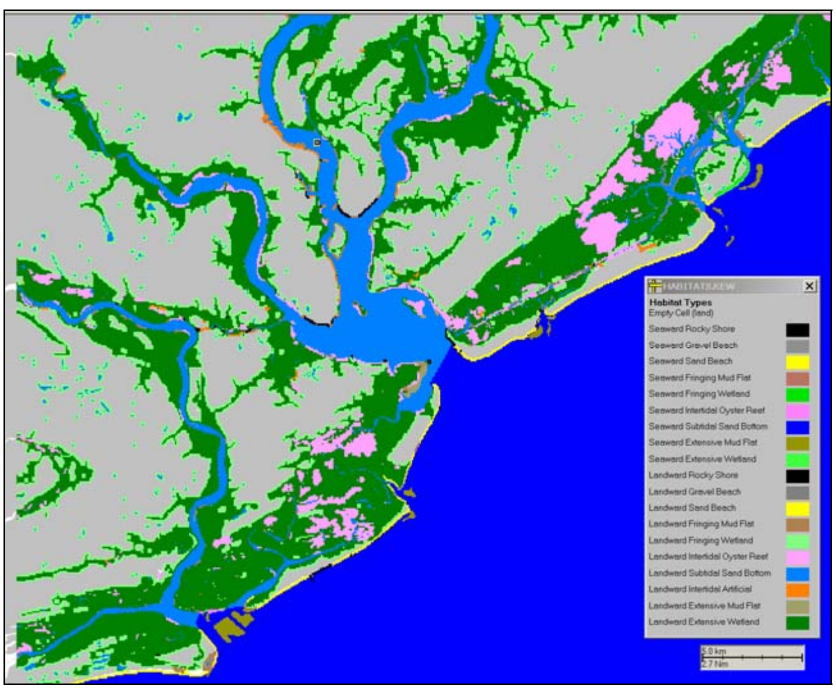

Figure A.2-2. Closer view of habitat grid used in modeling.

The location and dimensions of habitat grid are listed in Table A.2-1.

Table A.2-1. Location and dimensions of the habitat grid cells.

Characteristic	Value
Grid W edge (°longitude)	80.100853 °W
Grid S edge (°latitude)	32.367374 °N
Cell size (°longitude)	0.000688
Cell size (°latitude)	0.000688
Cell size (m) west-east	64.50
Cell size (m) south-north	76.37
# cells west-east	1,094
# cells south-north	807
Water cell area (m^2)	4,926
Shore cell length (m)	70.2
Shore cell width	1.0

A.3 Gridded Water Depth Data

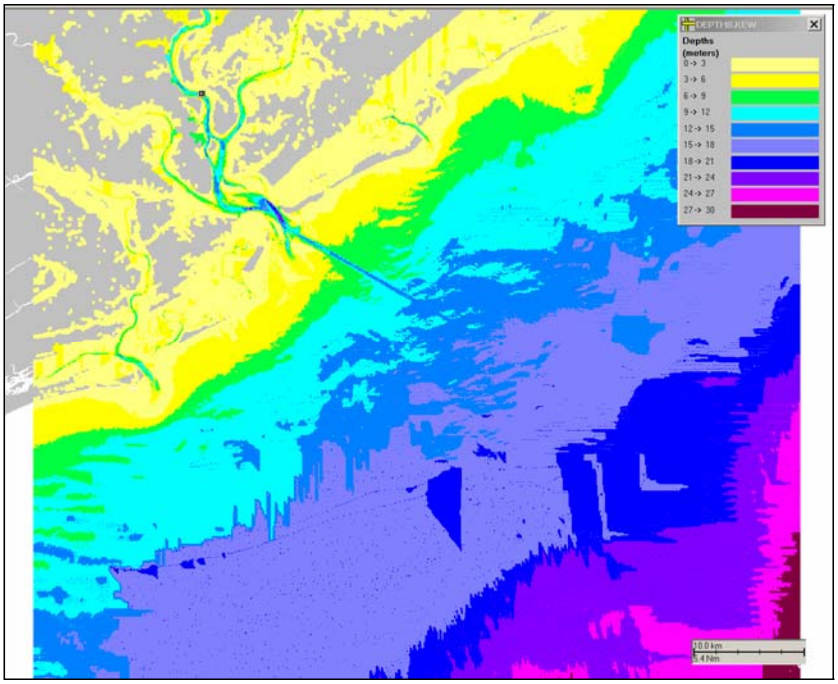

Figure A.3-1. Depth grid used in modeling (full view).

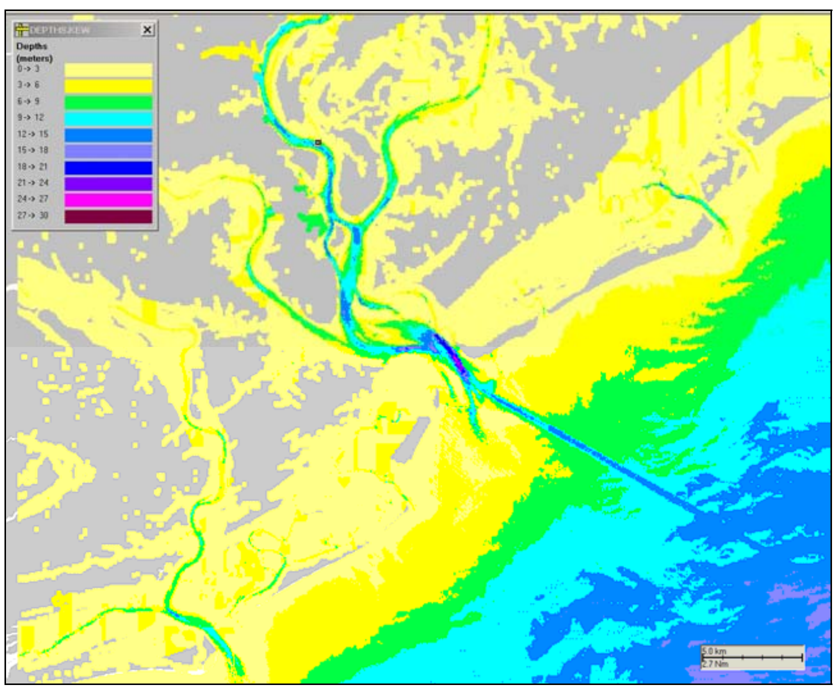

Figure A.3-2. Closer view of depth grid used in modeling.

APPENDIX B: OBSERVATIONS OF OIL CONTAMINATION AND RESPONSE ACTIVITIES

B.1 Observations of Oil Movements

The figures in this appendix are summaries of over-flights made by NOAA HAZMAT (2002), which were made the mornings of 2,3 and 4 October 2002. The over-flights depicted shoreline oiling, oil slicks on the water surface, and some subsurface oil.

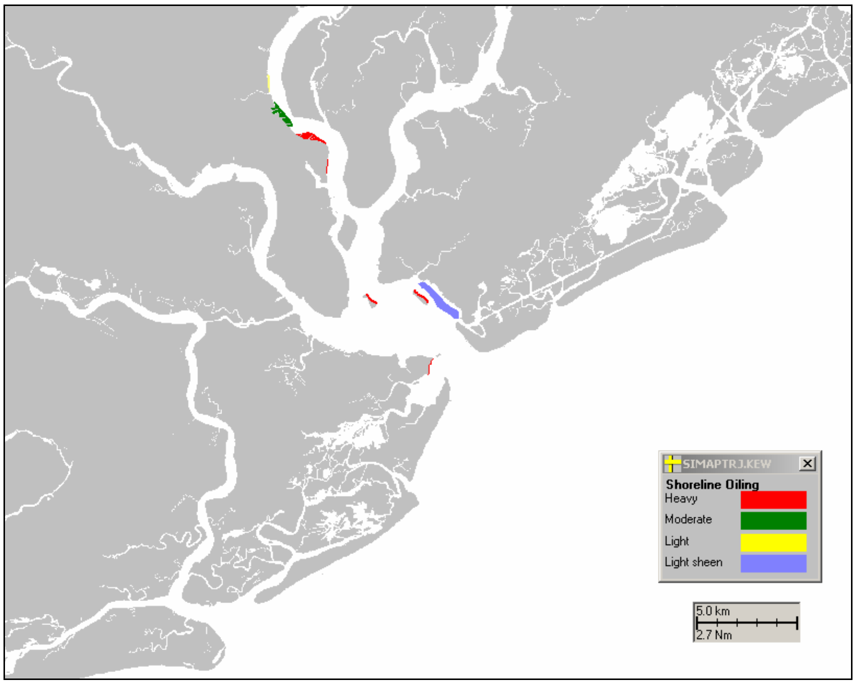

Figure B.1-1. Overflight for 2 October 2002 for 07:30 – 09:00 hours.

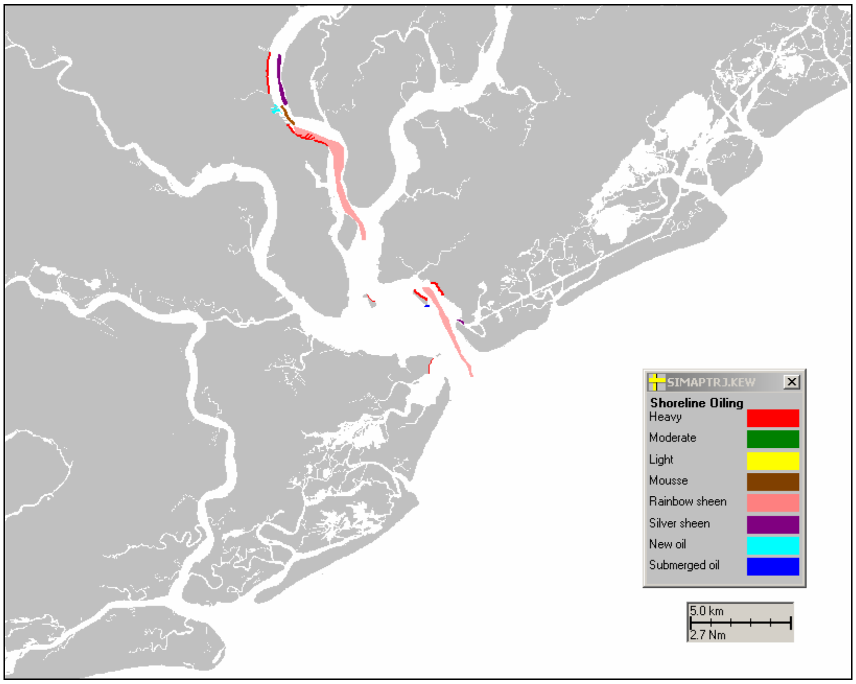

Figure B.1-2. Overflight for 3 October 2002 for 08:00 – 09:00 hours.

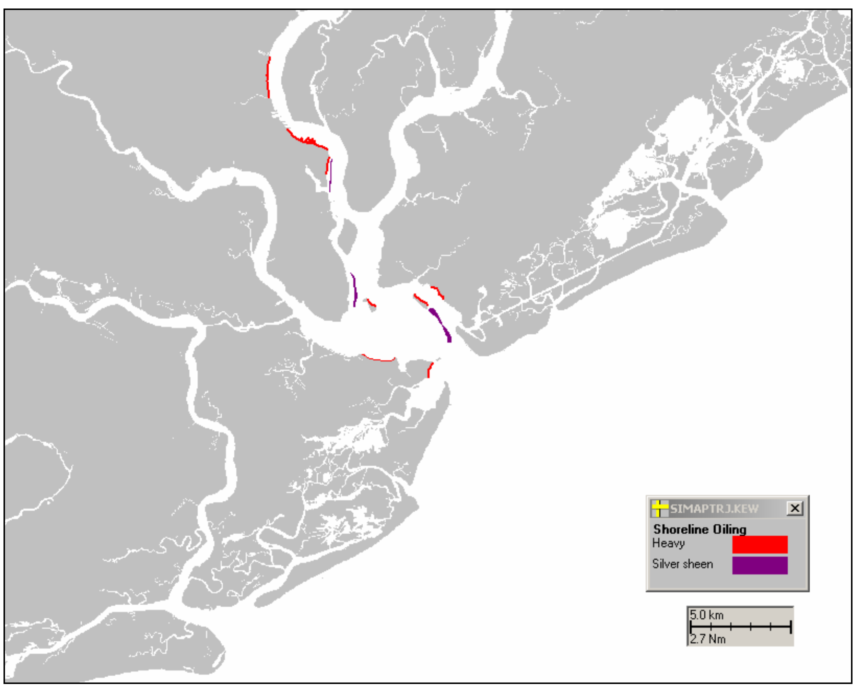

Figure B.1-3. Overflight for 4 October 2002 for 09:00 – 10:30 hours.

B.2 Shoreline Contamination

The figures in this appendix are of shoreline oiling, based on SCAT observations and data from the updated Preassessment Data Report (Polaris, 2004).

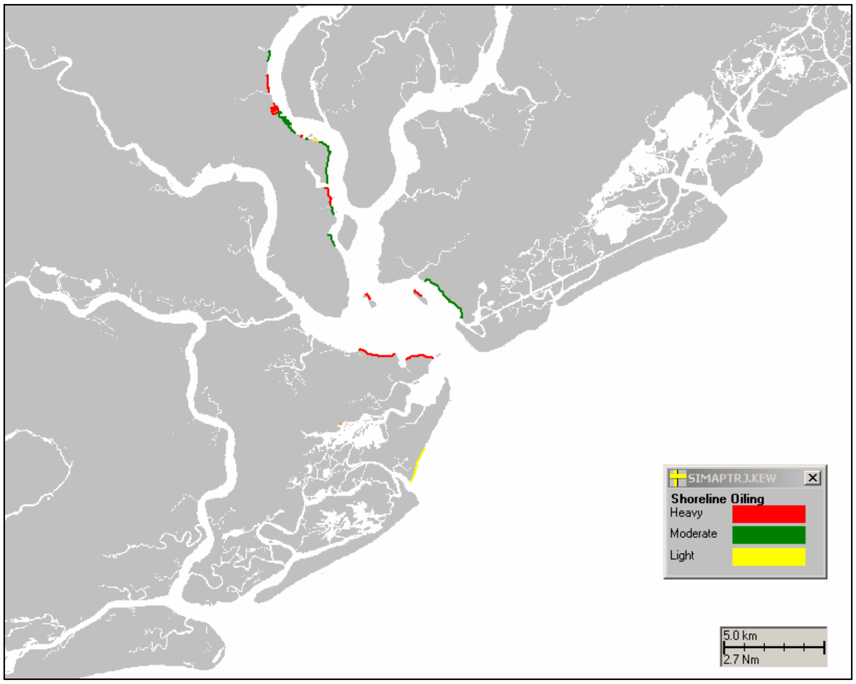

Figure B.2-1. SCAT observations for 2 October 2002.

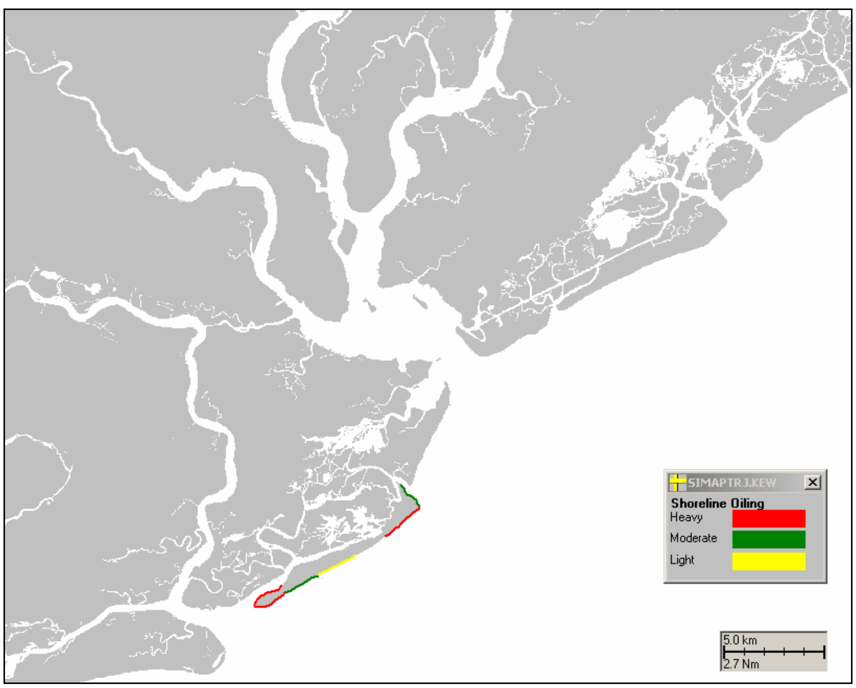

Figure B.2-2. SCAT observations for 3 October 2002.

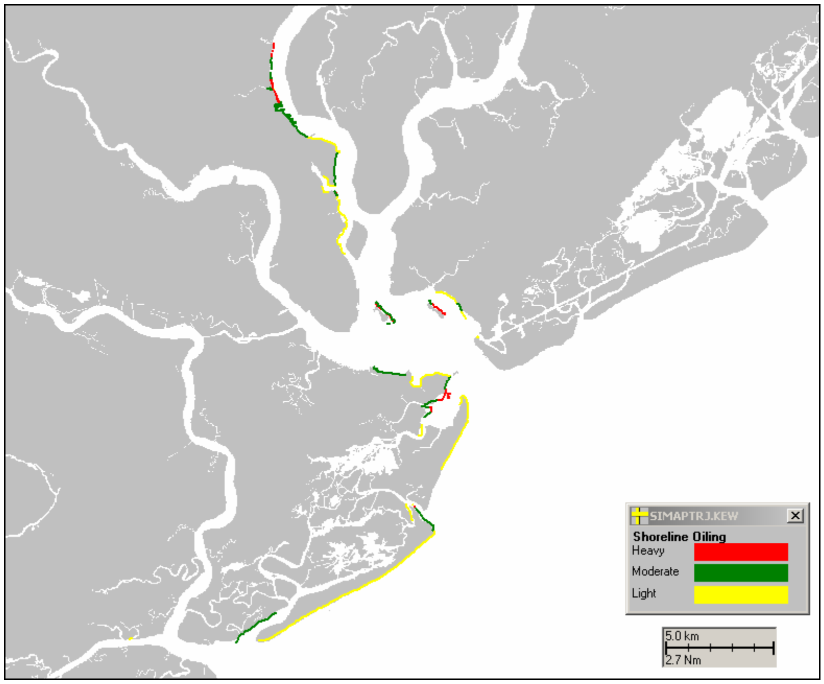

Figure B.2-3. Composite of shoreline oiling from updated data provided by Polaris 2004.

B.3 Sediment Contamination

Sediment samples were taken by South Carolina Department of Natural Resources (SCDNR) in October 2002, following the oil spill. Figure B.2-3 is a map of sampling locations and differentiates those locations for which PAH analyses were conducted.

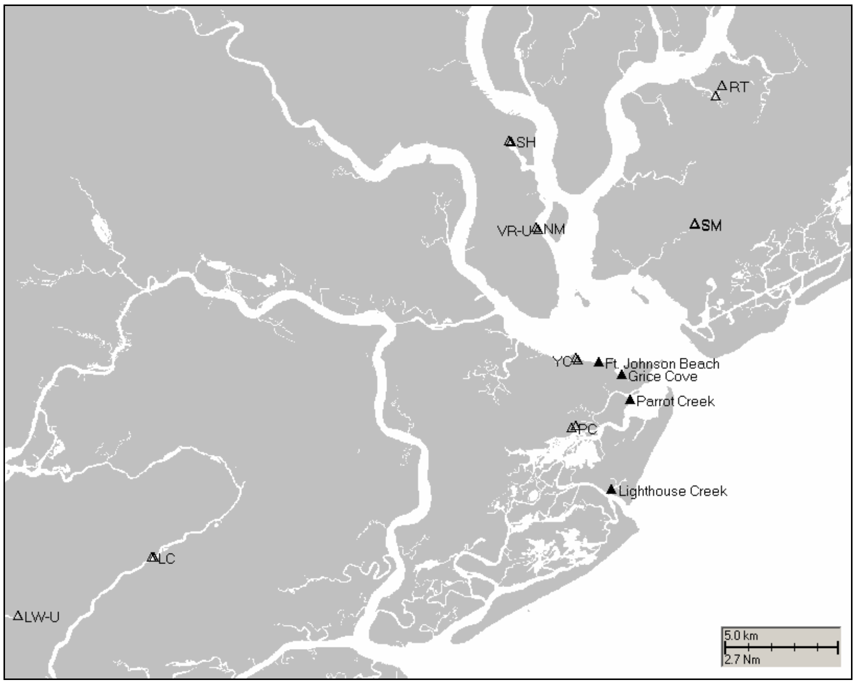

Figure B.2-3. SCDNR sediment sample locations and analyzed samples for October 2002. Open triangles indicate sites where no chemical analyses occurred, and closed triangles indicate PAH analyses.

B.4 Oiled Birds

Table B.4-1. Oiled birds observed after the spill. Of the pelicans oiled, 21 were treated by Tri-State.

Species Observed	# Oiled Birds Observed	Location Where Observed	Degree of oiling	Field Notes on Abundance
Brown pelicans	15-20	Crab Bank	moderately to heavily oiled	Total of ~200 brown pelicans noted on Crab Bank
Brown pelicans	30	Crab Bank	spots or stains of oil	
Brown pelicans	3	Hog Island	moderately oiled	Total of 10 pelicans observed on Hog Island
Great blue heron	2	Sullivan's Island to Shem's Creek	small smudges of oil	
Egrets	several	Sullivan's Island to Shem's Creek	small smudges of oil	
Wood stork				1 clean bird observed
Cormorant	1	Hog Island		
Ruddy turnstones	15	Sullivan's Island	15 with some oil: 1 heavily oiled, others with spotty or light oiling	75 birds observed on Sullivan's Island
Dowitchers				60 clean birds observed around piers
Boat-tailed grackle	1	Pier P	Oiled (treated and released)	

APPENDIX C: HOURLY WIND SPEED AND DIRECTION AT AND AFTER THE TIME OF THE SPILL

Hourly wind speed and direction data were compiled from 2 stations in the vicinity of the spill-affected area. The data are listed in the following tables.

Table C-1. Wind data from National Data Buoy Center for buoy off of Folly Beach.

Source:
(http://www.ndbc.noaa.gov/station_page.phtml?station=fbis1)
NOAA NDBC Station, Station FBIS1 - Folly Beach, SC
C-MAN station
32.68°N 79.89°W

Year	Month	Day	Hour	Direction	Speed (m/s)
2002	9	30	0	87	16
2002	9	30	1	85	16
2002	9	30	2	41	10
2002	9	30	3	32	11
2002	9	30	4	30	12
2002	9	30	5	16	11
2002	9	30	6	31	15
2002	9	30	7	32	14
2002	9	30	8	31	14
2002	9	30	9	31	13
2002	9	30	10	47	14
2002	9	30	11	55	16
2002	9	30	12	64	17
2002	9	30	13	63	18
2002	9	30	14	67	19
2002	9	30	15	97	17
2002	9	30	16	95	15
2002	9	30	17	104	16
2002	9	30	18	115	14
2002	9	30	19	103	12
2002	9	30	20	111	12
2002	9	30	21	91	10
2002	9	30	22	87	8
2002	9	30	23	98	12
2002	10	1	0	86	10
2002	10	1	1	106	13
2002	10	1	2	83	11
2002	10	1	3	93	11
2002	10	1	4	101	14
2002	10	1	5	102	13
2002	10	1	6	103	11
2002	10	1	7	23	10

2002	10	1	8	33	10
2002	10	1	9	40	9
2002	10	1	10	55	10
2002	10	1	11	71	10
2002	10	1	12	89	15
2002	10	1	13	99	12
2002	10	1	14	97	10
2002	10	1	15	98	11
2002	10	1	16	93	9
2002	10	1	17	91	9
2002	10	1	18	98	10
2002	10	1	19	94	10
2002	10	1	20	101	10
2002	10	1	21	106	10
2002	10	1	22	101	9
2002	10	1	23	105	8
2002	10	2	0	95	8
2002	10	2	1	98	9
2002	10	2	2	100	9
2002	10	2	3	93	7
2002	10	2	5	22	6
2002	10	2	6	2	5
2002	10	2	7	40	9
2002	10	2	8	39	9
2002	10	2	9	52	9
2002	10	2	10	73	9
2002	10	2	11	87	7
2002	10	2	12	82	7
2002	10	2	13	99	6
2002	10	2	14	117	7
2002	10	2	15	130	7
2002	10	2	16	132	9
2002	10	2	17	130	8
2002	10	2	18	124	8
2002	10	2	19	117	8
2002	10	2	20	138	7
2002	10	2	21	144	6
2002	10	2	22	168	5
2002	10	2	23	174	4
2002	10	3	0	186	3
2002	10	3	1	301	2
2002	10	3	2	323	2
2002	10	3	3	352	3
2002	10	3	4	3	3
2002	10	3	5	349	4
2002	10	3	6	351	4
2002	10	3	7	342	3
2002	10	3	8	346	4
2002	10	3	9	353	4
2002	10	3	10	43	4

2002	10	3	11	85	3
2002	10	3	12	148	4
2002	10	3	13	178	4
2002	10	3	14	202	5
2002	10	3	15	210	6
2002	10	3	16	212	7
2002	10	3	17	214	4
2002	10	3	18	190	4
2002	10	3	19	174	4
2002	10	3	20	253	2
2002	10	3	21	194	4
2002	10	3	22	200	3
2002	10	3	23	283	2
2002	10	4	0	229	2
2002	10	4	1	219	2
2002	10	4	2	297	3
2002	10	4	3	331	3
2002	10	4	4	305	3
2002	10	4	5	331	2
2002	10	4	6	344	4
2002	10	4	7	346	3
2002	10	4	8	2	7
2002	10	4	9	3	3
2002	10	4	10	53	4
2002	10	4	11	96	3
2002	10	4	12	131	6
2002	10	4	13	138	6
2002	10	4	14	147	5
2002	10	4	15	155	6
2002	10	4	16	189	5
2002	10	4	17	178	7
2002	10	4	18	194	8
2002	10	4	19	198	7
2002	10	4	20	204	8
2002	10	4	21	210	10
2002	10	4	22	229	9
2002	10	4	23	210	10
2002	10	5	0	219	9
2002	10	5	1	237	10
2002	10	5	2	240	8
2002	10	5	3	243	7
2002	10	5	4	258	5
2002	10	5	5	282	3
2002	10	5	6	277	5
2002	10	5	7	270	5
2002	10	5	8	272	6
2002	10	5	9	266	8
2002	10	5	10	296	6
2002	10	5	11	331	7
2002	10	5	12	348	3

2002	10	5	13	143	4
2002	10	5	14	210	10
2002	10	5	15	224	12
2002	10	5	16	221	11
2002	10	5	17	224	11
2002	10	5	18	240	9
2002	10	5	19	220	10
2002	10	5	20	249	6
2002	10	5	21	215	7
2002	10	5	22	235	10
2002	10	5	23	242	9
2002	10	6	0	248	6
2002	10	6	1	246	8
2002	10	6	2	257	4
2002	10	6	3	262	4
2002	10	6	4	287	3
2002	10	6	5	322	4
2002	10	6	6	318	4
2002	10	6	7	317	4
2002	10	6	8	336	4
2002	10	6	10	25	6
2002	10	6	11	92	3
2002	10	6	12	111	7
2002	10	6	13	98	12
2002	10	6	14	87	13
2002	10	6	15	95	13
2002	10	6	16	88	10
2002	10	6	17	89	10
2002	10	6	18	106	11
2002	10	6	20	70	9
2002	10	6	21	66	8
2002	10	6	22	95	6
2002	10	6	23	97	6
2002	10	7	0	76	3
2002	10	7	1	358	2
2002	10	7	2	353	3
2002	10	7	3	357	4
2002	10	7	4	340	4
2002	10	7	5	322	2
2002	10	7	6	344	3
2002	10	7	7	11	3
2002	10	7	8	339	5
2002	10	7	9	310	4
2002	10	7	10	284	1
2002	10	7	11	99	3
2002	10	7	12	119	4
2002	10	7	13	128	6
2002	10	7	14	138	7
2002	10	7	15	144	7
2002	10	7	16	156	5

2002	10	7	17	142	8
2002	10	7	18	136	9
2002	10	7	19	144	10
2002	10	7	20	169	9
2002	10	7	21	164	9
2002	10	7	22	175	8
2002	10	7	23	157	7
2002	10	8	0	168	4
2002	10	8	1	7	14
2002	10	8	2	355	6
2002	10	8	3	80	3
2002	10	8	4	34	8
2002	10	8	5	31	8
2002	10	8	6	6	8
2002	10	8	7	38	6
2002	10	8	8	54	3
2002	10	8	9	89	7
2002	10	8	10	64	8
2002	10	8	11	65	10
2002	10	8	12	45	7
2002	10	8	13	50	15
2002	10	8	14	45	17
2002	10	8	15	67	19
2002	10	8	16	81	18
2002	10	8	17	70	14
2002	10	8	18	56	19
2002	10	8	19	53	17
2002	10	8	20	43	14
2002	10	8	21	26	14
2002	10	8	22	16	11
2002	10	8	23	15	11
2002	10	9	0	13	13
2002	10	9	1	4	11
2002	10	9	2	3	9
2002	10	9	3	2	8
2002	10	9	4	3	8
2002	10	9	5	360	8
2002	10	9	6	359	10
2002	10	9	7	9	11
2002	10	9	8	24	12
2002	10	9	9	32	14
2002	10	9	10	51	19
2002	10	9	11	36	13
2002	10	9	12	46	14
2002	10	9	13	33	14
2002	10	9	14	62	20
2002	10	9	15	57	20
2002	10	9	16	58	21
2002	10	9	17	55	19
2002	10	9	18	43	13

2002	10	9	19	33	15
2002	10	9	20	40	12
2002	10	9	21	29	13
2002	10	9	22	34	12
2002	10	9	23	29	15

Table C-2. Wind data from Charleston International Airport.

Source: National Climatic Data Center (NCDC)
(http://www4.ncdc.noaa.gov/cgi-win/wwcgi.dll?wwDI~StnSrch~StnID~20017349)
NCDC Station, Charleston, SC
32.90^{o}N 80.03^{o}W

Year	**Month**	**Day**	**Hour**	**Direction**	**Speed (m/s)**
2002	9	30	0	40	6
2002	9	30	1	40	6
2002	9	30	2	50	7
2002	9	30	3	40	8
2002	9	30	4	30	7
2002	9	30	5	30	9
2002	9	30	6	40	8
2002	9	30	7	40	12
2002	9	30	8	40	11
2002	9	30	9	30	10
2002	9	30	10	50	10
2002	9	30	11	70	9
2002	9	30	12	70	10
2002	9	30	13	70	11
2002	9	30	14	110	12
2002	9	30	15	100	13
2002	9	30	16	120	11
2002	9	30	17	120	10
2002	9	30	18	110	5
2002	9	30	19	90	4
2002	9	30	20	30	3
2002	9	30	21	20	4
2002	9	30	22	30	6
2002	9	30	23	40	8
2002	10	1	0	40	6
2002	10	1	1	50	6
2002	10	1	2	50	4
2002	10	1	3	40	5
2002	10	1	4	40	6
2002	10	1	5	30	6
2002	10	1	6	50	7
2002	10	1	7	40	7
2002	10	1	8	70	8
2002	10	1	9	80	8
2002	10	1	10	100	8

2002	10	1	11	60	5
2002	10	1	12	120	11
2002	10	1	13	110	8
2002	10	1	14	100	9
2002	10	1	15	100	9
2002	10	1	16	140	9
2002	10	1	17	110	7
2002	10	1	18	110	6
2002	10	1	19	110	5
2002	10	1	20	0	0
2002	10	1	21	0	0
2002	10	1	22	40	3
2002	10	1	23	40	3
2002	10	2	0	0	0
2002	10	2	1	0	0
2002	10	2	2	0	0
2002	10	2	3	20	3
2002	10	2	4	40	5
2002	10	2	5	40	4
2002	10	2	6	40	4
2002	10	2	7	50	5
2002	10	2	8	80	5
2002	10	2	9	70	6
2002	10	2	10	60	9
2002	10	2	11	100	5
2002	10	2	12	50	4
2002	10	2	13	0	0
2002	10	2	14	160	7
2002	10	2	15	170	7
2002	10	2	16	160	6
2002	10	2	17	150	5
2002	10	2	18	130	5
2002	10	2	19	160	3
2002	10	2	20	190	3
2002	10	2	21	0	0
2002	10	2	22	0	0
2002	10	2	23	360	3
2002	10	3	0	0	0
2002	10	3	1	0	0
2002	10	3	2	0	0
2002	10	3	3	340	3
2002	10	3	4	360	3
2002	10	3	5	0	0
2002	10	3	6	340	4
2002	10	3	7	340	6
2002	10	3	8	330	4
2002	10	3	9	10	3
2002	10	3	10	0	0
2002	10	3	11	0	0
2002	10	3	12	0	0

2002	10	3	13	130	3
2002	10	3	14	0	0
2002	10	3	15	200	6
2002	10	3	16	190	5
2002	10	3	17	200	6
2002	10	3	18	200	4
2002	10	3	19	190	3
2002	10	3	20	0	0
2002	10	3	21	0	0
2002	10	3	22	0	0
2002	10	3	23	0	0
2002	10	4	0	0	0
2002	10	4	1	0	0
2002	10	4	2	280	4
2002	10	4	3	320	3
2002	10	4	4	0	0
2002	10	4	5	0	0
2002	10	4	6	0	0
2002	10	4	7	360	4
2002	10	4	8	185	3
2002	10	4	9	10	3
2002	10	4	10	80	4
2002	10	4	11	160	4
2002	10	4	12	140	7
2002	10	4	13	145	5
2002	10	4	14	150	10
2002	10	4	15	160	6
2002	10	4	16	170	7
2002	10	4	17	210	7
2002	10	4	18	180	4
2002	10	4	19	170	3
2002	10	4	20	210	5
2002	10	4	21	200	4
2002	10	4	22	160	3
2002	10	4	23	200	4
2002	10	5	0	220	3
2002	10	5	1	0	0
2002	10	5	2	0	0
2002	10	5	3	0	0
2002	10	5	4	240	5
2002	10	5	5	260	4
2002	10	5	6	240	4
2002	10	5	7	250	8
2002	10	5	8	270	8
2002	10	5	9	295	5
2002	10	5	10	320	7
2002	10	5	11	340	8
2002	10	5	12	285	5
2002	10	5	13	270	8
2002	10	5	14	0	0

2002	10	5	15	320	5
2002	10	5	16	20	5
2002	10	5	17	250	10
2002	10	5	18	160	5
2002	10	5	19	220	5
2002	10	5	20	0	0
2002	10	5	21	200	3
2002	10	5	22	210	4
2002	10	5	23	0	0
2002	10	6	0	240	3
2002	10	6	1	0	0
2002	10	6	2	280	4
2002	10	6	3	270	4
2002	10	6	4	300	4
2002	10	6	5	260	3
2002	10	6	6	300	3
2002	10	6	7	340	4
2002	10	6	8	10	3
2002	10	6	9	10	6
2002	10	6	10	25	4
2002	10	6	11	40	6
2002	10	6	12	50	3
2002	10	6	13	80	3
2002	10	6	14	110	9
2002	10	6	15	90	10
2002	10	6	16	100	10
2002	10	6	17	100	8
2002	10	6	18	120	5
2002	10	6	19	70	4
2002	10	6	20	80	5
2002	10	6	21	80	4
2002	10	6	22	360	3
2002	10	6	23	0	0
2002	10	7	0	360	3
2002	10	7	1	30	3
2002	10	7	2	350	3
2002	10	7	3	0	0
2002	10	7	4	0	0
2002	10	7	5	0	0
2002	10	7	6	320	3
2002	10	7	7	360	4
2002	10	7	8	0	0
2002	10	7	9	340	3
2002	10	7	10	227	3
2002	10	7	11	113	5
2002	10	7	12	0	0
2002	10	7	13	180	4
2002	10	7	14	360	5
2002	10	7	15	150	7
2002	10	7	16	160	6

2002	10	7	17	180	8
2002	10	7	18	150	3
2002	10	7	19	0	0
2002	10	7	20	160	5
2002	10	7	21	180	3
2002	10	7	22	180	3
2002	10	7	23	360	13
2002	10	8	0	350	10
2002	10	8	1	140	3
2002	10	8	2	10	5
2002	10	8	3	30	5
2002	10	8	4	30	5
2002	10	8	5	10	4
2002	10	8	6	50	4
2002	10	8	7	60	4
2002	10	8	8	60	8
2002	10	8	9	60	6
2002	10	8	10	30	6
2002	10	8	11	10	5
2002	10	8	12	20	3
2002	10	8	13	70	6
2002	10	8	14	20	7
2002	10	8	15	20	9
2002	10	8	16	50	11
2002	10	8	17	50	10
2002	10	8	18	40	8
2002	10	8	19	20	7
2002	10	8	20	10	10
2002	10	8	21	20	8
2002	10	8	22	20	6
2002	10	8	23	20	7
2002	10	9	0	10	9
2002	10	9	1	10	7
2002	10	9	2	10	8
2002	10	9	3	10	7
2002	10	9	4	10	5
2002	10	9	5	20	7
2002	10	9	6	30	9
2002	10	9	7	20	6
2002	10	9	8	360	6
2002	10	9	9	30	7
2002	10	9	10	30	5
2002	10	9	11	50	8
2002	10	9	12	20	7
2002	10	9	13	20	7
2002	10	9	14	80	7
2002	10	9	15	70	8
2002	10	9	16	70	7
2002	10	9	17	50	8
2002	10	9	18	50	6

2002	10	9	19	20	8
2002	10	9	20	10	7
2002	10	9	21	30	9
2002	10	9	22	30	9
2002	10	9	23	30	8

APPENDIX D: CURRENT DATA

D.1 Development of Current Data

A current file was prepared using the hydrodynamic model BFHYDRO. Section 3.3.1 contains a description of the model and application to the area of the spill. Figure D.1-1 shows the hydrodynamic model grid.

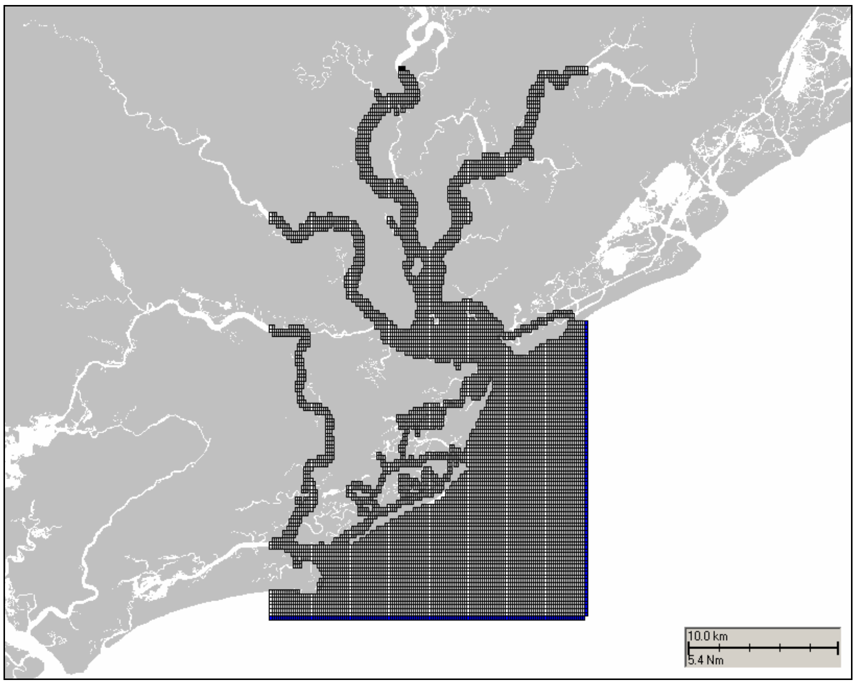

Figure D.1-1. Hydrodynamic model grid used for estimation of currents.

D.2 Current Vector Plots for Current Data Used in the Oil Spill Simulations

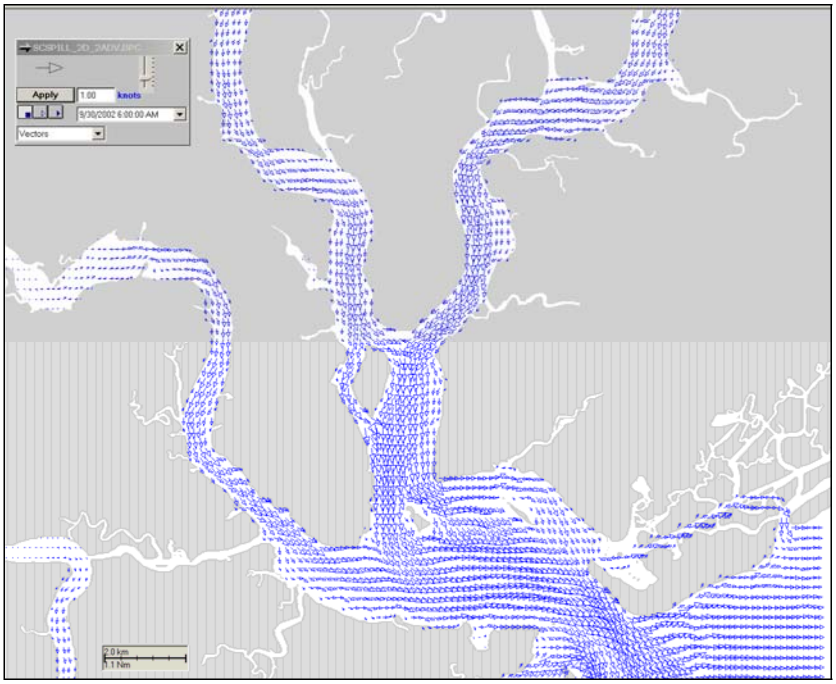

Figure D.2-1. Current data used in modeling in area of oil trajectory: 30 September at 06:00 hours. Vector length indicates speed in the indicated direction.

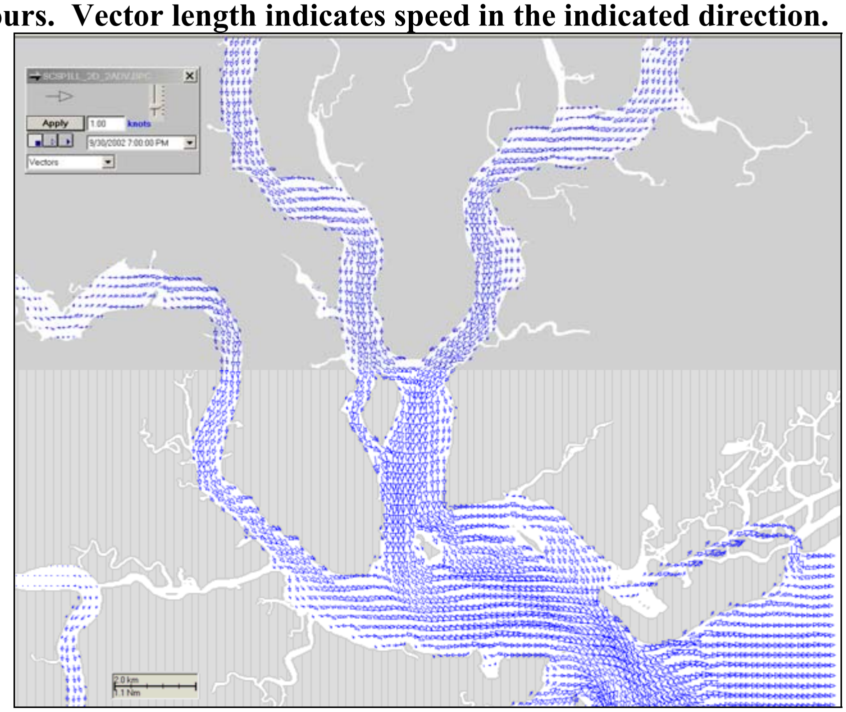

Figure D.2-2. Current data used in modeling in area of oil trajectory: 30 September at 19:00 hours. Vector length indicates speed in the indicated direction.

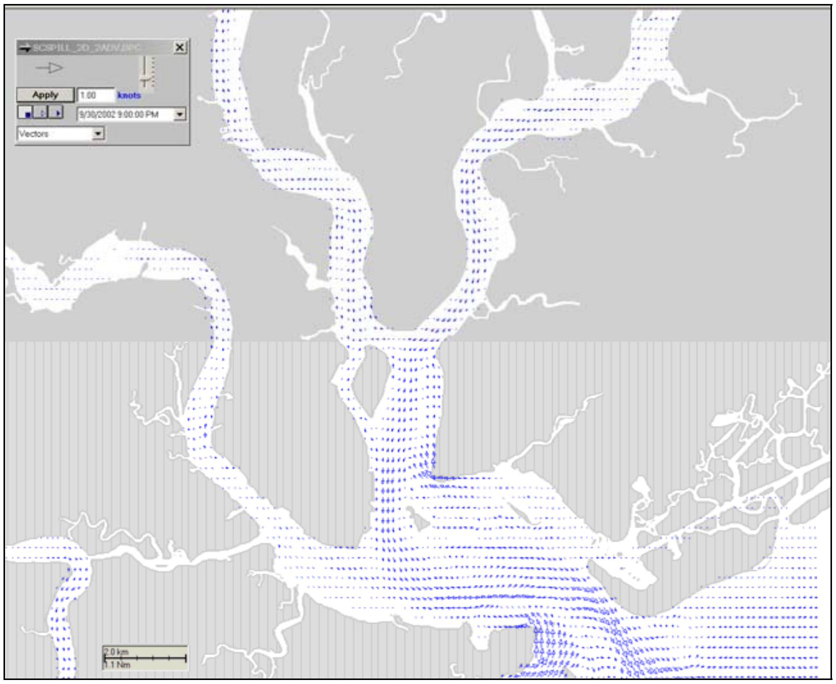

Figure D.2-3. Current data used in modeling in area of oil trajectory: 30 September at 21:00 hours. Vector length indicates speed in the indicated direction.

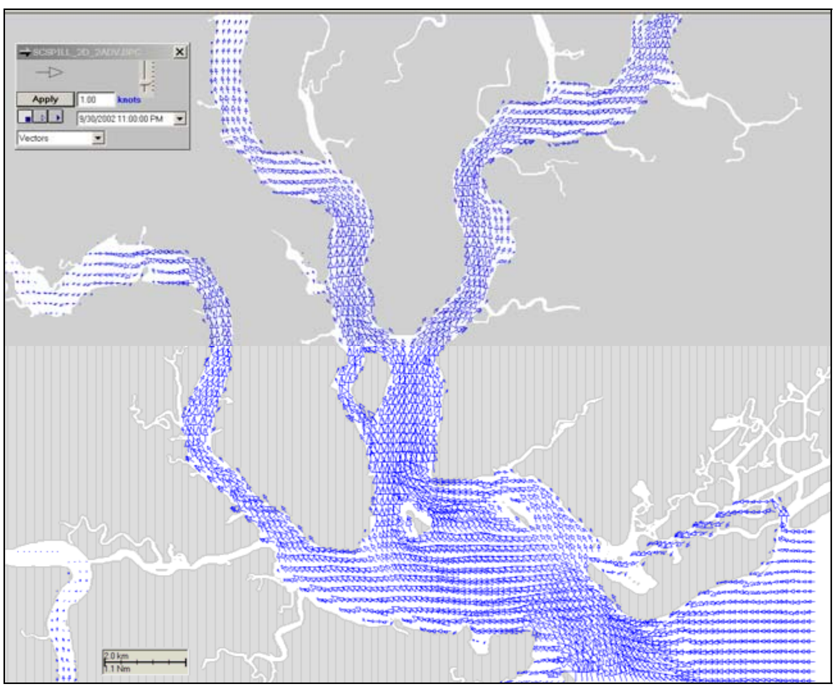

Figure D.2-4. Current data used in modeling in area of oil trajectory: 30 September at 23:00 hours. Vector length indicates speed in the indicated direction.

APPENDIX E. INPUTS TO THE SIMAP PHYSICAL FATES MODEL

Table E-1. Inputs describing the scenario.

Name	Description	Units	Source(s) of Information	Value(s)
Spill Site	Location of the spill site	-	Reports and the Ship's Log from the Responsible Party	See below and Table E-2
Spill Latitude	Latitude of the spill site	Degrees	chart	See Table E-2
Spill Longitude	Longitude of the spill site	Degrees	chart	See Table E-2
Depth of release	Depth below the water surface of the release	m	Assumed, oil would float immediately	0 m (surface)
Start time and date	Date and time the release began	Date, hr,min	USCG and Responsible Party	30 Sept 2002 05:35 EST
Duration	Duration of the release	(hrs)	Assumed until last waypoint outbound	16.74 hours
Total spill volume or mass	Total volume (or weight) released	bbl, gal., MT, kg, m^3	USCG	12,500 gal. (46.4 MT)
Salinity	Surface water salinity	ppt	French et al. (1996b)	27 ppt
Water Temperature	Surface water temperature	Degrees C	NOAA CO-OPS, http://co-ops.nos.noaa.gov	23^{o}C
Air Temper-ature	Air water temperature at water surface	Degrees C	(assume = water temperature)	23^{o}C
Fetch	Fetch = distance to land to N, S, E, W (if landfall not in model domain)	km	>0 km; 1000 km if open ocean	Charts
Wind drift speed	Speed oil moves down wind relative to wind	% of wind speed	ASCE, 1996: see section 3.3.2	3.5%
Wind drift angle	Angle to right of wind (in northern hemisphere) oil drifts	Deg. to right of downwind	ASCE, 1996: see section 3.3.2	0^o
Horizontal turbulent diffusion coefficient	Randomized turbulent mixing parameter in x & y	m^2/sec	French et al. (1996a, 1999) based on Okubo and Ozmidov (1970); Okubo (1971)	1 m^2/sec (estuaries and low energy coastal areas)
Vertical turbulent diffusion coefficient	Randomized turbulent mixing parameter in z	m^2/sec	French et al. (1996a, 1999) based on Okubo and Ozmidov (1970); Okubo (1971)	0.0001 m^2/sec
Suspended sediment concentration	Average suspended sediment concentration during spill period	mg/l	SCDHEC (David Graves, pers. comm., January 2004)	11.7 mg/l
Suspended sediment settling rate	Net settling rate for suspended sediments	m/day	French et al. (1996b)	1 m/day

Table E-2. Assumed ship locations and times during the oil release.

GIS Point #	Model Point #	Longitude (deg.)	Latitude (deg.)	Location	Time	Hours After Spill
0	1	-79.936424	32.85283	At dredge pipe	05:35	0.00
1	2	-79.956429	32.86052			0.19
2	3	-79.964562	32.87533			0.38
3	4	-79.962868	32.89042	HWY 526 Bridge	06:09	0.57
4	5	-79.95948	32.89754			0.95
5	6	-79.961174	32.89953	First line ashore	06:54	1.32
6	7	-79.962189	32.89981	Fast at Berth 1	07:18	1.72
7	8	-79.962189	32.89981	Left Berth 1	19:00	13.42
8	9	-79.965241	32.87533			13.65
9	10	-79.95948	32.86337			13.78
10	11	-79.95134	32.85796			13.87
11	12	-79.947609	32.85682			13.90
12	13	-79.936424	32.85254			13.99
13	14	-79.93235	32.8514			14.02
14	15	-79.929642	32.84314			14.10
15	16	-79.928619	32.82149			14.29
16	17	-79.915741	32.8138			14.33
17	18	-79.91404	32.80439	Cooper R. Bridge	20:04	14.49
18	19	-79.913704	32.78957			14.61
19	20	-79.909638	32.78302	by Shutes Folly	20:15	14.67
20	21	-79.901161	32.78017			14.71
21	22	-79.895393	32.77817			14.74
22	23	-79.888954	32.77446	by Crab Bank	20:21	14.77
23	24	-79.878777	32.76933			14.86
24	25	-79.865898	32.75964			14.92
25	26	-79.856064	32.74852			14.98
26	27	-79.846565	32.73996			15.03
27	28	-79.793678	32.714			15.26
28	29	-79.756714	32.69318			15.43
29	30	-79.67704	32.64151	GPS noted	21:24	15.82
30	31	-79.624481	32.59496			16.10
31	32	-79.552261	32.53181			16.48
32	33	-79.499703	32.48835	GPS noted	22:19	16.74

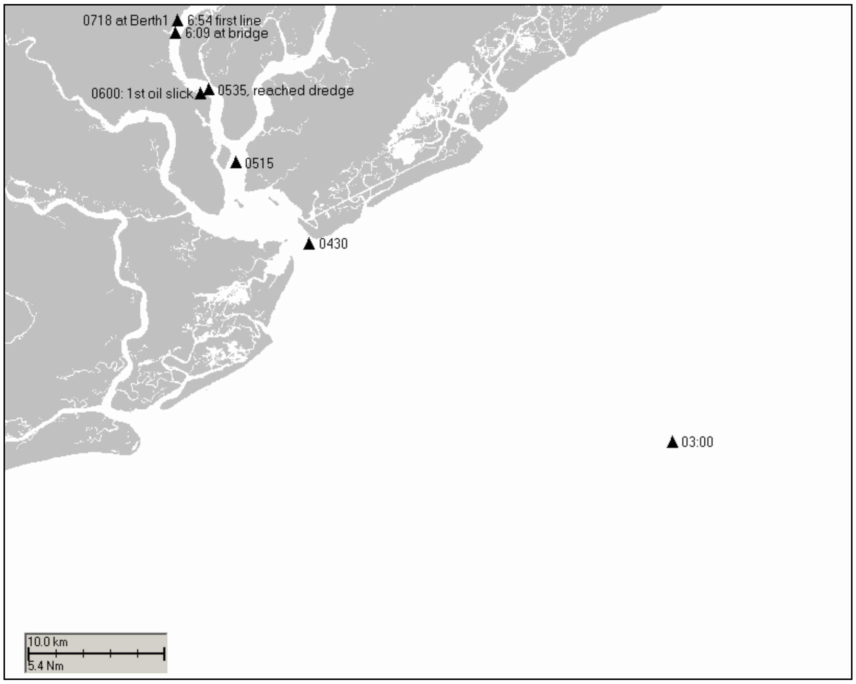

Figure E-1. Waypoints for vessel entering the harbor.

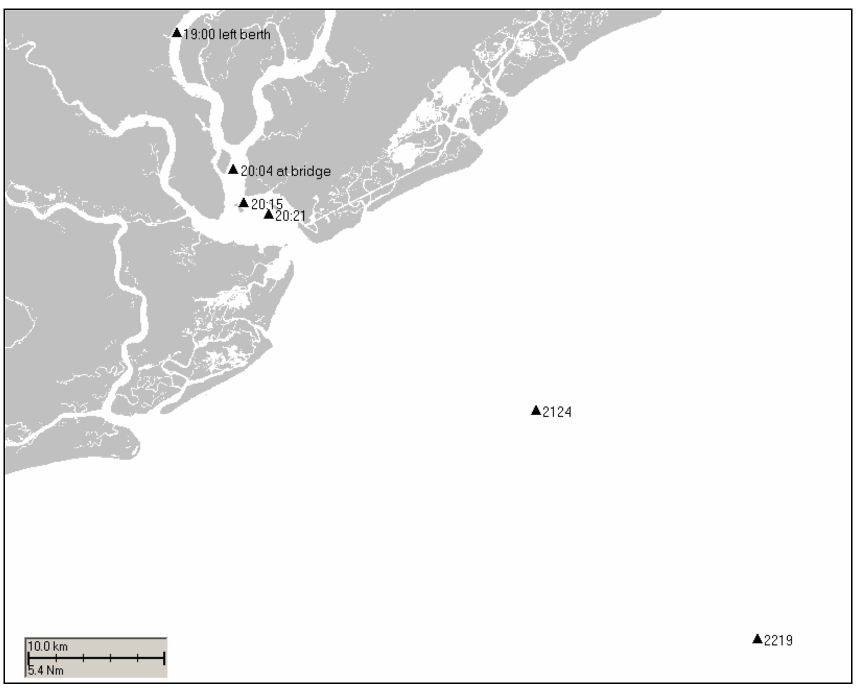

Figure E-2. Waypoints for vessel exiting the harbor.

Table E-3. Oil name and properties.

Name	Description	Units	Source(s) of Information	Value(s)
Oil: name	Oil type or chemical released	(name)	USCG	IFO 380 (heavy fuel oil)
Oil: density	Density of the oil	g/cm^3 or API	Typical heavy fuel oil (Jokuty et al., 1996)	0.98 g/cm^3 (API = 12.888)
Oil: viscosity	Viscosity of the oil	Centi-poise (cp)	Typical heavy fuel oil (Jokuty et al., 1996)	14,470 cp
Oil: surface tension	Surface tension of the oil	Dyne/cm	Typical heavy fuel oil (Jokuty et al., 1996)	32.6 dyne/cm
Oil: BTEX fraction	Fraction of oil which is monoaromatics (BTEX)	fraction	Typical heavy fuel oil (Wang et al., 1995)	0.000640
Oil: 2-ring PAH fraction	Fraction of oil which is 2-ring aromatics (PAHs)	fraction	analysis of source oil (Battelle)	0.004756
Oil: 3-ring PAH fraction	Fraction of oil which is 3-ring aromatics (PAHs)	fraction	analysis of source oil (Battelle)	0.009086
Oil: non-aromatic volatile fraction	Fraction of oil which is not aromatic and with boiling point <180°C (volatilizes)	fraction	Typical heavy fuel oil (Jokuty et al., 1996)	0.004355
Oil: non-aromatic volatile fraction	Fraction of oil which is not aromatic and with boiling point 180-265°C (semi-volatilizes)	fraction	Typical heavy fuel oil (Jokuty et al., 1996)	0.046530
Oil: non-aromatic volatile fraction	Fraction of oil which is not aromatic and with boiling point 265-380°C (low volatility)	fraction	Typical heavy fuel oil (Jokuty et al., 1996)	0.083310
Oil: initial water fraction	Fraction of initial spill volume which is water	fraction	(assumed)	0
Oil: water fraction in mousse	Fraction of oil mousse which is water (maximum)	fraction	analysis of mousse (Jokuty et al., 1996)	0%

APPENDIX F. FATES MODEL RESULTS

The figures in this appendix show the fates model results for the best simulation of the spill, scenario name "P7V2-2PHA-3W2DA-35-0-H1". Other model runs may be examined using the SIMAP Viewer. Below is a list of the cases run and the assumptions that varied.

Table F-1 Model scenarios run and parameters varied between runs.

Scenario Name	Horizontal turbulent diffusion coefficient (m^2/sec)	Wind Drift (% of wind speed, angle)
P7V2-2PHA-3W2DA-35-0-Hp1	0.1	3.5%, 0^o
P7V2-2PHA-3W2DA-35-0-H1	1.0	3.5%, 0^o
P7V2-2PHA-3W2DA-35-0-H5	5.0	3.5%, 0^o
P7V2-2PHA-3W2DA-35-0-H10	10.0	3.5%, 0^o
P7V2-2PHA-3W2DA- MDRFT -H1	1.0	Model calculated
P7V2-2PHA-3W2DA- MDRFT -H10	10.0	Model calculated
AtDredge-3W2DA-35-0-H1	1.0	3.5%, 0^o

F.1 Description of Fate and Mass Balance

The over-all mass balance of oil hydrocarbons as a function of time is in Figure F.1-1.

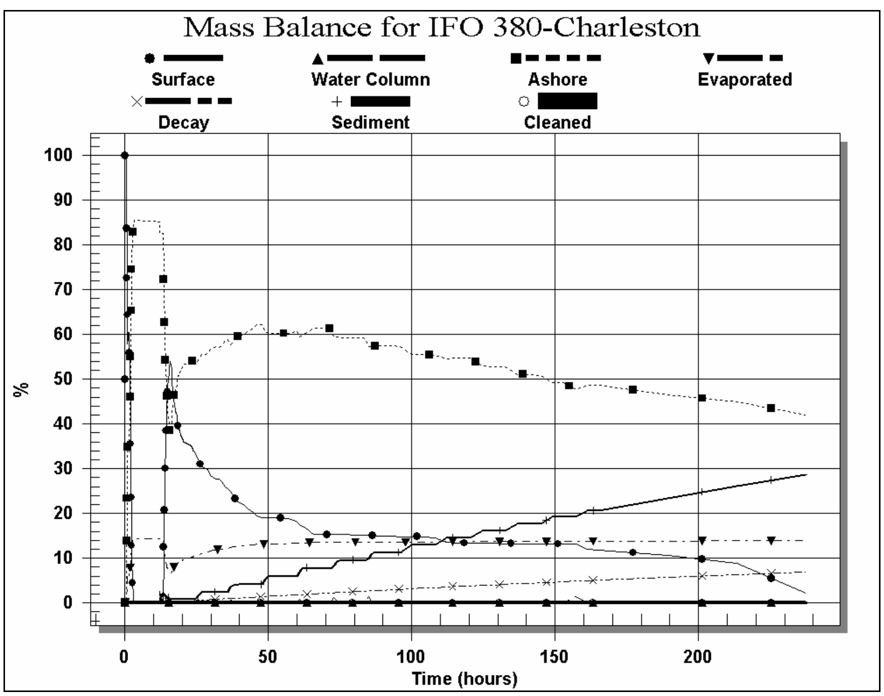

Figure F.1-1. Over all mass balance of oil versus time after the spill.

Table F-2 Mass balance of oil over time (hours since the spill started) in the best simulation.

Time (hr)	% on Water Surface	% in Atmos-phere	% in Water Column	% in Sediment	% Ashore	% Decayed	% Spilled	% of Soluble Aromatics in Surface Oil	% of Soluble Aromatics in Subsurface Droplets	% of Soluble Aromatics Dissolved in Water
0.08	99.8918	0.1048	0.0000	0.0000	0.0000	0.0035	1.5	99.1741	0.0000	0.0002
0.17	99.8876	0.1071	0.0000	0.0000	0.0000	0.0053	2.9	99.1563	0.0000	0.0003
0.25	99.8810	0.1120	0.0000	0.0000	0.0000	0.0069	4.4	99.1185	0.0000	0.0003
0.33	99.8695	0.1218	0.0000	0.0000	0.0000	0.0087	5.8	99.0415	0.0000	0.0003
0.42	99.8586	0.1310	0.0000	0.0000	0.0000	0.0104	7.3	98.9695	0.0000	0.0004
0.5	99.8449	0.1429	0.0000	0.0000	0.0000	0.0122	8.7	98.8765	0.0000	0.0004
0.58	99.8187	0.1674	0.0000	0.0000	0.0000	0.0139	10.2	98.6864	0.0000	0.0004
0.67	90.3522	1.5168	0.0001	0.0000	8.1153	0.0156	11.6	89.3267	0.0001	0.0005
0.75	76.9711	3.4137	0.0001	0.0000	19.5979	0.0172	13.1	76.1801	0.0001	0.0005
0.83	68.1716	4.6615	0.0002	0.0000	27.1478	0.0188	14.5	67.5316	0.0001	0.0005
0.92	60.5384	5.7466	0.0003	0.0000	33.6944	0.0204	16.0	60.0087	0.0002	0.0005
1	57.9644	6.1130	0.0003	0.0000	35.9002	0.0220	17.4	57.4662	0.0002	0.0006
2	38.5389	8.9448	0.0004	0.0000	52.4694	0.0465	30	37.7574	0.0003	0.0009
3	0.9890	14.2609	0.0005	0.0000	84.6668	0.0828	30	0.9218	0.0004	0.0011
4	0.0000	14.3945	0.0005	0.0000	85.4865	0.1185	30	0.0000	0.0004	0.0011
5	0.0000	14.3945	0.0005	0.0000	85.4509	0.1541	30	0.0000	0.0004	0.0011
6	0.0000	14.3945	0.0005	0.0000	85.4153	0.1897	30	0.0000	0.0004	0.0011
7	0.0000	14.3945	0.0005	0.0000	85.3798	0.2253	30	0.0000	0.0004	0.0011
8	0.0000	14.3945	0.0005	0.0000	85.3442	0.2608	30	0.0000	0.0004	0.0011
9	0.0000	14.3945	0.0005	0.0000	85.3086	0.2964	30	0.0000	0.0004	0.0011
10	0.0000	14.3945	0.0005	0.0000	85.2731	0.3319	30	0.0000	0.0004	0.0011
11	0.0000	14.3945	0.0005	0.0000	85.2376	0.3674	30	0.0000	0.0004	0.0011
12	0.0000	14.3945	0.0005	0.0000	85.2021	0.4029	30	0.0000	0.0004	0.0011

13	0.0000	14.3945	0.7467	1.7938	82.6237	0.4412	30	0.0000	0.0004	0.0011
14	28.6490	10.2873	0.1445	1.6592	58.9156	0.3445	42	28.5119	0.0003	0.0009
15	49.0505	7.3864	0.0349	1.1659	42.0991	0.2631	63	48.6170	0.0002	0.0010
16	53.1556	6.8083	0.0102	0.8901	38.9029	0.2329	84	52.6082	0.0001	0.0013
17	45.4705	7.9316	0.0045	0.7528	45.6064	0.2342	100	44.7741	0.0001	0.0016
18	42.2380	8.4957	0.0019	0.7534	48.2370	0.2740	100	40.7584	0.0002	0.0022
19	38.6020	9.1235	0.0009	0.7524	51.2076	0.3136	100	36.3296	0.0002	0.0028
20	36.5602	9.5264	0.0006	0.7506	52.8092	0.3531	100	33.4951	0.0002	0.0036
21	35.8166	9.7425	0.0005	0.7485	53.2995	0.3925	100	31.9792	0.0003	0.0042
22	35.4541	9.9184	0.0013	0.7463	53.4480	0.4318	100	30.7562	0.0010	0.0047
23	35.0821	10.1037	0.0027	0.7441	53.5964	0.4710	100	29.4783	0.0021	0.0050
24	33.8484	10.3839	0.0035	0.7419	54.5122	0.5101	100	27.5486	0.0028	0.0052
25	33.0398	10.5816	1.3724	1.0099	53.4472	0.5491	100	26.1865	0.0027	0.0053
26	31.4456	10.8837	0.4519	1.9279	54.7031	0.5877	100	24.1067	0.0029	0.0054
27	30.3433	11.1213	0.0538	2.3236	55.5321	0.6259	100	22.4735	0.0028	0.0055
28	30.1278	11.2390	0.0094	2.3657	55.5941	0.6639	100	21.6655	0.0027	0.0056
29	29.7224	11.3765	0.0045	2.3683	55.8263	0.7019	100	20.7211	0.0027	0.0056
30	28.4513	11.6141	0.0042	2.3666	56.8240	0.7398	100	19.0866	0.0028	0.0057
31	27.9531	11.7602	0.0042	2.3643	57.1405	0.7777	100	18.0836	0.0028	0.0058
32	27.7625	11.8543	0.0041	2.3619	57.2017	0.8155	100	17.4379	0.0027	0.0059
33	27.6745	11.9308	0.0041	2.3596	57.1779	0.8532	100	16.9128	0.0026	0.0060
34	27.0322	12.0520	0.0040	2.3572	57.6637	0.8909	100	16.0766	0.0025	0.0061
35	25.8431	12.2111	0.0040	2.3547	58.6585	0.9286	100	14.9750	0.0024	0.0062
36	25.4989	12.2899	0.0040	2.3523	58.8887	0.9662	100	14.4308	0.0024	0.0063
37	24.8785	12.3907	0.5547	3.5605	57.6121	1.0035	100	13.7339	0.0023	0.0064
38	23.6190	12.5375	0.1446	3.9680	58.6905	1.0403	100	12.7156	0.0023	0.0065
39	22.7343	12.6494	0.0661	4.0441	59.4290	1.0771	100	11.9400	0.0023	0.0066
40	22.3166	12.7187	0.0250	4.0827	59.7432	1.1138	100	11.4596	0.0023	0.0067
41	22.0896	12.7671	0.0094	4.0958	59.8877	1.1504	100	11.1245	0.0022	0.0067
42	21.5002	12.8393	0.0049	4.0977	60.3708	1.1870	100	10.6222	0.0022	0.0068
43	20.9136	12.9093	0.0041	4.0960	60.8534	1.2236	100	10.1356	0.0021	0.0069

44	20.6938	12.9512	0.0040	4.0936	60.9973	1.2602	100	9.8448	0.0021	0.0070
45	20.0246	13.0199	0.0039	4.0911	61.5638	1.2967	100	9.3654	0.0020	0.0070
46	19.2703	13.0897	0.0039	4.0885	62.2144	1.3332	100	8.8776	0.0020	0.0071
47	19.1542	13.1133	0.0039	4.0859	62.2730	1.3697	100	8.7125	0.0020	0.0072
48	19.1320	13.1275	0.0039	4.0833	62.2471	1.4062	100	8.6131	0.0019	0.0072
49	19.1080	13.1436	0.5745	5.3657	60.3659	1.4424	100	8.5006	0.0019	0.0073
50	19.0809	13.1626	0.0602	5.8774	60.3408	1.4781	100	8.3679	0.0019	0.0074
51	19.0548	13.1808	0.0094	5.9257	60.3157	1.5136	100	8.2411	0.0018	0.0074
52	19.0307	13.1970	0.0044	5.9282	60.2906	1.5492	100	8.1283	0.0018	0.0075
53	19.0089	13.2109	0.0039	5.9261	60.2655	1.5847	100	8.0309	0.0018	0.0075
54	18.9883	13.2236	0.0039	5.9237	60.2404	1.6202	100	7.9416	0.0017	0.0076
55	18.9687	13.2353	0.0039	5.9212	60.2154	1.6556	100	7.8591	0.0017	0.0077
56	18.9498	13.2463	0.0039	5.9187	60.1903	1.6911	100	7.7815	0.0017	0.0077
57	18.8418	13.2622	0.0039	5.9162	60.2494	1.7265	100	7.6690	0.0017	0.0078
58	18.7334	13.2786	0.0038	5.9137	60.3085	1.7619	100	7.5532	0.0016	0.0078
59	18.3578	13.3102	0.0038	5.9112	60.6197	1.7973	100	7.3306	0.0016	0.0079
60	17.8949	13.3453	0.0038	5.9086	61.0146	1.8327	100	7.0828	0.0016	0.0079
61	17.3442	13.3847	0.6573	7.0780	59.6680	1.8679	100	6.8046	0.0016	0.0080
62	17.1506	13.4031	0.0877	7.6450	59.8111	1.9025	100	6.6744	0.0016	0.0080
63	16.3362	13.4550	0.0164	7.7138	60.5416	1.9370	100	6.3072	0.0015	0.0081
64	15.9681	13.4807	0.0061	7.7216	60.8520	1.9715	100	6.1249	0.0015	0.0081
65	15.6904	13.5001	0.0043	7.7208	61.0783	2.0060	100	5.9867	0.0015	0.0082
66	15.5028	13.5136	0.0039	7.7187	61.2206	2.0404	100	5.8900	0.0015	0.0082
67	15.4936	13.5163	0.0038	7.7162	61.1951	2.0749	100	5.8696	0.0015	0.0083
68	15.4850	13.5184	0.0038	7.7137	61.1697	2.1093	100	5.8525	0.0014	0.0083
69	15.4762	13.5208	0.0038	7.7112	61.1443	2.1438	100	5.8342	0.0014	0.0084
70	15.4675	13.5230	0.0038	7.7086	61.1189	2.1782	100	5.8164	0.0014	0.0084
71	15.4583	13.5258	0.0038	7.7061	61.0935	2.2126	100	5.7951	0.0014	0.0084
72	15.4487	13.5289	0.0038	7.7036	61.0681	2.2469	100	5.7715	0.0014	0.0085
73	15.4399	13.5313	1.1725	8.3507	59.2243	2.2812	100	5.7533	0.0014	0.0085
74	15.4314	13.5334	0.3007	9.2198	59.1997	2.3149	100	5.7363	0.0013	0.0086

75	15.4223	13.5361	0.0704	9.4477	59.1751	2.3485	100	5.7160	0.0013	0.0086
76	15.4129	13.5391	0.0191	9.4965	59.1505	2.3820	100	5.6935	0.0013	0.0086
77	15.4037	13.5418	0.0077	9.5054	59.1260	2.4154	100	5.6723	0.0013	0.0087
78	15.3947	13.5444	0.0048	9.5058	59.1014	2.4489	100	5.6525	0.0013	0.0087
79	15.3856	13.5471	0.0040	9.5042	59.0768	2.4823	100	5.6319	0.0013	0.0088
80	15.3763	13.5499	0.0038	9.5019	59.0523	2.5157	100	5.6105	0.0013	0.0088
81	15.3670	13.5529	0.0038	9.4995	59.0278	2.5491	100	5.5882	0.0012	0.0088
82	15.3575	13.5560	0.0038	9.4970	59.0032	2.5825	100	5.5649	0.0012	0.0089
83	15.3485	13.5586	0.0038	9.4946	58.9787	2.6158	100	5.5449	0.0012	0.0089
84	15.3402	13.5605	0.0038	9.4921	58.9542	2.6492	100	5.5300	0.0012	0.0090
85	15.3319	13.5624	1.1868	10.0611	57.1754	2.6824	100	5.5146	0.0012	0.0090
86	15.1486	13.5731	0.3576	10.8877	57.3179	2.7152	100	5.4373	0.0012	0.0090
87	15.1408	13.5746	0.1108	11.1320	57.2941	2.7478	100	5.4247	0.0012	0.0091
88	14.9577	13.5852	0.0314	11.2090	57.4364	2.7803	100	5.3476	0.0012	0.0091
89	14.8626	13.5910	0.0128	11.2252	57.4956	2.8128	100	5.3049	0.0011	0.0091
90	14.8554	13.5921	0.0071	11.2285	57.4717	2.8452	100	5.2954	0.0011	0.0092
91	14.8481	13.5932	0.0050	11.2283	57.4479	2.8777	100	5.2856	0.0011	0.0092
92	14.7534	13.5987	0.0041	11.2267	57.5069	2.9101	100	5.2443	0.0011	0.0093
93	14.7460	13.5999	0.0038	11.2246	57.4831	2.9425	100	5.2341	0.0011	0.0093
94	14.7385	13.6013	0.0038	11.2223	57.4592	2.9749	100	5.2226	0.0011	0.0093
95	14.7312	13.6025	0.0037	11.2199	57.4353	3.0073	100	5.2124	0.0011	0.0094
96	14.7238	13.6037	0.0037	11.2176	57.4115	3.0397	100	5.2018	0.0011	0.0094
97	14.7163	13.6051	1.3550	11.5715	55.6802	3.0720	100	5.1905	0.0011	0.0094
98	14.7084	13.6069	0.3010	12.6228	55.6571	3.1038	100	5.1765	0.0011	0.0095
99	14.7007	13.6085	0.0624	12.8591	55.6340	3.1354	100	5.1633	0.0010	0.0095
100	14.6935	13.6095	0.0185	12.9006	55.6109	3.1669	100	5.1540	0.0010	0.0095
101	14.6862	13.6107	0.0074	12.9094	55.5878	3.1985	100	5.1441	0.0010	0.0096
102	14.6789	13.6119	0.0045	12.9100	55.5647	3.2299	100	5.1335	0.0010	0.0096
103	14.6713	13.6134	0.0038	12.9084	55.5417	3.2614	100	5.1213	0.0010	0.0096
104	14.6638	13.6147	0.0037	12.9062	55.5186	3.2929	100	5.1103	0.0010	0.0097
105	14.6565	13.6160	0.0037	12.9039	55.4956	3.3243	100	5.1000	0.0010	0.0097

106	14.6492	13.6171	0.0037	12.9016	55.4726	3.3558	100	5.0899	0.0010	0.0097
107	14.6419	13.6184	0.0037	12.8993	55.4496	3.3872	100	5.0793	0.0010	0.0098
108	14.5476	13.6242	0.0037	12.8970	55.5089	3.4186	100	5.0368	0.0010	0.0098
109	14.4535	13.6299	1.2137	13.3371	53.9159	3.4500	100	4.9945	0.0009	0.0098
110	14.0998	13.6483	0.1673	14.3810	54.2228	3.4808	100	4.8623	0.0009	0.0099
111	13.6600	13.6709	0.0208	14.5252	54.6117	3.5114	100	4.7003	0.0009	0.0099
112	13.5664	13.6765	0.0055	14.5383	54.6713	3.5421	100	4.6589	0.0009	0.0099
113	13.4729	13.6821	0.0039	14.5376	54.7308	3.5726	100	4.6180	0.0009	0.0100
114	13.4661	13.6833	0.0038	14.5355	54.7081	3.6032	100	4.6078	0.0009	0.0100
115	13.3730	13.6887	0.0038	14.5332	54.7676	3.6338	100	4.5682	0.0009	0.0100
116	13.3663	13.6897	0.0038	14.5309	54.7449	3.6644	100	4.5591	0.0009	0.0100
117	13.3599	13.6906	0.0038	14.5287	54.7221	3.6949	100	4.5512	0.0009	0.0101
118	13.3537	13.6913	0.0037	14.5264	54.6995	3.7254	100	4.5447	0.0009	0.0101
119	13.3477	13.6917	0.0037	14.5241	54.6768	3.7560	100	4.5400	0.0009	0.0101
120	13.3417	13.6922	0.0037	14.5219	54.6541	3.7865	100	4.5352	0.0009	0.0101
121	13.3356	13.6927	1.4084	14.7385	53.0079	3.8169	100	4.5298	0.0008	0.0102
122	13.3296	13.6932	0.2584	15.8859	52.9859	3.8469	100	4.5244	0.0008	0.0102
123	13.3234	13.6938	0.0375	16.1046	52.9640	3.8767	100	4.5183	0.0008	0.0102
124	13.3173	13.6944	0.0082	16.1317	52.9420	3.9064	100	4.5125	0.0008	0.0102
125	13.3112	13.6949	0.0043	16.1334	52.9201	3.9361	100	4.5073	0.0008	0.0102
126	13.3053	13.6953	0.0038	16.1317	52.8981	3.9658	100	4.5026	0.0008	0.0103
127	13.2994	13.6957	0.0037	16.1296	52.8762	3.9954	100	4.4983	0.0008	0.0103
128	13.2931	13.6963	0.0038	16.1275	52.8543	4.0251	100	4.4926	0.0008	0.0103
129	13.2868	13.6970	0.0039	16.1253	52.8324	4.0547	100	4.4858	0.0009	0.0103
130	13.2805	13.6977	0.0040	16.1231	52.8105	4.0843	100	4.4793	0.0009	0.0103
131	13.2743	13.6983	0.0040	16.1209	52.7886	4.1139	100	4.4734	0.0009	0.0104
132	13.2683	13.6988	0.0039	16.1187	52.7667	4.1435	100	4.4682	0.0009	0.0104
133	13.2624	13.6992	1.4140	16.2728	51.1785	4.1731	100	4.4633	0.0008	0.0104
134	13.1709	13.7037	0.1967	17.4878	51.2387	4.2022	100	4.4300	0.0008	0.0104
135	13.1652	13.7040	0.0340	17.6483	51.2175	4.2310	100	4.4260	0.0008	0.0104
136	13.1593	13.7044	0.0073	17.6729	51.1963	4.2599	100	4.4217	0.0008	0.0104

137	13.1534	13.7047	0.0042	17.6739	51.1751	4.2887	100	4.4173	0.0008	0.0105
138	13.1477	13.7050	0.0039	17.6720	51.1539	4.3175	100	4.4135	0.0008	0.0105
139	13.1419	13.7053	0.0038	17.6699	51.1327	4.3463	100	4.4099	0.0008	0.0105
140	13.1363	13.7055	0.0038	17.6678	51.1115	4.3750	100	4.4066	0.0008	0.0105
141	13.1307	13.7057	0.0038	17.6657	51.0904	4.4038	100	4.4038	0.0008	0.0105
142	13.1251	13.7058	0.0038	17.6636	51.0692	4.4325	100	4.4012	0.0007	0.0105
143	13.1195	13.7059	0.0038	17.6615	51.0481	4.4613	100	4.3985	0.0007	0.0105
144	13.1139	13.7061	0.0038	17.6594	51.0269	4.4900	100	4.3957	0.0007	0.0105
145	13.1083	13.7062	1.5175	17.6573	49.4921	4.5187	100	4.3930	0.0007	0.0105
146	13.1027	13.7063	0.4569	18.7154	49.4716	4.5471	100	4.3903	0.0007	0.0105
147	13.0971	13.7064	0.0948	19.0754	49.4511	4.5752	100	4.3876	0.0007	0.0105
148	13.0915	13.7066	0.0188	19.1493	49.4306	4.6031	100	4.3849	0.0007	0.0105
149	13.0859	13.7067	0.0069	19.1592	49.4102	4.6311	100	4.3822	0.0007	0.0105
150	13.0803	13.7069	0.0044	19.1597	49.3897	4.6591	100	4.3795	0.0007	0.0105
151	13.0745	13.7071	0.0040	19.1582	49.3693	4.6870	100	4.3761	0.0007	0.0106
152	13.0687	13.7073	0.0040	19.1562	49.3488	4.7149	100	4.3726	0.0008	0.0106
153	13.0630	13.7076	0.0040	19.1541	49.3284	4.7428	100	4.3693	0.0008	0.0106
154	13.0575	13.7077	0.0040	19.1521	49.3080	4.7707	100	4.3662	0.0007	0.0106
155	12.8824	13.7159	0.0039	19.1501	49.4492	4.7986	100	4.3066	0.0007	0.0106
156	12.8768	13.7160	0.0039	19.1480	49.4287	4.8265	100	4.3038	0.0007	0.0106
157	12.8713	13.7162	0.0039	19.1460	49.4082	4.8544	100	4.3010	0.0007	0.0106
158	12.4426	13.7362	0.2198	20.3930	48.3265	4.8818	100	4.1568	0.0007	0.0106
159	12.0142	13.7562	0.0278	20.5829	48.7098	4.9091	100	4.0130	0.0007	0.0106
160	11.7554	13.7682	0.0073	20.6015	48.9315	4.9362	100	3.9260	0.0007	0.0106
161	11.6659	13.7722	0.0044	20.6023	48.9918	4.9634	100	3.8956	0.0006	0.0106
162	11.5765	13.7762	0.0038	20.6008	49.0521	4.9906	100	3.8654	0.0006	0.0106
163	11.4872	13.7802	0.0037	20.5988	49.1123	5.0177	100	3.8354	0.0006	0.0106
164	11.3135	13.7882	0.0037	20.5968	49.2530	5.0448	100	3.7772	0.0006	0.0106
165	11.3087	13.7882	0.0037	20.5948	49.2326	5.0720	100	3.7754	0.0006	0.0106
166	11.2196	13.7922	0.0037	20.5928	49.2927	5.0991	100	3.7453	0.0006	0.0106
167	11.2149	13.7922	0.0037	20.5907	49.2723	5.1262	100	3.7435	0.0006	0.0106

168	11.2102	13.7923	0.0037	20.5887	49.2519	5.1533	100	3.7418	0.0006	0.0106
174	11.0976	13.7964	0.0068	22.0321	47.7521	5.3150	100	3.7031	0.0006	0.0106
180	11.0697	13.7966	0.0036	22.0234	47.6338	5.4729	100	3.6923	0.0005	0.0106
186	10.0379	13.8439	0.0038	23.4239	47.0630	5.6275	100	3.3469	0.0005	0.0106
192	10.0125	13.8440	0.0038	23.4125	46.9465	5.7808	100	3.3377	0.0006	0.0106
198	9.5712	13.8636	0.0039	24.7942	45.8361	5.9310	100	3.1901	0.0005	0.0106
204	9.2964	13.8754	0.0055	24.7830	45.9601	6.0797	100	3.0979	0.0011	0.0106
210	8.9411	13.8909	0.0062	26.1329	44.8036	6.2253	100	2.9792	0.0013	0.0107
216	8.8363	13.8948	0.0060	26.1219	44.7716	6.3694	100	2.9442	0.0012	0.0107
222	8.8134	13.8948	0.0067	27.4334	43.3409	6.5107	100	2.9364	0.0015	0.0107
228	8.7883	13.8948	0.0088	27.4227	43.2338	6.6505	100	2.9279	0.0023	0.0107
234	6.3899	13.8948	0.0033	28.6880	41.8534	6.7848	100	2.1288	0.0009	0.0108
240	0.3268	13.8948	0.0005	28.6777	41.7501	6.9061	100	0.1089	0.0002	0.0108

F.2 Model Trajectory

The following figures show the model trajectory for the best simulation of the spill indicating where there is exposure to surface oil. The points in the trajectory plots below represent the center of mass for "spillets" used to simulate the spill. The map locations are cumulative, the previous oil locations are displayed along with the present ones at the time of the snapshot. Each spillet is a sublot of the total mass spilled. The spillet is transported by currents and surface wind drift. The mass distribution around the spillet center spreads (for surface slicks) and disperses over time according to the horizontal dispersion coefficient. Note that the shoreline shown in these model outputs are for visual reference only, whereas the habitat (and corresponding depth) grid (Appendix A.2) defines the actual shoreline to the model.

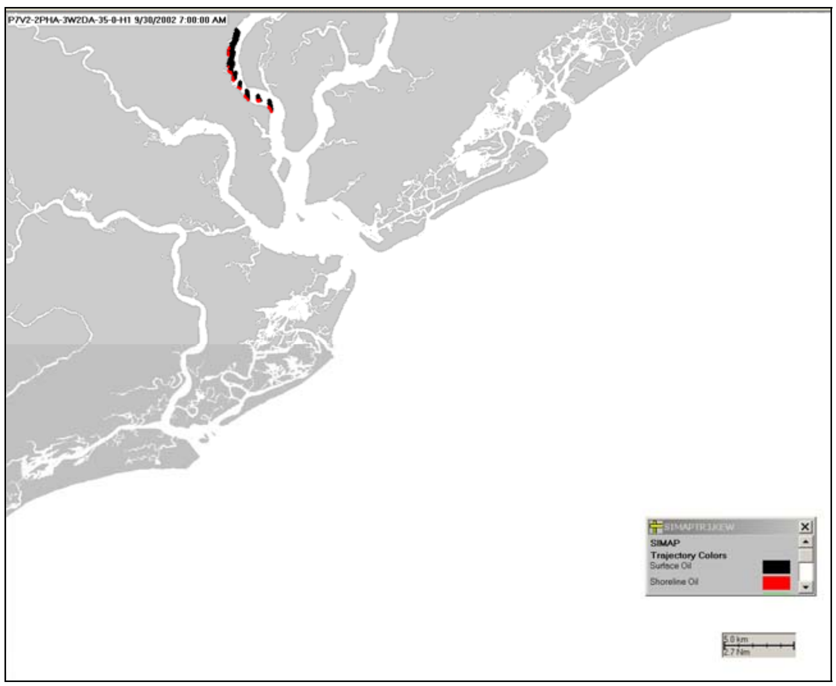

Figure F.2-1. Trajectory of surface oil at 07:00 on 30 September 2002.

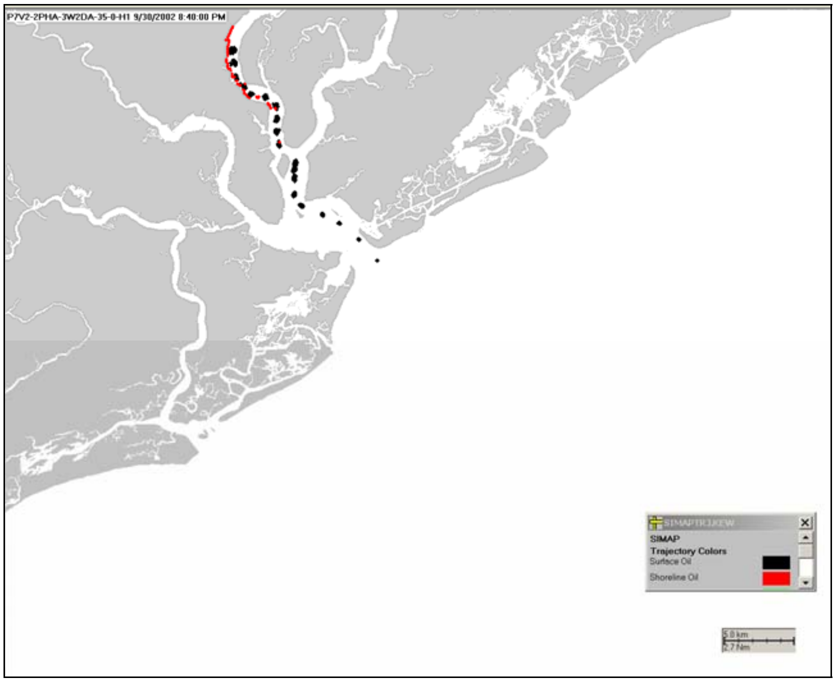

Figure F.2-2. Trajectory of surface oil at 20:40 on 30 September 2002.

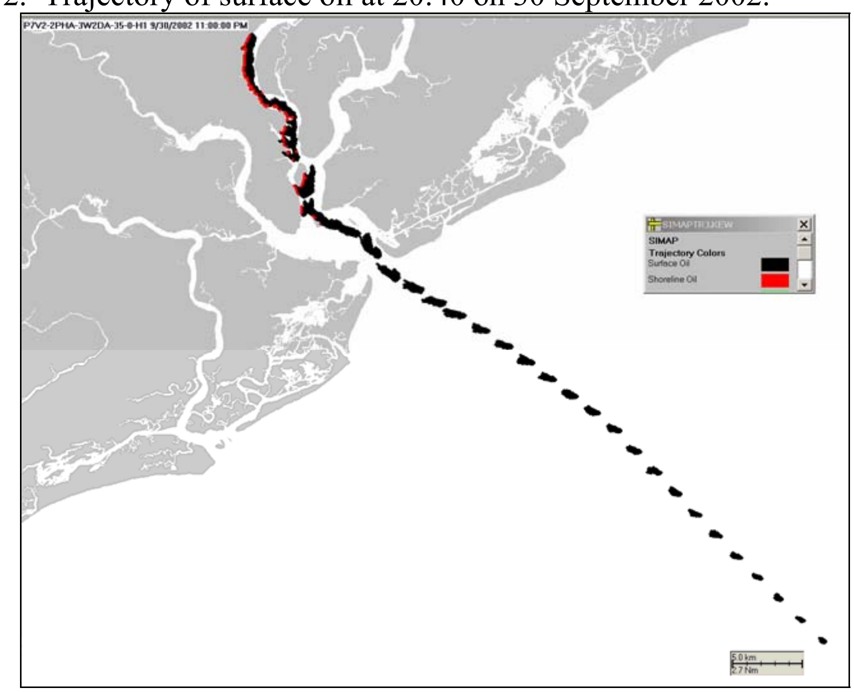

Figure F.2-3. Trajectory of surface oil at 23:00 on 30 September 2002.

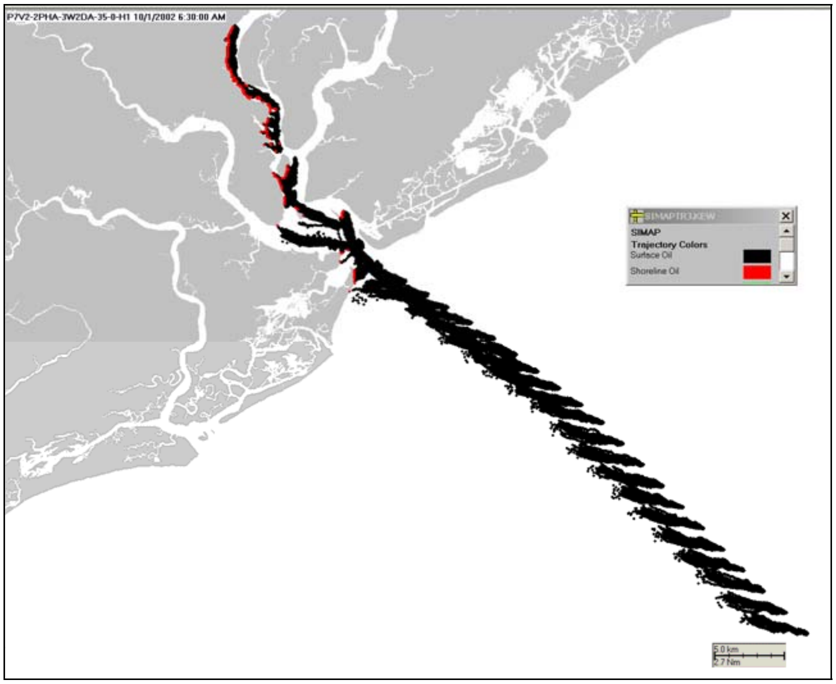

Figure F.2-4. Trajectory of surface oil at 06:30 on 01 October 2002.

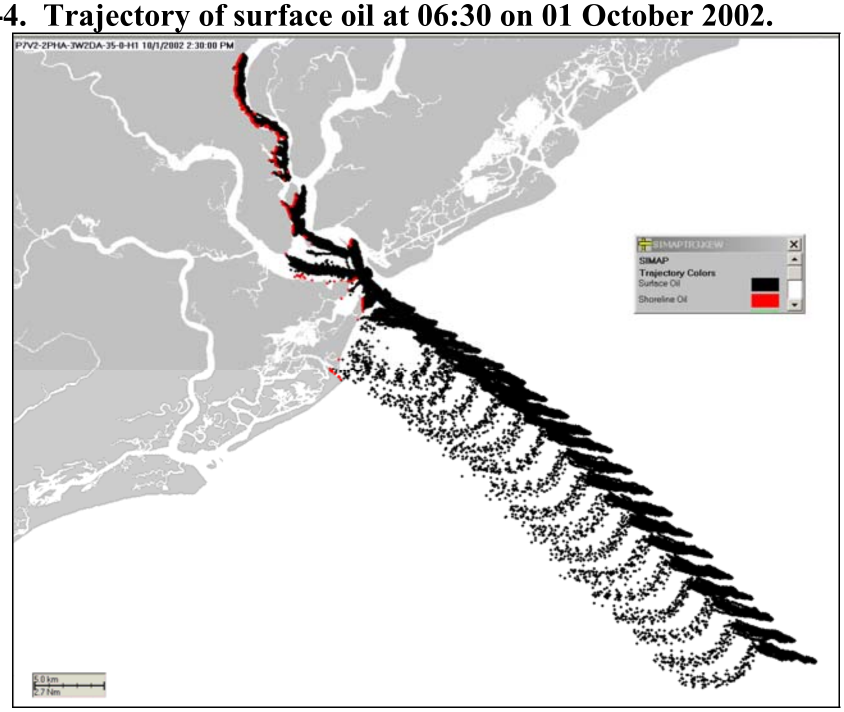

Figure F.2-5. Trajectory of surface oil at 14:30 on 01 October 2002.

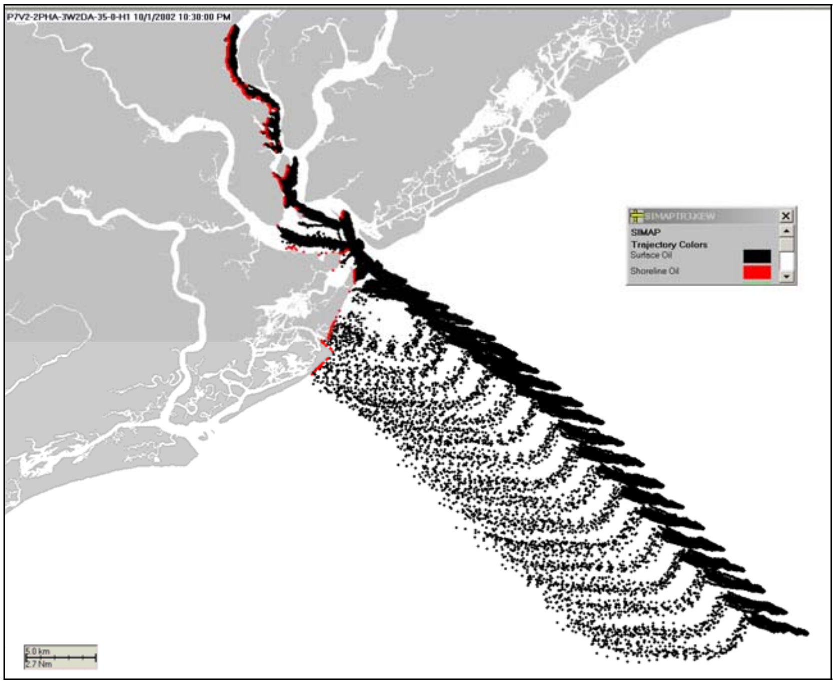

Figure F.2-6. Trajectory of surface oil at 22:30 on 01 October 2002.

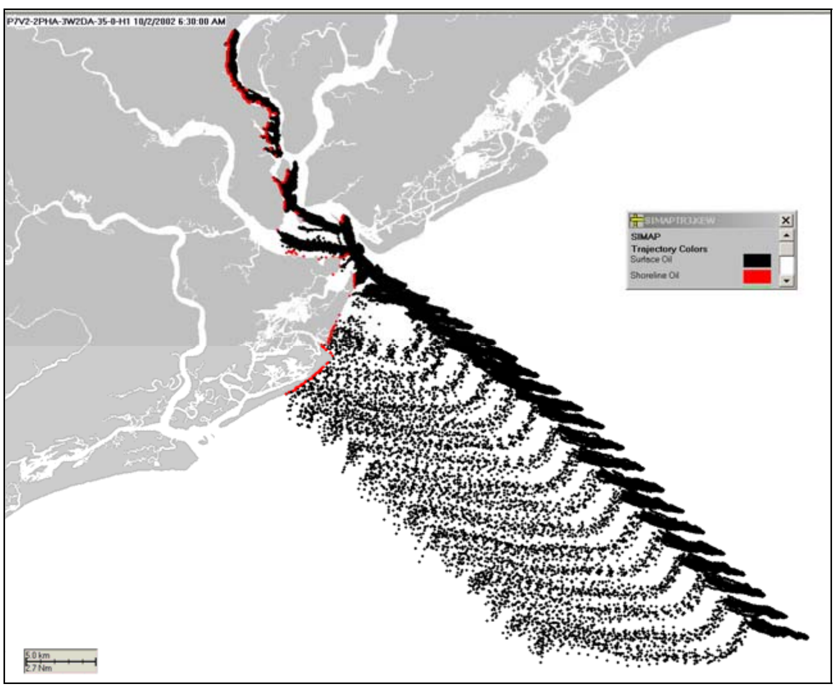

Figure F.2-7. Trajectory of surface oil at 06:30 on 02 October 2002.

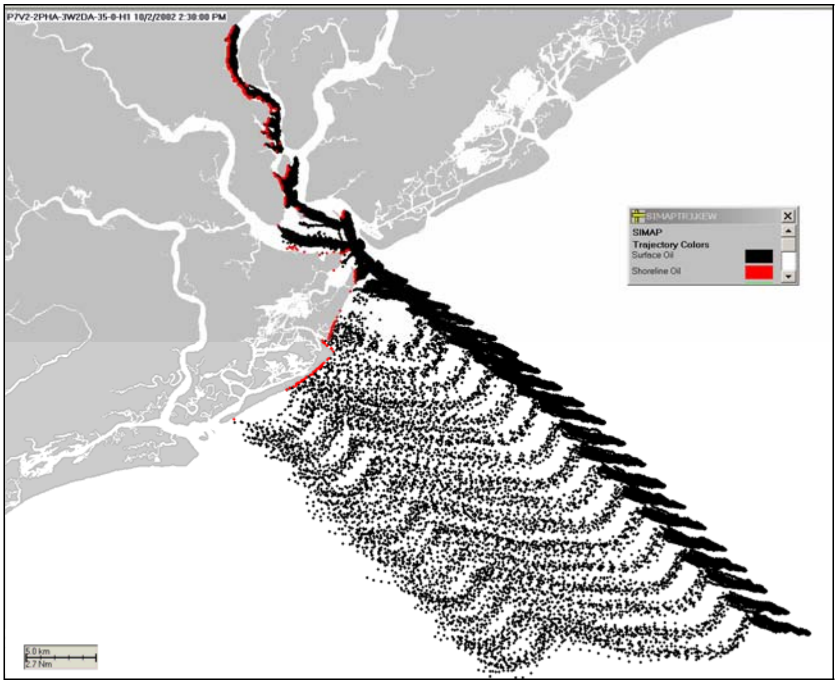

Figure F.2-8. Trajectory of surface oil at 14:30 on 02 October 2002.

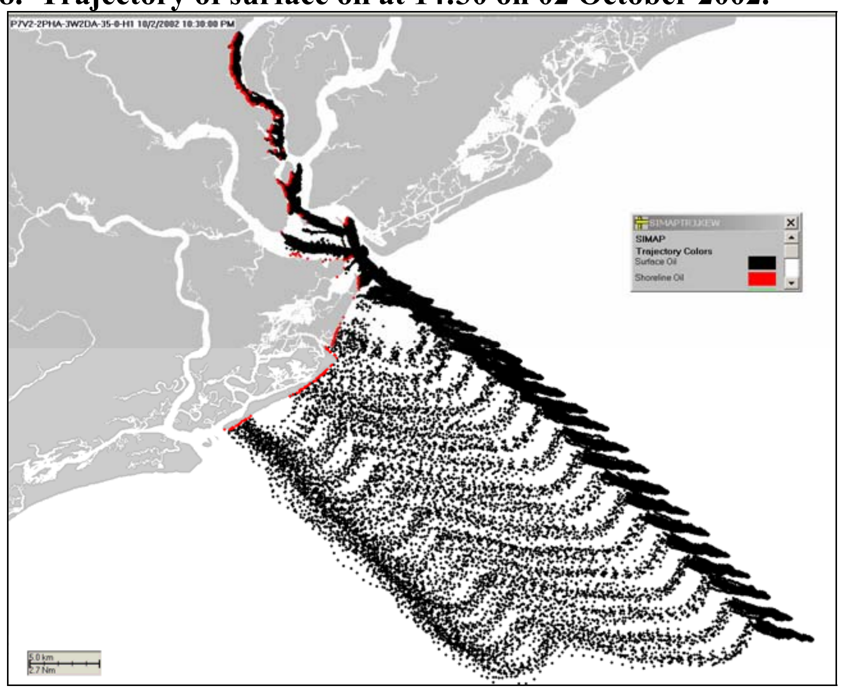

Figure F.2-9. Trajectory of surface oil at 22:30 on 02 October 2002.

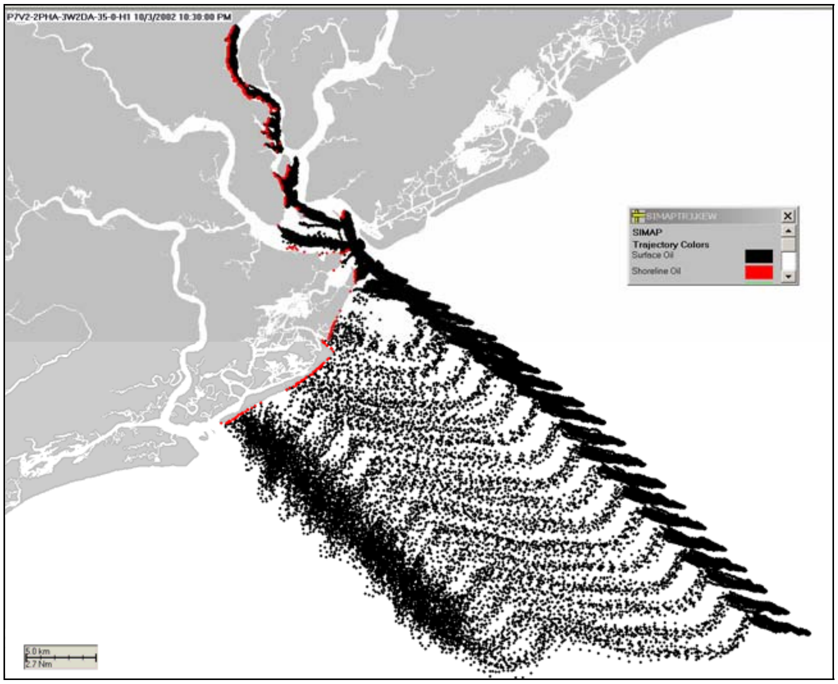

Figure F.2-10. Trajectory of surface oil at 22:30 on 03 October 2002.

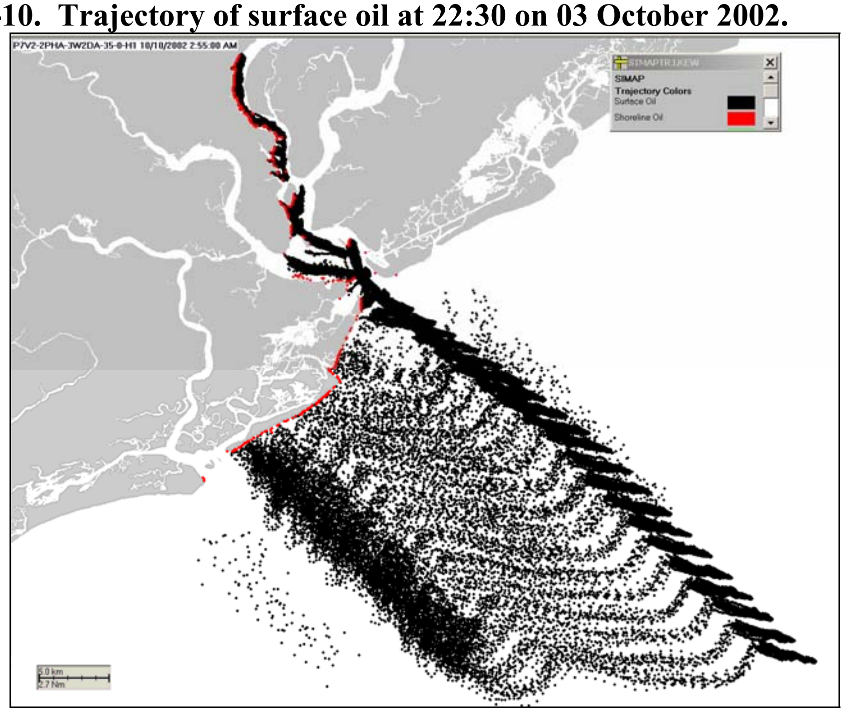

Figure F.2-11. Trajectory of surface oil at end of simulations (02:55 on 10 October 2002).

F.3 Contamination on Shorelines and in Sediments

The following figures show mass of total hydrocarbons remaining on shorelines at the end of the simulations. Sediment contamination was negligible in all the simulations. No shoreline cleanup was simulated in the model. Thus, oil simply accumulates and remains on the shore.

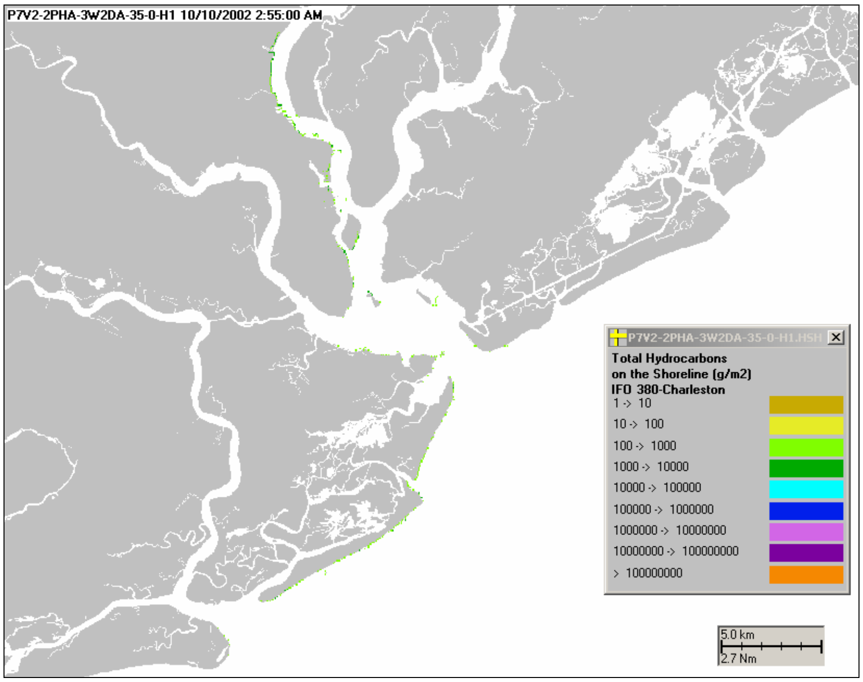

Figure F.3-1. Total hydrocarbons on shorelines for the base case (P7V2-2PHA-3W2DA-35-0-H1).

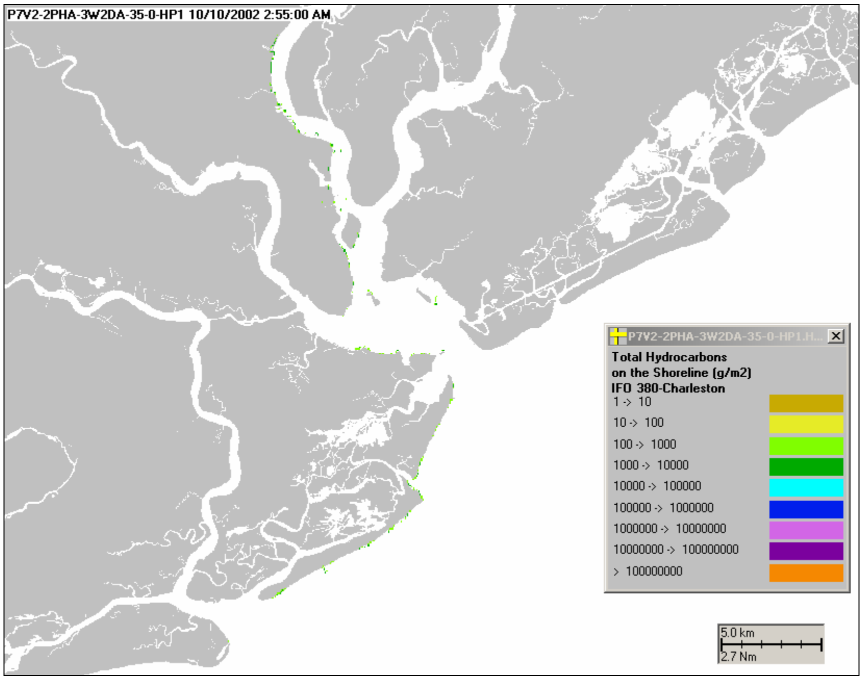

Figure F.3-2. Total hydrocarbons on shorelines for the case with the horizontal diffusion coefficient changed to 0.1 m^2/sec (P7V2-2PHA-3W2DA-35-0-Hp1).

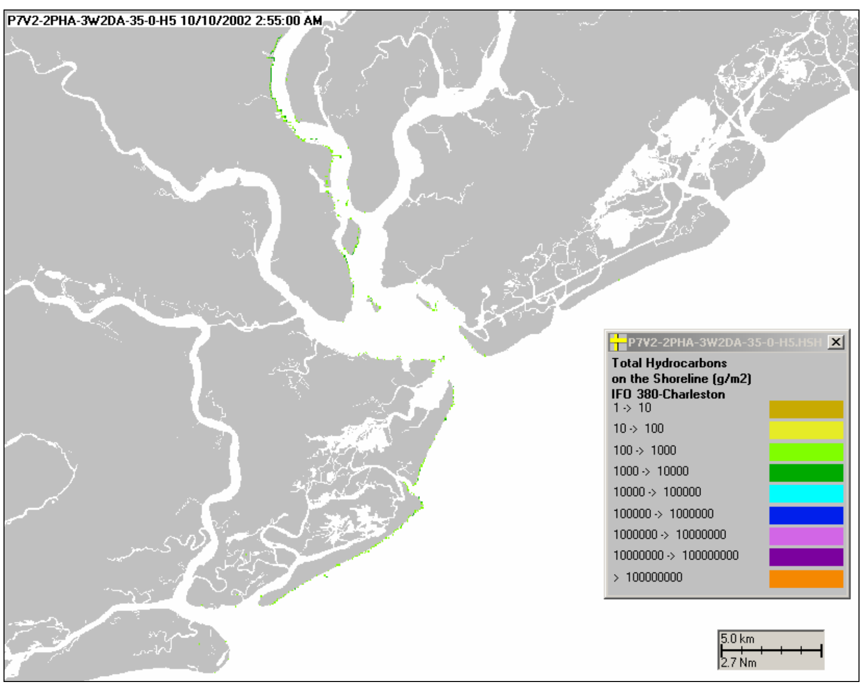

Figure F.3-3. Total hydrocarbons on shorelines for the case with the horizontal diffusion coefficient changed to 5.0 m^2/sec (P7V2-2PHA-3W2DA-35-0-H5).

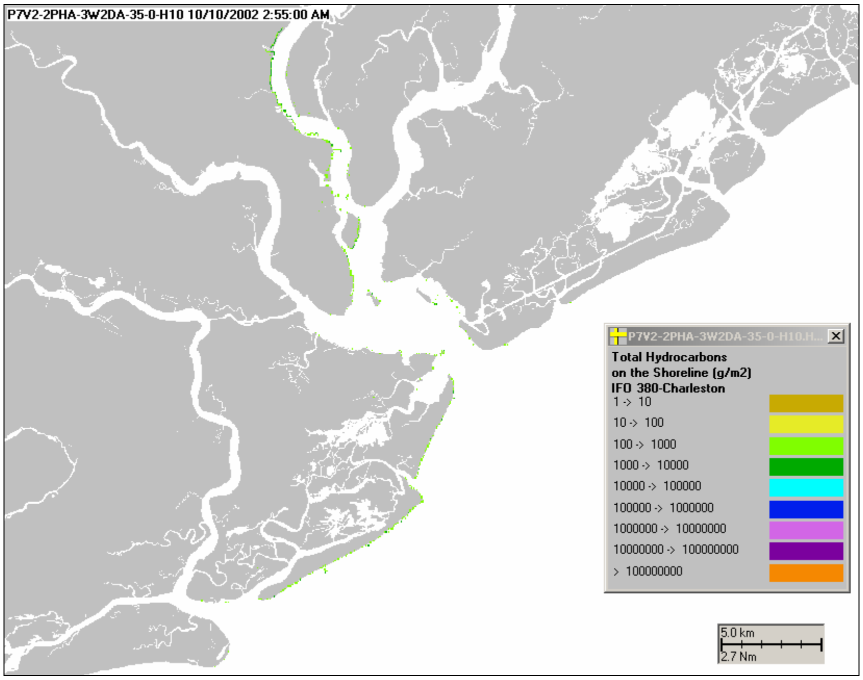

Figure F.3-4. Total hydrocarbons on shorelines for the case with the horizontal diffusion coefficient changed to 10.0 m^2/sec (P7V2-2PHA-3W2DA-35-0-H10).

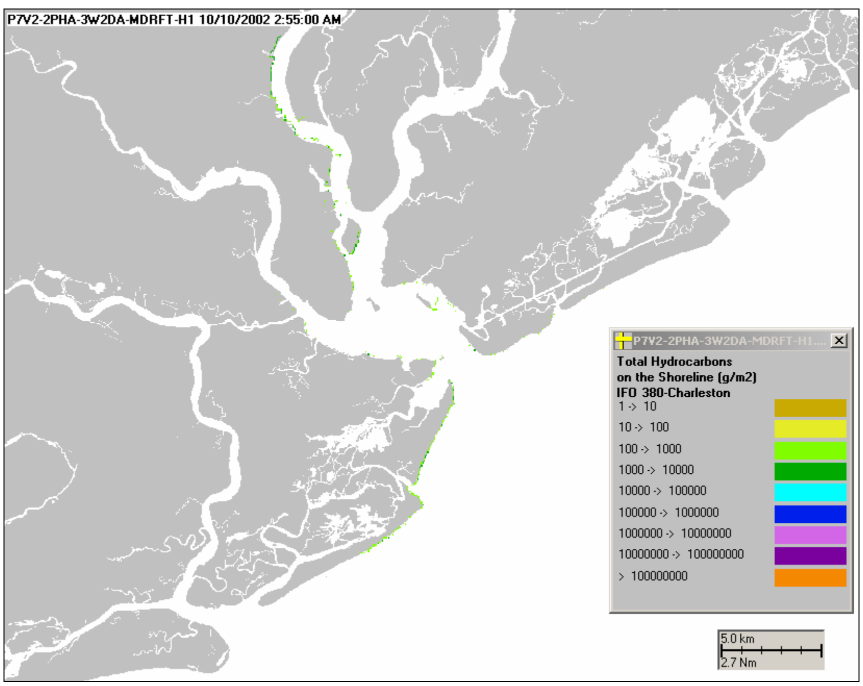

Figure F.3-5. Total hydrocarbons on shorelines for the case with model drift calculated by the model and the horizontal diffusion coefficient 1.0 m^2/sec (P7V2-2PHA-3W2DA-MDRFT-H1).

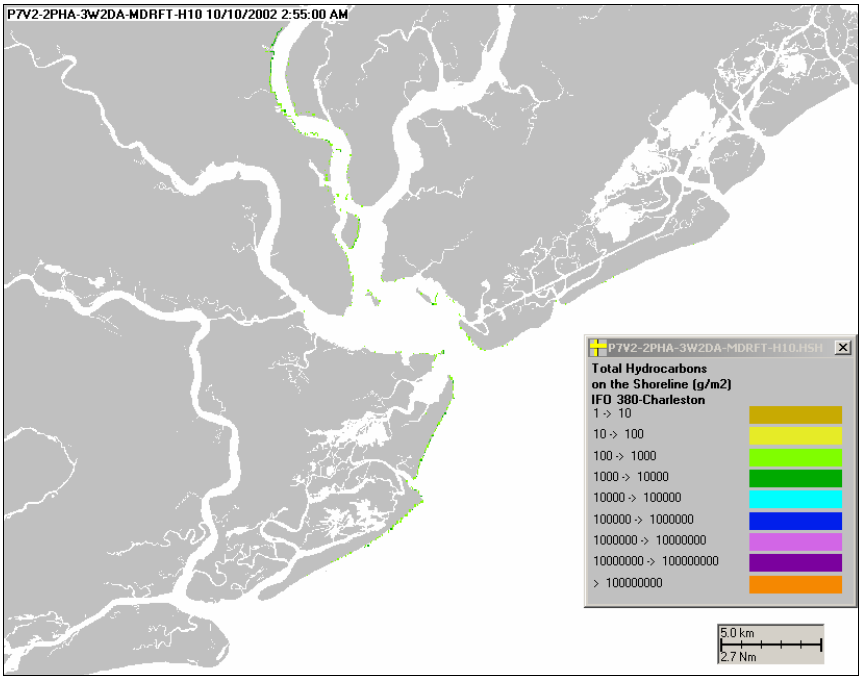

Figure F.3-6. Total hydrocarbons on shorelines for the case with model drift calculated by the model and the horizontal diffusion coefficient 10.0 m^2/sec (P7V2-2PHA-3W2DA- MDRFT-H10).

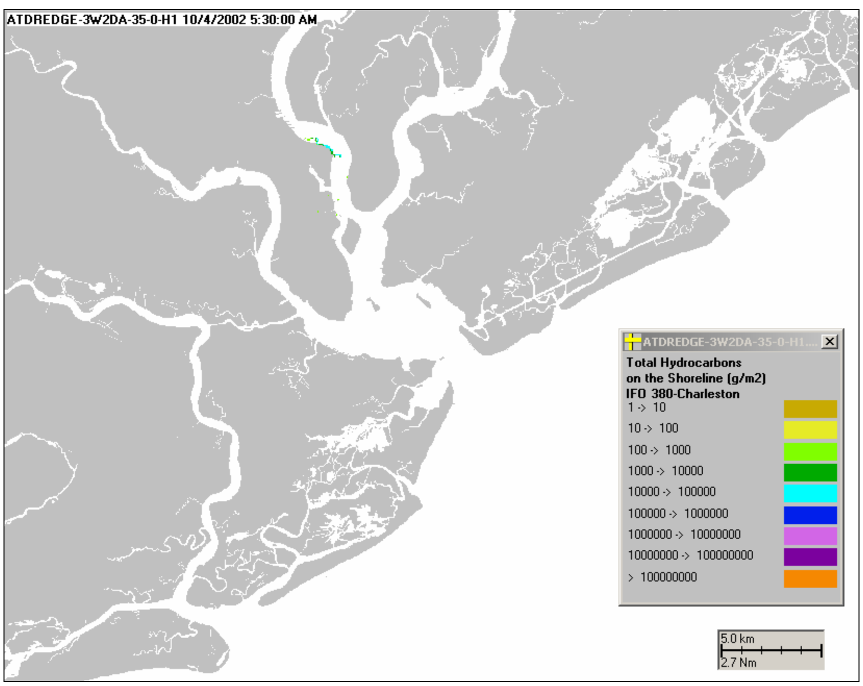

Figure F.3-7. Total hydrocarbons on shorelines for the case where the spill is assumed instantaneous at the submerged dredge site (AtDredge-3W2DA-35-0-H1).

F.4 Floating Oil Distribution

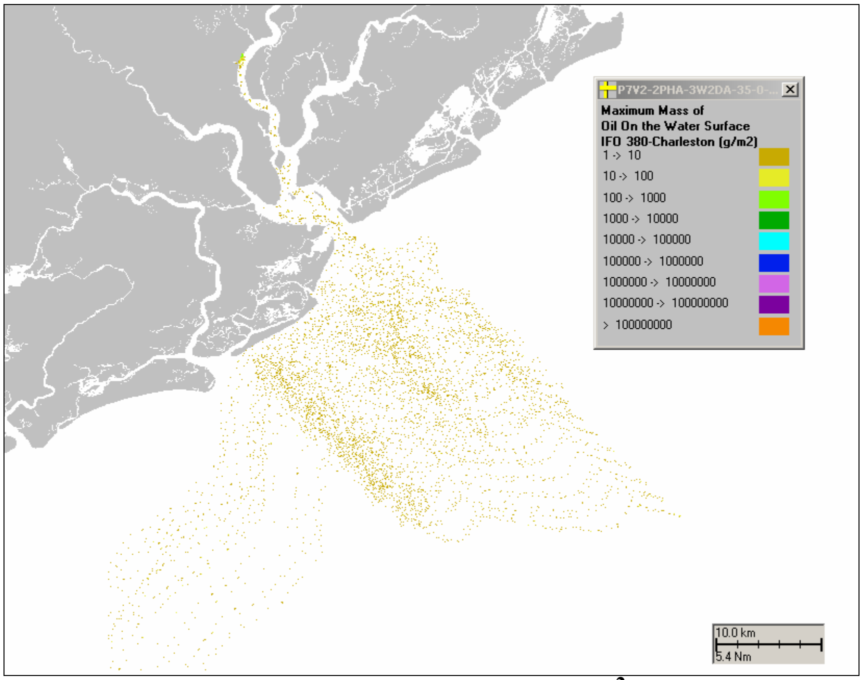

Figure F.4-1. The maximum amount of surface oil (g/m^2) passing through each model grid cell.

APPENDIX G. BIOLOGICAL DATA FOR FISH AND INVERTEBRATES

Biological data used as model inputs are listed in this appendix. Data for fish and invertebrates are in Tables G-1 to G-3. All of the data were obtained from French et al. (1996c) using province 21, for South Carolina coastal waters

Table G-1. Fish and invertebrate densities (kg/km^2) by habitat.

Species group	Habitat	Winter	Spring	Summer	Fall
Atlantic anchovies	Seaward Open Water	29	68	11	27
	Landward Open Water	0.7	24	7	6
	Swd Wetland/Seagrass	0.7	24	7	6
	Seaward Reef	0.7	24	7	6
	Lwd Wetland/Seagrass	0.7	24	7	6
	Landward Reef	0.7	24	7	6
Atlantic mackerel	Seaward Open Water	7	5	2	31
Atlantic menhaden	Landward Open Water	1198	221	9	13
	Swd Wetland/Seagrass	1198	221	9	13
	Seaward Reef	1198	221	9	13
	Lwd Wetland/Seagrass	1198	221	9	13
	Landward Reef	1198	221	9	13
Bay anchovy	Landward Open Water	27	39	4	20
	Swd Wetland/Seagrass	27	39	4	20
	Seaward Reef	27	39	4	20
	Lwd Wetland/Seagrass	27	39	4	20
	Landward Reef	27	39	4	20
Butterfish	Seaward Open Water	186	177	5	20
	Landward Open Water	59	24	12	16
	Swd Wetland/Seagrass	59	24	12	16
	Seaward Reef	59	24	12	16
	Lwd Wetland/Seagrass	59	24	12	16
	Landward Reef	59	24	12	16
Sardines	Seaward Open Water	132	150	10	222
Spanish sardine	Seaward Open Water	3	19	110	219
Striped anchovy	Seaward Open Water	44	1	0	30
	Landward Open Water	9	22	40	107
	Swd Wetland/Seagrass	9	22	40	107
	Seaward Reef	9	22	40	107
	Lwd Wetland/Seagrass	9	22	40	107
	Landward Reef	9	22	40	107
Thread herrings	Landward Open Water	9	26	21	40
	Swd Wetland/Seagrass	9	26	21	40
	Seaward Reef	9	26	21	40
	Lwd Wetland/Seagrass	9	26	21	40
	Landward Reef	9	26	21	40

Atlantic bumper	Seaward Open Water	0	18	392	1
	Landward Open Water	0	315	104	16
	Swd Wetland/Seagrass	0	315	104	16
	Seaward Reef	0	315	104	16
	Lwd Wetland/Seagrass	0	315	104	16
	Landward Reef	0	315	104	16
Atlantic moonfish	Landward Open Water	0	6	13	22
	Swd Wetland/Seagrass	0	6	13	22
	Seaward Reef	0	6	13	22
	Lwd Wetland/Seagrass	0	6	13	22
	Landward Reef	0	6	13	22
Blue runner	Seaward Open Water	0	0	2	0
Bluefish	Seaward Open Water	0	0	0	30
	Landward Open Water	27	77	25	84
	Swd Wetland/Seagrass	27	77	25	84
	Seaward Reef	27	77	25	84
	Lwd Wetland/Seagrass	27	77	25	84
	Landward Reef	27	77	25	84
Scads	Seaward Open Water	29	170	176	484
Cobia	Seaward Open Water	68	37	25	245
Dogfish, general	Seaward Open Water	295	51	0	0
Hakes (similar)	Seaward Open Water	66	56	21	129
King mackerel	Seaward Open Water	98	98	98	98
	Landward Open Water	98	98	98	98
	Swd Wetland/Seagrass	98	98	98	98
	Seaward Reef	98	98	98	98
	Lwd Wetland/Seagrass	98	98	98	98
	Landward Reef	98	98	98	98
Kingfish	Seaward Open Water	26	6	0	9
	Landward Open Water	108	159	402	543
	Swd Wetland/Seagrass	108	159	402	543
	Seaward Reef	108	159	402	543
	Lwd Wetland/Seagrass	108	159	402	543
	Landward Reef	108	159	402	543
Northern searobin	Landward Open Water	0.1	161	102	1
	Swd Wetland/Seagrass	0.1	161	102	1
	Seaward Reef	0.1	161	102	1
	Lwd Wetland/Seagrass	0.1	161	102	1
	Landward Reef	0.1	161	102	1
Silver sea trout	Seaward Open Water	0	0	5	1
	Landward Open Water	11	89	86	406
	Swd Wetland/Seagrass	11	89	86	406
	Seaward Reef	11	89	86	406
	Lwd Wetland/Seagrass	11	89	86	406
	Landward Reef	11	89	86	406

Snappers, general	Seaward Open Water	12	45	28	52
Spanish mackerel	Seaward Open Water	50	50	50	50
	Landward Open Water	25	25	25	25
	Swd Wetland/Seagrass	25	25	25	25
	Seaward Reef	25	25	25	25
	Lwd Wetland/Seagrass	25	25	25	25
	Landward Reef	25	25	25	25
Weakfish	Seaward Open Water	0	0	1	0
	Landward Open Water	84	158	34	98
	Swd Wetland/Seagrass	84	158	34	98
	Seaward Reef	84	158	34	98
	Lwd Wetland/Seagrass	84	158	34	98
	Landward Reef	84	158	34	98
Atlantic croaker	Seaward Open Water	24	8	9	58
	Landward Open Water	3483	348	408	256
	Swd Wetland/Seagrass	3483	348	408	256
	Seaward Reef	3483	348	408	256
	Lwd Wetland/Seagrass	3483	348	408	256
	Landward Reef	3483	348	408	256
Black drum	Seaward Open Water	54	0	0	0
Black sea bass	Seaward Open Water	6	14	3	55
Catfishes, general	Seaward Open Water	0	43	51	23
	Landward Open Water	0	74	406	6
	Swd Wetland/Seagrass	0	74	406	6
	Seaward Reef	0	74	406	6
	Lwd Wetland/Seagrass	0	74	406	6
	Landward Reef	0	74	406	6
Cutlassfishes	Landward Open Water	44	44	101	68
	Swd Wetland/Seagrass	44	44	101	68
	Seaward Reef	44	44	101	68
	Lwd Wetland/Seagrass	44	44	101	68
	Landward Reef	44	44	101	68
Drums, general	Landward Open Water	5	139	373	48
	Swd Wetland/Seagrass	5	139	373	48
	Seaward Reef	5	139	373	48
	Lwd Wetland/Seagrass	5	139	373	48
	Landward Reef	5	139	373	48
Flatfish	Landward Open Water	42	125	40	359
	Swd Wetland/Seagrass	42	125	40	359
	Seaward Reef	42	125	40	359
	Lwd Wetland/Seagrass	42	125	40	359
	Landward Reef	42	125	40	359

Flounders	Seaward Open Water	53	68	56	40
	Landward Open Water	4	8	38	11
	Swd Wetland/Seagrass	4	8	38	11
	Seaward Reef	4	8	38	11
	Lwd Wetland/Seagrass	4	8	38	11
	Landward Reef	4	8	38	11
Fringed flounder	Landward Open Water	15	11	46	43
	Swd Wetland/Seagrass	15	11	46	43
	Seaward Reef	15	11	46	43
	Lwd Wetland/Seagrass	15	11	46	43
	Landward Reef	15	11	46	43
Groupers, general	Seaward Open Water	0	0	23	0
Grunts, general	Seaward Open Water	24	24	6	124
Hogchoker	Landward Open Water	0.9	95	38	48
	Swd Wetland/Seagrass	0.9	95	38	48
	Seaward Reef	0.9	95	38	48
	Lwd Wetland/Seagrass	0.9	95	38	48
	Landward Reef	0.9	95	38	48
Lizardfish	Seaward Open Water	56	152	103	114
Porgies=sparids,gen	Seaward Open Water	189	951	340	1174
Rays, general	Seaward Open Water	2406	4584	1708	1134
Rock sea bass	Landward Open Water	4	10	69	59
	Swd Wetland/Seagrass	4	10	69	59
	Seaward Reef	4	10	69	59
	Lwd Wetland/Seagrass	4	10	69	59
	Landward Reef	4	10	69	59
Sand perch	Seaward Open Water	48	112	105	57
Spot	Seaward Open Water	88	52	15	48
	Landward Open Water	3864	6127	1257	1090
	Swd Wetland/Seagrass	3864	6127	1257	1090
	Seaward Reef	3864	6127	1257	1090
	Lwd Wetland/Seagrass	3864	6127	1257	1090
	Landward Reef	3864	6127	1257	1090
Triggerfish	Seaward Open Water	280	488	135	237
Windowpane flounder	Landward Open Water	6	82	62	47
	Swd Wetland/Seagrass	6	82	62	47
	Seaward Reef	6	82	62	47
	Lwd Wetland/Seagrass	6	82	62	47
	Landward Reef	6	82	62	47
Blue crab	Seaward Open Water	55.5	95	0	204
	Landward Open Water	0	95	7965	204
	Swd Wetland/Seagrass	0	95	7965	204
	Seaward Reef	0	95	7965	204
	Lwd Wetland/Seagrass	0	95	7965	204
	Landward Reef	0	95	7965	204

Brown shrimp	Seaward Open Water	1.7	0.6	13.1	12.2
	Landward Open Water	1.7	0.6	13.1	12.2
	Swd Wetland/Seagrass	1.7	0.6	13.1	12.2
	Seaward Reef	1.7	0.6	13.1	12.2
	Lwd Wetland/Seagrass	1.7	0.6	13.1	12.2
	Landward Reef	1.7	0.6	13.1	12.2
Pink shrimp	Seaward Open Water	0.3	0.3	0.4	0.4
Stone crab	Seaward Open Water	0.4	0.4	0.4	0.4
	Landward Open Water	0.4	0.4	0.4	0.4
	Swd Wetland/Seagrass	0.4	0.4	0.4	0.4
	Seaward Reef	0.4	0.4	0.4	0.4
	Lwd Wetland/Seagrass	0.4	0.4	0.4	0.4
	Landward Reef	0.4	0.4	0.4	0.4
White shrimp	Seaward Open Water	1.1	7.2	10.8	1.6
	Landward Open Water	1.1	7.2	10.8	1.6
	Swd Wetland/Seagrass	1.1	7.2	10.8	1.6
	Seaward Reef	1.1	7.2	10.8	1.6
	Lwd Wetland/Seagrass	1.1	7.2	10.8	1.6
	Landward Reef	1.1	7.2	10.8	1.6
Squid, general	Seaward Open Water	0.2	0.2	0.2	0.2
	Landward Open Water	0.2	0.2	0.2	0.2
	Swd Wetland/Seagrass	0.2	0.2	0.2	0.2
	Seaward Reef	0.2	0.2	0.2	0.2
	Lwd Wetland/Seagrass	0.2	0.2	0.2	0.2
	Landward Reef	0.2	0.2	0.2	0.2
Bay scallop	Landward Open Water	12.1	12.1	12.1	12.1
	Swd Wetland/Seagrass	12.1	12.1	12.1	12.1
	Seaward Reef	12.1	12.1	12.1	12.1
	Lwd Wetland/Seagrass	12.1	12.1	12.1	12.1
	Landward Reef	12.1	12.1	12.1	12.1
Conchs, whelks, gen.	Seaward Open Water	5.7	5.7	5.7	5.7
	Landward Open Water	5.7	5.7	5.7	5.7
	Swd Wetland/Seagrass	5.7	5.7	5.7	5.7
	Seaward Reef	5.7	5.7	5.7	5.7
	Lwd Wetland/Seagrass	5.7	5.7	5.7	5.7
	Landward Reef	5.7	5.7	5.7	5.7
Hard clams, general	Landward Open Water	1000	1000	1000	1000
	Swd Wetland/Seagrass	1000	1000	1000	1000
	Seaward Reef	1000	1000	1000	1000
	Lwd Wetland/Seagrass	1000	1000	1000	1000
	Landward Reef	1000	1000	1000	1000

Octopus, general	Seaward Open Water	0.4	0.4	0.4	0.4
	Landward Open Water	0.4	0.4	0.4	0.4
	Swd Wetland/Seagrass	0.4	0.4	0.4	0.4
	Seaward Reef	0.4	0.4	0.4	0.4
	Lwd Wetland/Seagrass	0.4	0.4	0.4	0.4
	Landward Reef	0.4	0.4	0.4	0.4
Total all species	Seaward Open Water	4338.3	7556.8	3521	4936.9
	Landward Open Water	10145.3	9628.601	12827.7	4766.6
	Swd Wetland/Seagrass	10145.3	9628.601	12827.7	4766.6
	Seaward Reef	10145.3	9628.601	12827.7	4766.6
	Lwd Wetland/Seagrass	10145.3	9628.601	12827.7	4766.6
	Landward Reef	10145.3	9628.601	12827.7	4766.6

Table G-2. Fish and invertebrate young-of-the-year densities (# age-1 equivalents/km^2) by habitat, as seasonal means.

Species group	Habitat	Winter	Spring	Summer	Fall
Bay anchovy	Seaward Open Water	530.43	440.9	165.4	255.83
	Landward Open Water	310.7	786.03	2249.33	1769
Cobia	Seaward Open Water	4.52	3.93	5.53	4.61
	Landward Open Water	4.52	3.32	2.9	4.38
Spanish mackerel	Landward Open Water	2.12	2.12	2.12	2.12
Weakfish	Landward Open Water	704.8	704.73	704.77	704.8
Black sea bass	Seaward Open Water	6.01	42.2	2.86	0
	Landward Open Water	296.5	140.25	324.9	324.9
	Swd Wetland/Seagrass	296.5	140.25	324.9	324.9
	Seaward Reef	296.5	140.25	324.9	324.9
	Lwd Wetland/Seagrass	296.5	140.25	324.9	324.9
	Landward Reef	296.5	140.25	324.9	324.9
Grunts, general	Seaward Open Water	173.76	173.76	173.76	173.76
Spot	Seaward Open Water	4.85	1.52	0	3.3
	Landward Open Water	311.7	417.63	466.2	361.07
Blue crab	Seaward Open Water	43.72	305.6	308	165.91
	Landward Open Water	52873.34	45362.04	45294	49371.53
Stone crab	Seaward Open Water	0	97.57	114.8	54.19
	Landward Open Water	4637	4118.67	4027	4349
White shrimp	Seaward Open Water	174.07	125	177.33	192.8
	Landward Open Water	16.17	58.49	13.35	0
	Swd Wetland/Seagrass	16.17	58.49	13.35	0
	Seaward Reef	16.17	58.49	13.35	0
	Lwd Wetland/Seagrass	16.17	58.49	13.35	0
	Landward Reef	16.17	58.49	13.35	0
Bay scallop	Landward Open Water	320	320	319.95	319.93
Total all species	Seaward Open Water	937.36	1190.48	947.67	850.41
	Landward Open Water	59476.84	51913.28	53404.52	57206.74
	Swd Wetland/Seagrass	312.67	198.74	338.25	324.9
	Seaward Reef	312.67	198.74	338.25	324.9
	Lwd Wetland/Seagrass	312.67	198.74	338.25	324.9
	Landward Reef	312.67	198.74	338.25	324.9

Table G-3. Fish and invertebrate life history parameters.
(M = annual instantaneous natural mortality rate, F = annual instantaneous fishing mortality rate; YrRecr = age of recruitment (yr), Life = maximum age (yrs); Lmax, K, to = von Bertallanfy parameters; a,b =wt(kg)-L(cm) parameters; kg-max = maximum weight in kg)

Species group	M	F	YrRecr	Life	Lmax(cm)	K	to	a	b	kg-max
Atlantic anchovies	1.5	1	1	3	12	0.28	-1.1	0	2.81	0.012
Atlantic mackerel	0.15	0.02	2	20	42.9	0.36	-1.14	0	3.21	0.695
Atlantic menhaden	1.1	0.43	2	4	23.8	0.493	-0.385	0	3.25	0.286
Bay anchovy	1.5	1	1	3	12	0.28	-1.1	0	2.81	0.012
Butterfish	0.1	0.2	3	20	50	0.1	0.1	0	3	0.125
Sardines	1	0.13	1	13	29	0.45	0	0	3	0.146
Spanish sardine	1	0.13	1	13	29	0.45	0	0	3	0.146
Striped anchovy	1.5	1	1	3	12	0.28	-1.1	0	2.81	0.012
Thread herrings	1	0.13	1	13	29	0.45	0	0	3	0.146
Atlantic bumper	0.2	0.4	2	10	165	0.173	-0.653	0	2.84	57.749
Atlantic moonfish	0.2	0.4	2	10	165	0.173	-0.653	0	2.84	57.749
Blue runner	0.2	0.4	2	10	165	0.173	-0.653	0	2.84	57.749
Bluefish	0.35	0.35	1	9	94.4	0.18	-1.033	0	2.99	11.575
Scads	0.2	0.4	2	10	165	0.173	-0.653	0	2.84	57.749
Cobia	0.4	0.3	2	10	143	0.253	0.07	0	3.09	36.566
Dogfish, general	0.05	0.08	1	28	96	0.093	0	0	3.15	3.334
Hakes (similar)	0.4	0.56	2	15	50.7	0.246	0	0	3.1	7.681
King mackerel	0.51	0.29	2	7	67.2	0.328	-1.085	0	3.06	3.633
Kingfish	0.45	0.24	3	5	77.4	0.09	-2.54	0	3.11	4.489
Northern searobin	0.1	0.2	3	20	50	0.1	0.1	0	3	0.125
Silver sea trout	0.45	0.24	3	5	77.4	0.09	-2.54	0	3.11	4.489
Snappers, general	0.2	0.53	2	13	58.2	0.076	-1.268	0	2.93	2.314
Spanish mackerel	0.51	0.29	2	7	67.2	0.328	-1.085	0	3.06	3.633
Weakfish	0.45	0.24	3	5	77.4	0.09	-2.54	0	3.11	4.489
Atlantic croaker	0.15	0.86	2	27	105.3	0.29	-0.636	0	3.05	15.768

Black drum	0.15	0.86	2	27	105.3	0.29	-0.636	0	3.05	15.768
Black sea bass	0.3	0.3	1	10	35	0.222	0.186	0	3.02	1.289
Catfishes, general	0.1	0.2	3	20	50	0.1	0.1	0	3	0.125
Cutlassfishes	0.1	0.2	3	20	50	0.1	0.1	0	3	0.125
Drums, general	0.15	0.86	2	27	105.3	0.29	-0.636	0	3.05	15.768
Flatfish	0.1	0.3	2	9	146.1	0.031	0.137	0	2.95	67.085
Flounders	0.1	0.3	2	9	146.1	0.031	0.137	0	2.95	67.085
Fringed flounder	0.1	0.3	2	9	146.1	0.031	0.137	0	2.95	67.085
Groupers, general	0.3	0.3	1	10	35	0.222	0.186	0	3.02	1.289
Grunts, general	0.6	0.4	1	11	47.5	0.164	-1.144	0	3.06	1.729
Hogchoker	0.1	0.3	2	9	146.1	0.031	0.137	0	2.95	67.085
Lizardfish	0.1	0.2	3	20	50	0.1	0.1	0	3	0.125
Porgies=sparids,gen	0.2	0.3	5	20	76.3	0.096	-1.88	0	2.89	5.46
Rays, general	0.1	0.2	3	20	50	0.1	0.1	0	3	0.125
Rock sea bass	0.3	0.3	1	10	35	0.222	0.186	0	3.02	1.289
Sand perch	0.3	0.3	1	10	35	0.222	0.186	0	3.02	1.289
Spot	0.15	0.86	2	27	105.3	0.29	-0.636	0	3.05	15.768
Triggerfish	0.1	0.2	3	20	50	0.1	0.1	0	3	0.125
Windowpane flounder	0.1	0.3	2	9	146.1	0.031	0.137	0	2.95	67.085
Blue crab	0.1	2.3	1	3	24	0.75	0	0	2.71	0.644
Brown shrimp	3.3	3.2	1	1	19.6	2.4	0	0	3.21	0.094
Pink shrimp	3.3	3.2	1	1	19.6	2.4	0	0	3.21	0.094
Stone crab	0.7	0.3	3	7	14	0.173	-0.397	0	3.3	0.012
White shrimp	3.3	3.2	1	1	19.6	2.4	0	0	3.21	0.094
Squid, general	0.3	0.1	1	1	28.5	0.7	0	0	2.29	0.73
Bay scallop	0.1	1	1	2	6.4	1.95	0.058	0	2.93	0.041
Conchs, whelks, gen.	0.1	0.2	3	20	50	0.1	0.1	0	3	0.125
Hard clams, general	0.1	0.3	3	20	8.5	0.333	0.594	0	2.83	0.066
Octopus, general	0.1	0.2	3	20	50	0.1	0.1	0	3	0.125

Appendix D- Signed FONSI Determination

DETERMINATION

In view of the information presented in the supporting Restoration Plan and Environmental Assessment prepared for the Noisette Creek Golf Course Wetland Restoration in North Charleston, South Carolina it is hereby determined that the preferred alternative identified for implementation will not significantly impact the quality of the human environment as described in the EA. In addition, all beneficial and adverse impacts of the proposed action have been addressed to reach the conclusion of no significant impacts. Accordingly, preparation of an Environmental Impact Statement for this action is not necessary.

Brian T. Pawlak
Acting Director, Office of Habitat Conservation
NOAA National Marine Fisheries Service

3/7/2012
Date