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VOLUME 3 of 3:

DRAFT
ENVIRONMENTAL IMPACT STATEMENT
ON THE EXPANSION OF THE

Strategic Petroleum Reserve

Alabama, Louisiana, Mississippi, and Texas

VOLUME 3 OF 3:
TECHNICAL APPENDICES

October 1992

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APPENDIX A

PUBLIC SCOPING PROCESS AND MEETINGS HELD WITH REGULATORY AGENCIES

A major objective of the NEPA process is to allow opportunities for interested and affected parties (e.g., the public and state and Federal agencies) to provide substantive information and to express opinions about the proposed action. To facilitate this process, DOE held two public scoping meetings and a series of meetings with Federal and state agencies. This appendix provides an overview of DOE's activities, including lists of attendees at regulatory meetings. The Implementation Plan for the Environmental Impact Statement on the Strategic Petroleum Reserve Expansion provides more details on the public scoping process, including a summary of comments received. For more information on regulatory considerations, see section 8.1 of this DEIS for a summary of regulations and Chapter 13 for a listing of required consultations.

A.1 Description of the Scoping Process

In compliance with Council on Environmental Quality regulations, DOE conducted the following scoping activities. On May 3, 1991, DOE published a Notice of Intent (NOI) to Prepare an Environmental Impact Statement in the Federal Register (56 FR 20417) for the Proposed Expansion of the Strategic Petroleum Reserve. Also in May, DOE published a fact sheet entitled "Site Selection for Proposed SPR Expansion: Information and Opportunities for Public Involvement." Both documents invited written comments until June 17, 1991, and announced two public scoping meetings to provide information to the public on the proposed action and to elicit input from the public (both oral and written comments) regarding sensitive issues and concerns. DOE distributed fact sheets to news media in the potentially affected areas, state and Federal agencies, local, state, and Federal government representatives, environmental groups, selected industries, local libraries, and concerned individuals. DOE also published a public notice announcing the scoping meetings in the New Orleans Times Picayune and the Houston Chronicle newspapers.

DOE held two public scoping meetings:

- June 4, 1991; 7:00 p.m.
  Music Theater
  Center for Arts and Sciences
  400 College Drive
  Lake Jackson, TX

- June 6, 1991; 7:00 p.m.
  Gouaux Hall
  Madewood Drive
  Nicholls State University
  Thibodaux, LA

There were a total of 28 commenters during the scoping period. Twelve people spoke at the scoping meeting in Lake Jackson, and three people spoke at the Thibodaux meeting. Sixteen written comments were received. Three people commented both orally and in writing. Several questions were submitted in writing and answers were included in the Implementation Plan.

Table A.1-1 presents a breakdown of the types of organizations and individuals that commented and the number of fact sheets distributed to each type of organization or individual during the scoping period.

Table A.1-1
Types of Organizations and Individuals Commenting

Type of Organization/Individual	Number of Fact Sheets Distributed	Number of commenters
Federal Agencies	14	8
U.S. Senators & Representatives	16	1
State Agencies	15	1
State Legislators	62	1
Local Government	25	2
Environmental Groups	20	3
Industry/Commercial Associations/Unions	11	8
Chambers of Commerce	0	4
Individuals	3	2

Table A.1-2 summarizes the comments received by subject matter. In this table, a commenter is tallied only once under each applicable subject heading, even if the commenter made several different points related to the subject. The Implementation Plan provides a detailed summary of the oral and written comments received during the scoping period. Most of the commenters urged the selection or elimination of a particular site. Many of these comments were based on socioeconomic concerns. Other commenters focused on potential environmental consequences of SPR expansion or specific aspects of SPR operations.

Table A.1-2
Summary of Comments Received

Subject	Number of Comments
Alternatives	
Big Hill	12
Boling	3
Hawkinsville	5
Stratton Ridge	9
Napoleonville	1
Weeks Island	1
Environmental Consequences	
Wetlands	9
Aquatic life	6
Geology	4
Water quality	3
Mineral resources	1
Socioeconomics	
Effects on industry (positive and/or negative)	9
Employment	10
Tax revenue	3
Property ownership	5
Economic impacts on the community	10
SPR Cost	1
Recreation resources	1
Historical and Archeological Resources	1
Scoping Process	2
SPR Operations and Facilities	
Brine disposal	7
Pipelines (including installation)	7
Water control structures	1
Other	1

A.2 State and Federal Consultation Meetings

Since the issuance of the NOI, DOE has held a series of meetings with representatives of state (i.e., Alabama, Louisiana, Mississippi, and Texas) and Federal agencies. At these meetings, DOE has received technical information and has solicited agency input. Information received has been considered in the development of this DEIS. In some instances, the proposed action has been altered to address the concerns expressed (e.g., pipeline routings have been changed to avoid environmentally sensitive areas). Meetings are presented by location in chronological order. The organizational affiliation of each attendee is followed by a list of the issues discussed.

A.2.1 Dallas, Texas, September 17, 1991

Name	Organization
Norm Sears	U.S. Environmental Protection Agency (EPA) - Region VI
Carl Townsend	EPA - Region VI
James T. Highland	EPA - Region VI
Bill Nully	EPA - Region VI
Mike Jansky	EPA - Region VI
Wes McQuiddy	EPA - Region VI
Mac Weaver	EPA - Region VI
Brian Burgess	EPA - Region VI
Ken Holley	EPA - Region VI
Bob Hiller	EPA - Region VI
Meritt Nicewander	EPA - Region VI
Stanley M. Spruiell	EPA - Region VI
Rick Hartman	National Marine Fisheries Service, Baton Rouge, LA
Bruce Bennett	US Army Corps of Engineers, Galveston, TX
William Jackson	National Marine Fisheries Service, Galveston, TX
Hal Delaplane	DOE, Washington, DC
Melissa W. Smith	DOE, New Orleans, LA
Sid Evans	DOE, New Orleans, LA
David Brine	DOE, New Orleans, LA
Deb Shaver	ICF Inc.
Jean Hoff	ICF Inc.
Steve Wyngarden	ICF Inc.

Issues:

- General overview of the SPR expansion plan, including an overview of the proposed action, the potential environmental impacts, and the EIS schedule
- Federal agency concerns on wetlands, ocean discharge, air and underground injection permitting requirements

A.2.2 Austin, Texas, November 6, 1991

Name	Organization
Richard Lynn Benefield	Texas Parks and Wildlife Department
Steve Hagle	Texas Air Control Board
Bruce A. Moultas	Texas Water Commission
Jeff Saitas	Texas Air Control Board
Tom Calnan	Texas General Land Office
Richard Ginn	Texas Railroad Commission
Larry Hannesschlager	Texas Railroad Commission
Jill Hybner	Texas Railroad Commission
Guy Cleveland	Texas Railroad Commission
Dan Prikryl	Texas Historical Commission
Fred Heller	South East Texas Regional Planning Commission
Dan Beckett	Texas Water Commission
Eddie Seidensticker	Soil Conservation Service
Hal Delaplane	DOE, Washington, DC
Deb Shaver	ICF Inc.
Jean Huff	ICF Inc.
Nancy O'Connor	ICF Inc.

Issues:

- General overview of the SPR expansion plan, including an overview of the proposed action, the potential environmental impacts, and the EIS schedule
- Follow-up discussion held regarding archeological and cultural resources with Dan Prikryl, DOE, and ICF

A.2.3 Austin, Texas, November 8, 1991

Name	Organization
Kimberly McKenna	Texas General Land Office
Dave Hyatt	Texas General Land Office
Christine Ritter	Texas General Land Office
Tom Calnan	Texas General Land Office
Lore Hantske	Texas General Land Office
Bruce Smith	Texas General Land Office
Hal Delaplane	DOE, Washington, DC
Deb Shaver	ICF Inc.
Jean Hoff	ICF Inc.
Nancy O'Connor	ICF Inc.

Issues:

- Brine disposal history, past impacts, and considerations
- Big Hill to East Houston pipeline routes, including wetlands and sensitive areas

A.2.4 Baton Rouge, Louisiana, November 18, 1991

Name	Organization
Bill Pittman	Louisiana Department of Natural Resources
Mike Windham	Louisiana Department of Wildlife & Fisheries (LA DWF)
Pete Juneau	LA DWF
Fred Dunham	LA DWF
Kerry Higgins	Louisiana Department of Environmental Quality (LA DEQ)
James Little	LA DEQ
Brian J. Harder	Louisiana Geological Survey
Vic Blanchard	LA DWF
Celeste Bonneeaze	LA DEQ
Sharon Ghiold	LA DEQ
Terry Rabot	US Fish and Wildlife Service
Richard Martin	LA DWF
Duke Rivet	Louisiana State Historic Preservation Office
Hal Delaplane	DOE, Washington, DC
Sid Evans	DOE, New Orleans, LA

Name	Organization
Deb Shaver	ICF Inc.
Rosemary Wisniewski	ICF Inc.
Rick Zeroka	ICF Inc.

Issues:

- General overview of the SPR expansion plan, including an overview of the proposed action, the potential environmental impacts, and the EIS schedule
- Location of oyster seed and lease areas and routing pipelines to avoid these areas
- Mitigation considerations if pipelines would impact oyster areas
- Pipeline routes through wetlands and Vermilion Bay

A.2.5 Baton Rouge, Louisiana, November 19, 1991

Name	Organization
Fred Dunham	LA DWF
Hal Delaplane	DOE, Washington, DC
Deb Shaver	ICF Inc.
Rosemary Wisniewski	ICF Inc.
Rick Zeroka	ICF Inc.

Issues:

- Location of oyster seed areas and other sensitive environments

A.2.6 Houston, Texas, December 5, 1991

Name	Organization
Bruce Smith	Texas General Land Office
Richard L. Benefield	Texas Parks and Wildlife Department
Andrew Sipocz	Texas Parks and Wildlife Department
Eddie Seidensticker	Soil Conservation Service
John A. Grimes	Galveston Bay Foundation
Robert W. McFarlane	Galveston Bay National Estuary Program
Diane Hyatt	Texas General Land Office
Donald Moore	National Marine Fisheries Service
David Hankla	US Fish and Wildlife Service, Houston, TX

Name	Organization
Carol Ward	Galveston Bay National Estuary Program
Hal Delaplane	DOE, Washington, DC
Dave Johnson	DOE, Washington, DC
Sid Evans	DOE, New Orleans, LA
Deb Shaver	ICF Inc.
Steve Wyngarden	ICF Inc.
Pete Trenham	ICF Inc.
Raghu Raman	PB-KBB, Inc.
Karl Langer	PB-KBB, Inc.
Charles R. Clark	PB-KBB, Inc.

Issues:

- Various alternative pipeline routes from Big Hill to Houston, and their potential to impact wetlands, croplands, and other ecologically sensitive areas in and around Trinity Bay

A.2.7 Jackson, Mississippi, January 22, 1992

Name	Organization
Hal Chappelle	Office of the Governor of Mississippi
Bill Bunkley	US Army Corps of Engineers, Mobile, AL
Thomas Craven	US Army Corps of Engineers, Mobile AL
John Green	Office of the Governor of Mississippi
Joe Clayton	US Forest Service
Curtis Stover	Mississippi Department of Environmental Quality (MS DEQ)
Jerry Ryan	US Geological Survey, Jackson, MS
Mike Mallory	US Geological Survey, Jackson, MS
Bob Bufler	US Fish and Wildlife Service, Daphne, AL
J.I. Palmer, Jr.	MS DEQ
Charles Clevenger	MS DEQ, Land and Water Resources
Robert Seyfarth	MS DEQ, Office of Pollution Control
Ernest Boswell	MS DEQ, Land and Water Resources
James H. Hoffman	MS DEQ, Land and Water Resources
Jack Moody	MS DEQ, Geology
Andrew Covington	MS DEQ, Underground Injection Control
Bill Barnett	MS DEQ, Office of Pollution Control
Dwight Wylie	MS DEQ, Office of Pollution Control
John Warner	MS DEQ, Geology
Charles A. Barbour	Department of Economic and Community Development
Billy Warden	MS DEQ

Name	Organization
John Burris	MS Department of Wildlife, Fisheries, and Parks
Ken Gordon	MS Department of Wildlife, Fisheries, and Parks
Rob Mannel	BCM Engineers
Hal Delaplane	DOE, Washington, DC
Dave Johnson	DOE, Washington, DC
Sid Evans	DOE, New Orleans, LA
Deb Shaver	ICF Inc.
Jean Hoff	ICF Inc.
William Baird	ICF Inc.

Issues:

- General overview of the SPR expansion plan, including an overview of the proposed action, the potential environmental impacts, and the EIS schedule

A.2.8 Jackson, Mississippi, January 23, 1992

Name	Organization
Shannon Lowery	MS DEQ, Land and Water Resources
Gary M. Meadows	MS DEQ, Land and Water Resources
Dave Bailey	MS DEQ, Land and Water Resources
Lloyd Long	MS DEQ, Land and Water Resources
Charles Clevenger	MS DEQ, Land and Water Resources
Charles Branch	MS DEQ, Land and Water Resources
Jay Duckworth	MS DEQ, Geology
Hal Delaplane	DOE, Washington, DC
Deb Shaver	ICF Inc.
Jean Hoff	ICF Inc.
Will Baird	ICF Inc.

Issues:

- Raw water availability in Leaf River
- Possible impacts of raw water withdrawal and water availability in the Pascagoula River
- Sensitive wetlands in Bangs Lake area
- Other sensitive areas near proposed pipeline routes

A.2.9 Biloxi, Mississippi, February 11, 1992

Name	Organization
Jennifer Buchanan	Bureau of Marine Resources (BMR), Coastal Zone Management, Biologist
Tom Van Devender	BMR, Chief, Saltwater Fisheries
Scott Gordon	BMR, Fisheries Coordinator
Larry Lewis	BMR, Chief, Coastal Management
Joseph A. Runnels, Jr.	BMR, Counsel
Gary J. Cuevas	BMR, Coastal Management Section
Cathy Holloman	BMR, Coastal Management Section
Jerry Mitchell	BMR, Coastal Management Section
Hal Delaplane	DOE, Washington, DC
Sid Evans	DOE, New Orleans, LA
Jean Hoff	ICF Inc.
Steve Wyngarden	ICF Inc.

Issues:

- Dual-purpose pipeline route
- Diffuser location
- Mississippi Coastal Management Act permitting requirements

A.2.10 Mobile, Alabama, February 11, 1992

Name	Organization
Susan Ivester Rees	US Army Corps of Engineers
F.L. (Les) Currie	US Army Corps of Engineers
Maj. Dennis W. Heuer	US Army Corps of Engineers
E. Patrick Robbins	US Army Corps of Engineers
Steven M. Jones	BCM Engineers
Rob Manuel	BCM Engineers
Hal Chappelle	BCM Engineers
Tom Craven	US Army Corps of Engineers
Deborah Shoemaker	US Army Corps of Engineers
Arch Middleton	US Army Corps of Engineers
Jeff Lundy	Self [Consultant to the State of Mississippi]
Charles Chisolm	MS DEQ
J.I. Palmer, Jr.	MS DEQ
N.D. "Skeeter" McClure	US Army Corps of Engineers
Ronald A. Krizman	US Army Corps of Engineers

Name	Organization
Bill Bunkley	US Army Corps of Engineers
Hal Delaplane	DOE, Washington, DC
Dave Johnson	DOE, Washington, DC
Sid Evans	DOE, New Orleans, LA
Jean Hoff	ICF Inc.
Steve Wyngarden	ICF Inc.

Issues:

- Public involvement in NEPA process in Mississippi
- Dual-purpose pipeline route
- Brine diffuser location
- Raw water availability in the Leaf River

A.2.11 New Orleans, Louisiana, March 25, 1992

Name	Organization
Ronnie Duke	U.S. Army Corps of Engineers
Martin Meyer	U.S. Army Corps of Engineers
Hal Delaplane	DOE, Washington, DC
Dave Johnson	DOE, Washington, DC
Sid Evans	DOE, New Orleans, LA
Jean Hoff	ICF Inc.
Ronald Benefield	PB-KBB
Tim Riechwein	PB-KBB

Issues:

- Overview of proposed project
- Brine diffuser location and routing of brine diffuser pipeline

A.2.12 Mobile, Alabama, March 26, 1992

Name	Organization
Bill Bunkley	US Army Corps of Engineers
Thomas Craven	US Army Corps of Engineers
Ronald Krizman	US Army Corps of Engineers
John McFadyen	US Army Corps of Engineers
Susan Ivester Rees	US Army Corps of Engineers
Deborah Shoemaker	US Army Corps of Engineers
Hal Delaplane	DOE, Washington, DC
Dave Johnson	DOE, Washington, DC
Jean Hoff	ICF Inc.
Deb Shaver	ICF Inc.
Ronald Benefield	PB-KBB Inc.
Tim Reichnein	PB-KBB Inc.

Issues:

- Brine diffuser location for Richton site
- Wetlands assessment for Richton site
- Crude oil pipeline route from Richton to Liberty

A.2.13 Montgomery, Alabama, May 11, 1992

Name	Organization
Marilyn Elliott	Alabama Department of Environmental Management (ADEM)
Jon Hornsby	Alabama Department of Conservation and Natural Resources
Greg Rhinehart	Alabama Historical Commission
Blake Roper	ADEM -- Coastal Program
Dave Johnson	DOE, Washington, DC
Jean Hoff	ICF Inc.
Jason Smith	ICF Inc.

Issues:

- Overview of proposed project
- Permitting requirements for crude oil pipeline in Alabama

- Identification of areas of interest (e.g., cultural, ecological) along pipeline route

A.2.14 Montgomery, Alabama, May 11, 1992

<u>Name</u>	<u>Organization</u>
James Woehr	Alabama Department of Conservation and Natural Resources
Dave Johnson	DOE, Washington, DC
Joan Hoff	ICF Inc.
Jason Smith	ICF Inc.

<u>Issues:</u>

- Habitat ranges of species of concern (e.g., endangered species) in the vicinity of proposed crude oil pipeline route in Alabama

APPENDIX B

WETLAND TYPES AND FUNCTIONAL VALUES

B.1 Wetland Types

The type of wetland that occurs in an area depends upon several factors, including salinity, type of water body (i.e., freshwater vs. saltwater, tidal vs. nontidal) and the frequency of disturbances (e.g., flooding or storm events) that inhibit succession to a more xeric (drier) community. NWI maps, available for most of the area of concern, contain locations of wetlands by type. For the purposes of this report, areas considered to be wetlands are those areas identified on the NWI maps. Field verification of some of these wetlands was conducted in support of this DEIS.

There are five systems of wetlands in the NWI scheme: marine, estuarine, riverine, lacustrine, and palustrine. The dominant wetland systems in the region are estuarine and palustrine systems. Estuarine systems consist of deepwater tidal habitats and adjacent tidal wetlands that are usually semi-enclosed by land but have open, partly obstructed, or sporadic access to the ocean, and in which ocean water is at least occasionally diluted by freshwater runoff from the land. Palustrine systems include all nontidal wetlands dominated by trees, shrubs, and persistent emergents, and all such wetlands that occur in tidal areas with a salinity less than 0.5 parts per thousand (ppt).

In the estuarine and palustrine systems, dominant classes of wetlands in the region are estuarine intertidal emergent, palustrine emergent, and palustrine forested wetlands. Salinity generally determines the type of vegetation that occurs in an area. As one moves inland from the coast, salinity decreases and estuarine emergent wetlands (eusaline and polysaline salt marshes) grade into palustrine emergent wetlands (mesosaline [brackish], intermediate [oligosaline], and freshwater). The wetlands that occur inland (north) of the ICW are typically oligohaline and freshwater because the ICW forms an artificial barrier between freshwater and saltwater systems.

Below, the dominant classes of wetlands in the region are described in order of decreasing salinity. Commonly occurring species are listed and net primary productivity is discussed for each class.

B.1.1 Estuarine Intertidal Wetlands

Estuarine intertidal wetlands, commonly referred to as saltwater marshes, occur along the Gulf Coast in narrow strips extending inland approximately two miles. Saltgrass is the dominant species in saltwater marshes. Other species are smooth cordgrass, blackrush, saltmeadow cordgrass, alligatorweed, and bulltongue. Estuarine intertidal wetlands support a large number of perennial species, as opposed to freshwater wetlands that support a large number of annual species. Primary productivity in estuarine intertidal wetlands along the Gulf of Mexico is less than that reported for palustrine emergent wetlands and is approximately 2,200 $g/m^2/yr$.[1] Reported salinities in deltaic plain estuarine intertidal wetlands range from 0.6 ppt to greater than 20 ppt.[2]

B.1.2 Palustrine Emergent Wetlands

Palustrine emergent wetlands vary greatly in vegetative species and productivity. Mesohaline and oligohaline palustrine emergent wetlands are the dominant wetlands along the coastal plain. These two wetland types differ by salinity, with salinity of mesohaline (brackish) emergent wetlands generally higher than that in oligohaline (intermediate) emergent wetlands. The reported salinities in Delta Plain mesohaline emergent wetlands ranges from 0.4 ppt to 28 ppt, with an average salinity of 5.1 ppt.[3] Salinity of oligohaline emergent wetlands averages 2.2 ppt, but sometimes reaches six ppt.[4] Saltmeadow cordgrass is the dominant plant in both mesohaline and oligohaline emergent wetlands. In addition to saltmeadow cordgrass, other species in mesohaline emergent wetlands include widgeon-grass and saltgrass. Vegetation in oligohaline emergent wetlands is generally more diverse due to the presence of several freshwater species such as bulltongue and common reed, and alligatorweed. Mesohaline emergent wetlands generally support a large number of perennials. Primary productivity in mesohaline and oligohaline emergent wetlands has been estimated to be 2,825 and 2,756 $g/m^2/yr$, respectively, slightly greater than that for freshwater marshes.[5]

Freshwater palustrine emergent wetlands, often referred to as freshwater marshes, support a large number of annuals. A common plant association in fresh palustrine emergent wetlands of the region is the maidencane association that includes water hyacinth [an introduced species], duckweed, water lettuce, smartweed, bulltongue, soft-stem bulrush, and cattail. Maidencane is the dominant freshwater species, although saltmeadow cordgrass flourishes here as well. Bulltongue and alligatorweed are also common. Salinities in freshwater palustrine emergent wetlands of the Delta Plain range from zero to five ppt.[6] Net primary productivity is estimated to be 2232 $g/m^2/yr$.[7]

B.1.3 Palustrine Forested Wetlands

In addition to palustrine emergent wetlands, palustrine forested wetlands are common in the region. Palustrine forested wetlands include two general types commonly referred to as swamps and bottomland hardwood forests. The dominant vegetation of palustrine forested wetlands in this region consists of woody species that are not adapted to stresses induced by salinity. The palustrine forested wetlands, therefore, are unique to freshwater systems.

Swamps are differentiated from bottomland hardwood forests in that the source of standing water in swamps is mostly groundwater, whereas that for bottomland hardwood forests is mostly surface water. The period of inundation is typically longer in swamps than in bottomland hardwood forests, and, therefore, the species that occur in swamps are generally limited to those that are tolerant of prolonged inundation. Species that occur in bottomland hardwood forests are flood-tolerant species intermixed with some less tolerant species because the duration of inundation is shorter and the standing water often is more shallow.

In the study area, dominant woody vegetation in forested wetlands is bald cypress, water tupelo, red maple, and ash species, as well as a number of woody shrubs. Boxelder, cottonwood, and black willow also are found. Vines include poison ivy, trumpet creeper, greenbriar, and peppervine. Ferns and lichens are also common in some areas.

In a typical bottomland forest in the region, black tupelo and bald cypress grow on the lowest land, where water stands longest. As elevation increases slightly, oak and water hickory become more dominant, followed by other oaks and hickories, then sweet gum, water oak, laurel oak, american elm, swamp chestnut oak, and other trees better adapted to drier land.[8] In general, forested wetlands do not have a well-developed herbaceous (ground) layer because the forest floor is inundated for much of the year and also because of the reduced light conditions under a dense forest canopy.

Primary productivity is lower in forested wetlands than in emergent wetlands because large nutrient stores are tied up in the standing crop of plants (e.g., in tree trunks and branches). Net primary productivity in a cypress-tupelo swamp is calculated to be 1,140 $g/m^2/yr$ or about one-half that reported for emergent wetlands.[9] Net primary productivity in bottomland hardwood forests is estimated to be 1,574 $g/m^2/yr$, slightly greater than that estimated for cypress-tupelo swamps.[10]

B.2 Functional Values of Wetlands

Several functional values have been attributed to wetland systems discussed above. These functions can be divided into four basic categories: 1) habitat functions; 2) hydrologic functions; 3) water quality functions; and 4) socioeconomic functions. Each of these functions is discussed below, in order to provide a basis for evaluation of wetland impacts in Chapter 7.

B.2.1 Habitat Functions

All wetlands have high primary productivity compared to most upland systems. Because they are highly productive, wetlands can support a relatively large number of animals per acre. They are important spawning and nursery areas and provide sources of nutrients for finfish and shellfish. Wetlands also provide essential breeding, nesting, feeding, and predator escape habitats for many forms of waterfowl, other birds, mammals, and reptiles. Almost 35 percent of all rare and endangered animal species in the U.S. are either located in or dependent upon wetlands.[11]

B.2.2 Hydrologic Functions

Wetlands often function as natural floodways that convey floodwaters from upstream to downstream points. Also, they may store water during floods and slowly release it to downstream areas, resulting in lower flood peaks. Wetlands decrease flood flows and the velocity of floodwaters, which results in reduced erosion and causes floodwaters to release sediment. Coastal wetlands and those inland wetlands adjacent to large water bodies reduce the impact of storm tides and waves on upland areas.

B.2.3 Water Quality Functions

Wetlands improve water quality by acting as sediment traps and removing excess nutrients and many chemical contaminants. Wetlands are particularly good water filters because of their location between land and water. Thus, they can both intercept runoff from land before it reaches the water and help filter nutrients, wastes, and sediments from floodwaters.

B.2.4 Socioeconomic Functions

Wetlands can provide recreational, educational, historic, aesthetic, and economic values. The species that comprise recreational and commercial fisheries are dependent upon the habitat wetlands provide. Cypress and water tupelo historically have been important timber species in the region, particularly in Louisiana. Early nondiscriminative logging is probably one of the major causes of wetland loss in the State.

ENDNOTES

1. Gosselink, J.G., C.L. Cordes, and J.W. Parsons, *An Ecological Characterization Study of the Chenier Plain Coastal Ecosystem of Louisiana and Texas*, Volume 1, U.S. Department of Interior, Fish and Wildlife Service, Office of Biological Services, 1979, FWS/OBS 78/9 through 78/11.

2. Gosselink, J.G., *The Ecology of Delta Marshes of Coastal Louisiana: A Community Profile*, U.S. Department of Interior, Fish and Wildlife Service, 1984.

3. *Ibid.*

4. Gosselink, J.G., C.L. Cordes, and J.W. Parsons, *An Ecological Characterization Study of the Chenier Plain Coastal Ecosystem of Louisiana and Texas*, Volume 1, U.S. Department of Interior, Fish and Wildlife Service, Office of Biological Services, 1979, FWS/OBS 78/9 through 78/11.

5. *Ibid.*

6. Gosselink, J.G., *The Ecology of Delta Marshes of Coastal Louisiana: A Community Profile*, U.S. Department of Interior, Fish and Wildlife Service, 1984.

7. Gosselink, J.G., C.L. Cordes, and J.W. Parsons, *An Ecological Characterization Study of the Chenier Plain Coastal Ecosystem of Louisiana and Texas*, Volume 1, U.S. Department of Interior, Fish and Wildlife Service, Office of Biological Services, 1979, FWS/OBS 78/9 through 78/11.

8. Florida Cooperative Extension Program, *Bottomland Hardwoods*, University of Florida, Institute of Food and Agricultural Sciences, 1984.

9. Gosselink, J.G., C.L. Cordes, and J.W. Parsons, *An Ecological Characterization Study of the Chenier Plain Coastal Ecosystem of Louisiana and Texas*, Volume 1, U.S. Department of Interior, Fish and Wildlife Service, Office of Biological Services, 1979, FWS/OBS 78/9 through 78/11.

10. *Ibid.*

11. The Conservation Foundation, *Protecting America's Wetlands: An Action Agenda, The Final Report of the National Wetlands Policy Forum*, Washington, DC, 1988.

APPENDIX C

GULF OF MEXICO BIOLOGICAL COMMUNITIES

C.1 Phytoplankton

There are a number of broad features of phytoplankton community composition in the northern Gulf. Nutrient levels on the continental shelf are derived primarily from major river systems, and to a lesser extent from the outflow of minor streams and from upwelling. Consequently, phytoplankton levels tend to be much higher and more variable off Louisiana than off south Texas, and higher and more variable inshore than offshore. In general, offshore waters are dominated by cyanobacteria (particularly *Trichlodesmium thiebauti*) and/or coccolithophores (particularly *Coccolithus huxley*). In nearshore waters, diatoms typically make up 70 to 100 percent of the community, but other groups become abundant at various times of the year. Cyanobacteria or less commonly, green angel, become most abundant during the fall, though they seldom comprise more than ten to 20 percent of the community. Dinoflagellates reach their maximum abundance in March or April or somewhat later and may dominate the community at times. Species composition varies markedly from month to month, site to site, and year to year. This may be attributable to sampling artifacts rather than real differences between sites.[1]

In the Gulf, phytoplankton population densities range from about 10^6 to 10^{11} cells/m^3. Because of the high turbidities in the area, plankton biomass attains maximum values in the near-surface waters. Biomass reaches a maximum from June through August and a minimum from October to March. Cell densities are highest in the coastal bays and neritic zone (waters above the continental shelf) and decrease seaward. In the neritic zone, phytoplankton diversity is greater than in either the open Gulf waters or inland waters due to the presence of both freshwater and marine species. Values for primary production in the inshore surface and integrated euphotic zone (the area from the surface to the maximum depth of active photosynthesis) are higher than those for offshore waters.[2]

Geographic variations within the Gulf are apparent, as there is a general seaward decrease in standing crop. Typical open Gulf densities range from 1 to 8 x 10^6 cells/m^3, and densities in inshore waters typically range from 10^7 to 10^9 cells/m^3 depending upon season and location. Thus, the lowest standing crops found inshore are typically greater than the highest standing crops in the open Gulf. There are strong long-shore differences in standing crop as well, though not so obvious as the onshore-offshore gradient. The area under the immediate influence of the Mississippi River shows elevated cell counts compared to western Louisiana, Texas coastal waters, and the northeast Gulf. In the open ocean primary productivity is low, with average values of 0.2 mg C/m^3/hr (a measure of carbon, or C, fixation). In coastal waters productivity ranges from 0.3 to 32 mg C/m^3/hr, with a value of about 4 to 5 mg C/m^3/hr being a typical mean. A number of authors present a wide variety of carbon-uptake data either as a daily value for surface production or as a daily or annual value for the euphotic zone. The variability in the data is great, but annual production of 150 to 200 g C/m^2/yr seems typical of coastal waters. In this light, production in the northwest Gulf would not seem to be exceptional, even around the mouth of the Mississippi River.[3]

Studies suggest that the phytoplankton in the Gulf are relatively abundant and diverse. Diatoms and, to a lesser extent, dinoflagellates dominate the community by varying amounts in different seasons. In general, diatoms make up more than 71 percent of the plankton, with some exceptions. One study identified 35 species and 26 genera of phytoplankton in the area.[4] Another study identified 115 species and 60 genera in these waters between September 1977 and April 1978.[5] A generally seaward gradient of decreasing abundance is suggested. The apparent inverse relationship between phytoplankton productivity and salinity is related to the nutrients supplied by freshwater runoff.[6]

C.2 Zooplankton

The zooplankton communities of the Gulf of Mexico are mostly tropical-subtropical species assemblages, except in the coastal areas where species more typical of the temperate Atlantic coast of the United States dominate. There are as many as five biogeographic zones in the Gulf: (1) oceanic; (2) continental slope transition between neritic and oceanic conditions; (3) central continental shelf region; (4) coastal neritic zone; and (5) estuarine. These zones are not fixed geographically, but are more or less related to particular water masses and current patterns.[7]

In the western Gulf, water mass distribution is strongly influenced by seasonal current reversals and even by northern excursions of the Loop Current, a strong current that flows through the Yucatan Channel between Mexico and Cuba, loops into the Gulf, and then flows through the Florida Straits. The result is that the western Gulf area is usually part of the coastal neritic zone, indicated by the dominance of certain copepod species and the presence of many meroplankton forms (principally fish and crustacean larvae). The presence of outer shelf and oceanic forms indicate intrusion of offshore waters, especially in summer.[8]

Like phytoplankton, zooplankton abundance varies in number and species and with respect to time and space. In general, a seaward gradient of decreasing population density measured in numbers per zooplankton species is indicated from various studies. Increasing variation is found from deep to shallow areas. Abundance generally peaks in spring and summer. One study noted an abundance of planktonic foraminiferans and spumellarians in shallow offshore waters and an abundance of nasellarians with planktonic foraminiferans and spumellarians in deeper offshore waters. Studies done off the Texas and Mississippi coastline found copepods to be most abundant. Copepods did not vary greatly relative to seasonal variance of the total zooplankton numbers.[9] Crop values for nearshore Louisiana average 85,408 individuals/m^3, with copepods making up a large portion of the zooplankton at all seasons and localities.[10]

C.3 Benthos

Benthos constitute the portion of the offshore biota that is most likely to be affected by pipeline activities. Benthic communities are far better known than other offshore communities. The benthic communities of the Outer Continental Shelf are distributed largely by sediment type and water depth. Factors that also control the occurrence of benthic organisms are salinity, temperature, dissolved oxygen, currents, and food availability. The benthos has both floral and faunal components. The floral representatives are algae and sea grasses. The benthic faunal representatives offshore include almost all animal phyla. The benthic fauna is composed of infauna (animals that live in the substrate such as burrowing worms and molluscs) and epifauna (animals that live on the substrate such as molluscs, crustaceans, hydroids, sponges, anemones, and corals). The commercial shrimps and commercial demersal fishes (flounders, snappers, groupers, and croakers) are closely associated with benthic communities.[11] Reduced species diversity in the benthos caused by brine diffusion could determine the presence or absence of bottom feeding nektonic organisms.[12]

The top 20 species collected in a 1980 study at Bryan Mound account for 91.1 and 92.3 percent of the total benthos collected at the offshore (12.5 mile) and the nearshore (five mile) sites, respectively. Thirteen species were among the 20 most abundant at both sites. *P. pinnata* dominated both sites, but to a greater degree at the nearshore site. The second most important species at the offshore site, *A. suecica*, was not in the top 20 at the nearshore site.[13] There is a striking similarity of the benthic assemblages across studies at Bryan Mound and the Texoma region. This is in agreement with the results from a Texoma region study, where small but discernable differences were found to exist.[14]

Over 200 species of benthic macroinvertebrate infauna have been identified in the vicinity of Bryan Mound and Stratton Ridge. Sampling at stations surrounding the Bryan Mound diffuser site (before it was in operation) produced 107 species of benthic invertebrates, dominated by 57 species of polychaetes. The frequency of occurrence and/or abundance of two species of amphipod and one species of bivalve helped set apart two distinct benthic assemblages in the diffuser area.[15]

Offshore from Weeks Island, 95 taxa of benthic invertebrates were collected at one site and 185 taxa were collected at another.[16] Sixty-four to 73 percent of individuals collected at the first site and 27 to 86 percent collected at the second were polychaetes. The differences in species distribution at the two sites may have resulted from seasonal life cycles, feeding preference, grain size preference, or water quality parameters.[17]

Off the coast of Mississippi, an Army Corps of Engineers study has defined two benthic habitat types: offshore mud bottom and offshore muddy sand. The mud bottom community is dominated by five polychaetes, one crustacean, one sipunculan, and one nemertean. The muddy sand community occurs in deeper water and is dominated by six polychaetes and one sipunculan.[18]

Available data indicate that benthic populations begin to increase in early winter, are most dense in spring, decline through the summer, and reach a minimum by fall. Offshore site populations at 12 to 14 miles were 1.6 to 1.7 times the population density of the nearshore sampling site near Bryan Mound.[19] Species composition and numbers of benthic animals from the nearshore Louisiana coast also show seasonal variations, including effects from seasonal storm surges. The benthic community has a rapid turnover rate, with many species completing their life cycles in one year or less.

The nearcoast system shows large month to month differences in standing crop. Going offshore at Bryan Mound, there appears to be both an increase in density of macrobenthos and a decrease in variability of both the hydrographic regime and macrobenthos. It appears that the spring peak in macrobenthos (benthic organisms larger than 0.5 mm) density becomes much less prominent at the offshore site due possibly to the smaller freshwater influence at the site. The higher standing crop at the offshore site is probably as much related to sediment composition as environmental stability. At certain times of the year, the two sites at Bryan Mound did not behave at all similarly. Also, going offshore, the dominance of the community by one or several species appeared to diminish.[20]

Another study detected densities of benthic organisms up to 18,736 individuals/m^2 in the nearshore waters of central Louisiana. This same study, however, found a low mean annual density of only 2,600 individuals/m^2. Again the organisms appeared to be more abundant in shallow than deep water and more abundant off Louisiana and upper Texas than off lower Texas.[21]

C.4 Nekton

Two distinct nekton communities were identified in the vicinity of the Bryan Mound diffuser with names derived from the dominant commercial shrimp fishery in each area. The white shrimp grounds are dominated by Atlantic croaker and the brown shrimp grounds by the longspined porgy. The white shrimp grounds tend to have fewer species and lower biomass, and the indigenous fish tend to be more dependent on the estuaries than those found in the brown shrimp grounds. However, in the vicinity of the diffuser, trawl surveys showed the brown shrimp grounds to have a lower biomass of common species than the white shrimp grounds. Nekton families found in the white shrimp grounds (inner shelf depths twelve to 72 feet) include drums, cutlassfishes, threadfins, and sea catfishes. The brown shrimp grounds (intermediate shelf depths 72 to 300 feet) include porgies, searobins, and drums. During summer months predatory pelagic fish are found in the area, including dolphins, bill fishes, mackerels, bonito, amber jack, blue runner, and several species of jack fish.[22] Also, during the late spring and summer, the nearshore northwestern Gulf experiences recurring periods of oxygen depletion in the near bottom waters. This phenomenon may totally disrupt the demersal nekton community, and occasionally results in mass mortalities of some species.[23]

Studies characterize the Weeks Island and Cote Blanche region as having more than 42 species of invertebrates.[24,25] Some of the more abundant invertebrates found in these studies are seabob, brief squid, white shrimp, brown shrimp, and blue crab. The regional ichthyofauna are comprised of at least 105 fish species.[26] Some of the more abundant fish of the region include the bay anchovy, Atlantic croaker, sea catfish, rock seabass, Gulf menhaden, Atlantic cutlassfish, fringed flounder, spot, sand seatrout, Gulf butterfish, Atlantic bumper, blue spotted sea robin, and Atlantic threadfin.[27] Other, more elusive species are also likely to inhabit the area, since more than 600 species of fish are known to occur in coastal Gulf water off Texas.[28] A study of six shallow-water hard-bottom sites revealed associated populations of Atlantic spadefish, red snapper, sheepshead, gray triggerfish, and tomtate.[29]

The existing Bryan Mound diffuser site (at 12.5 miles) is in a region of ecological transition between the shallow water/white shrimp community and the deep water/brown shrimp community.[30] In studies of this site, brown shrimp (*Penaeus aztecus*) has been the principal nektonic species, except in a few cases in which white shrimp (*Penaeus setiferus*) was the principal species. The overall diffuser area ichthyofauna has been dominated by a very few species whose year-to-year abundance continues to fluctuate widely. Species that are consistently abundant include longspined porgy, silver sea trout, Atlantic bumper, shoal flounder, striped anchovy, and Gulf butterfish. Temporal changes in relative species abundance have persisted throughout studies of the Bryan Mound diffuser area and are not unusual.[31]

ENDNOTES

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APPENDIX D

ENDANGERED OR THREATENED SPECIES

D.1 Introduction

This Appendix presents listings and some additional information on all endangered or threatened species reported to occur within the counties and parishes in which the proposed sites, pipeline routes, and structures are located and in the adjacent Gulf of Mexico waters. These counties, parishes, and portions of the Gulf of Mexico are referred to as "the study area" in the remainder of this Appendix. Table D.1-1 lists each species reported to occur within the study area, including its common name, scientific name, and endangered or threatened status at the Federal and state levels. Note that in many cases, species that are on the Federal list, but are thought to be extinct or nearly extinct in a particular state, will not be listed by the state even if the state includes a part of the species' historical range (e.g., the red wolf in Louisiana).[1] Note also that additional species within the study area are designated by Federal or State authorities as candidates for listing as endangered or threatened. We have not included these species in this Appendix. Tables D.1-2 through D.1-8 present county-by-county lists for each proposed site and associated pipeline routes and structures. Table D.1-9 presents species lists for the proposed brine diffusers in the Gulf of Mexico.

In reviewing these lists, it is important to note that site visits or other information have confirmed the presence of only a few species at a specific location. In most cases, information on presence or absence of each species within the study area is limited to the reported occurrence of the species within the indicated county or parish or the Gulf of Mexico. In many cases, reported occurrence is based on historical records rather than recent sightings, and some species may be extinct within the study area. Therefore, the reported occurrence of a species within a specified county (or parish or for the Gulf of Mexico) does not necessarily indicate that the species (a) is currently found within the county, (b) is currently found within the particular portion of the county or habitat potentially affected by the proposed SPR activities, or (c) would be adversely affected by the proposed SPR activities. The National Marine Fisheries Service (NMFS) and the U.S. Fish and Wildlife Service (USFWS) have expressed concern about several Federal endangered or threatened species. Biological assessments are presented for marine species of concern (Appendix E) and for terrestrial and freshwater species of concern (Appendix F).

In comparing lists for each proposed SPR site, it is important to note that criteria used to designate endangered or threatened species at the state level (and the level of effort devoted to listing) varies among the four states within the study area. Therefore, the relative number of endangered or threatened species listed for a particular county (or parish or for the Gulf of Mexico) does not necessarily indicate the relative level of risk to endangered species associated with the proposed SPR activities at an individual site.

Species lists are based on information provided by the USFWS, NMFS, the Texas Natural Heritage Program (Texas Parks and Wildlife Department), the Louisiana Natural Heritage Program (Louisiana Department of Wildlife and Fisheries), the Mississippi Natural Heritage Program (Mississippi Department of Wildlife, Fisheries, and Parks), the Alabama Natural Heritage Program, and the Alabama Department of Conservation and Natural Resources.

Table D.1-1
Status of Endangered or Threatened Species Reported to Occur in Study Area

Common Name of Endangered or Threatened Species	Scientific Name of Endangered or Threatened Species	Federal Status[1]	State Status[2]			
			TX	LA	MS	AL
Plants						
Prairie Dawn (Texas Bitterweed)	*Hymenoxys texana*	E	E	-	-	-
Birds						
American Oystercatcher	*Haematopus palliatus*	-	-	-	-	P
American Swallow-tailed Kite	*Elanoides forficatus*	-	T	-	-	-
American White Pelican	*Pelecanus erythrorhynchos*	-	-	-	-	P
Attwater's Greater Prairie Chicken	*Tympanuchus cupido attwateri*	E	E	-	-	-
Bachman's Sparrow	*Aimophilia aestivalis*	-	T	-	-	-
Bald Eagle	*Haliaeetus leucocephalus*	E	E	E	E	P
Bewick's Wren	*Thryomanes bewickii*	-	-	-	E	-
Brown Pelican	*Pelecanus occidentalis*	E	E	E	E	X
Common Ground Dove	*Columbiana passerina*	-	-	-	-	P
Cooper's Hawk	*Accipiter cooperi*	-	-	-	-	P
Gull-billed Tern	*Sterna nilotica*	-	-	-	-	P
Interior Least Tern	*Sterna antillarum athalossos*	E	E	-	-	-
Merlin	*Falco columbarius*	-	-	-	-	P
Mississippi Sandhill Crane	*Grus canadensis pulla*	E	-	-	E	-
Osprey	*Pandion haliaetus*	-	-	-	-	P
Peregrine Falcon[3]	*Falco peregrinus*	E (S/A)	-	-	E	P
American Peregrine Falcon[3]	*Falco peregrinus anatum*	E	-	-	-	
Arctic Peregrine Falcon[3]	*Falco peregrinus tundrius*	T	T	-	-	-
Piping Plover	*Charadrius melodus*	T	T	T/E	-	P
Red-cockaded Woodpecker	*Picoides borealis*	E	E	E	E	P
Reddish Egret	*Egretta rufescens*	-	T	-	-	P
Rose-throated Becard	*Pachyramphus aglaiae*	-	T	-	-	-

Table D.1-1 (continued)

Common Name of Endangered or Threatened Species	Scientific Name of Endangered or Threatened Species	Federal Status[1]	State Status[2]			
			TX	LA	MS	AL
Birds (cont.)						
Snowy Plover	*Charadrius alexandrinus*	-	-	-	E	P
Sooty Tern	*Sterna fuscata*	-	T	-	-	-
White-faced Ibis	*Plegadis chihi*	-	T	-	-	-
White-tailed Hawk	*Buteo albicaudatus*	-	T	-	-	-
Whooping Crane	*Grus americana*	E	E	-	-	-
Wilson's Plover	*Charadrius wilsonia*	-	-	-	-	P
Wood Stork	*Mycteria americana*	E	T	-	-	P
Terrestrial Mammals						
(Louisiana) Black Bear	*Ursus americanus*	T	T	T	E	-
Brazilian Free-tailed Bat	*Tadarida brasiliensis*	-	-	-	-	P
Florida Panther	*Felis concolor coryi*	E	-	E	E	-
Gray Bat	*Myotis grisescens*	E	-	-	E	-
Jaguarundi	*Felis yagouaroundi*	E	E	-	-	-
Rafinesque's Big-eared Bat	*Plecotus rafinesquii*	-	T	-	-	P
Red Wolf	*Canis rufus*	E	E	-	-	-
Southeastern Bat	*Myotis austroriparius*	-	-	-	-	P
Terrestrial/Freshwater Reptiles and Amphibians						
Alabama Map Turtle	*Graptemys pulchra*	-	-	-	-	P
Alabama Red-bellied Turtle	*Pseudemys alabamensis*	E	-	-	-	P
Alligator Snapping Turtle	*Macroclemys temminckii*	-	T	-	-	P
American Alligator	*Alligator mississippiensis*	T(S/A)	-	-	-	-
Black Pine Snake	*Pituophis melanoleucus lodingi*	-	-	-	E	P
Box Turtle	*Terrapine carolina*	-	-	-	-	P
Dusky Gopher Frog	*Rana areolata sevosa*	-	-	-	-	P

Table D.1-1 (continued)

Common Name of Endangered or Threatened Species	Scientific Name of Endangered or Threatened Species	Federal Status[1]	State Status[2]			
			TX	LA	MS	AL
Terrestrial/Freshwater Reptiles and Amphibians (cont.)						
Eastern Coachwhip Snake	*Masticophus flagellum flagellum*	-	-	-	-	P
Eastern Indigo Snake	*Drymarchon corais couperi*	T	-	-	E	P
Flatwoods Salamander	*Ambystoma cingulatum*	-	-	-	-	P
Gopher Tortoise	*Goperus polyphemus*	T	-	-	E	-
Gulf Salt Marsh Snake	*Nerodia fasciata clarki*	-	-	-	-	P
Houston Toad	*Bufo houstonensis*	E	E	-	-	-
Louisiana Pine Snake	*Pituophis melanoleucus ruthveni*	-	E	-	-	-
Mississippi Diamondback Terrapin	*Malaclemys terrapin pileata*	-	-	-	-	P
Northern Scarlet Snake	*Cemophora coccinea copei*	-	T	-	-	-
Rainbow Snake	*Farancia erytrogramma*	-	-	-	E	
Ringed Sawback Turtle	*Graptemys oculifera*	T	-	-	E	-
Southern Hognose Snake	*Heterodon simus*	-	-	-	E	P
Texas Horned Lizard	*Phrynosoma cornutum*	-	T	-	-	-
Texas Scarlet Snake	*Cemophora coccinea lineri*	-	T	-	-	-
Timber Rattlesnake	*Crotalus horridus*	-	T	-	-	-
Western Smooth Green Snake	*Opheodrys vernalis blanchardi*	-	E	-	-	
Yellow-blotched Sawback Turtle	*Graptemys flavimaculata*	T	-	-	E	-
Terrestrial Insects						
American Burying Beetle	*Nicrophorus americanus*	E	-	-	-	-
Freshwater Invertebrates						
Inflated Heelsplitter	*Potamilus inflatus*	T	-	-		-
Freshwater Fish						
Blue Sucker	*Cycleptus elongatus*	-	T	-	-	-
Creek Chubsucker	*Erimyzon oblongus*	-	T	-	-	-

Table D.1-1 (continued)

Common Name of Endangered or Threatened Species	Scientific Name of Endangered or Threatened Species	Federal Status[1]	State Status[2]			
			TX	LA	MS	AL
Freshwater Fish (cont.)						
Crystal Darter	*Ammocrypta asprella*	-	-	-	E	P
Frecklebelly Madtom	*Notorus munitus*	-	-	-	E	P
Paddlefish	*Polydon spathula*	-	E	-	-	-
Marine/Estuarine Fish						
Gulf (Atlantic) Sturgeon[4]	*Acipenser oxyrhynchus desotoi*	T	-	-	E	-
Pallid Sturgeon	*Scaphirhynchus albus*	E	-	-	-	-
Marine Mammals						
Atlantic Spotted Dolphin	*Stenella plagiodon*	-	T	-	-	-
Blue Whale	*Balaenoptera musculus*	E	E	E	E	-
Dwarf Sperm Whale	*Kogia simus*	-	T	-	-	-
False Killer Whale	*Psuedorca crassidens*	-	T	-	-	-
Finback Whale	*Balaenoptera physalus*	E	E	E	E	-
Gervais' Beaked Whale	*Mesoplodon europaeus*	-	T	-	-	-
Goose-beaked Whale	*Ziphius cavirostris*	-	T	-	-	-
Killer Whale	*Orcinus orca*	-	T	-		-
Pygmy Killer Whale	*Feresa attenuata*	-	T	-	-	-
Pygmy Sperm Whale	*Kogia breviceps*	-	T	-	-	-
Right Whale	*Balaena glacialis*	E	E	-	-	-
Rough-toothed Dolphin	*Steno bredanensis*	-	T	-	-	-
Sei Whale	Balaenoptera borealis	E	E	-	-	-
Short-finned Pilot Whale	*Globicephala macrorhynchus*	-	T	-	-	-
Sperm Whale	*Physeter macrocephalus*	E	E	E	E	-
West Indian Manatee	*Trichechus manatus*	E	-	E	-	-

Table D.1-1 (continued)

Common Name of Endangered or Threatened Species	Scientific Name of Endangered or Threatened Species	Federal Status[1]	State Status[2]			
			TX	LA	MS	AL
Marine Turtles						
Atlantic Green Sea Turtle	*Chelonia mydas mydas*	T	T	T	E	-
Kemp's Ridley Sea Turtle	*Lepidochelys kempii*	E	E	E	E	-
Leatherback Sea Turtle	*Dermochelys coriacea*	E	E	E	E	-
Loggerhead Sea Turtle	*Caretta caretta*	T	E	T	E	-

NOTES

1. Federal Status in Texas, Louisiana, Mississippi, and Alabama:

   E = Endangered Species
   T = Threatened Species
   E (S/A) = Endangered because of similarity in appearance to another species
   T (S/A) = Threatened because of similarity in appearance to another species
   \- = Species is not on the Federal List of Endangered Species
   X = The Federal Endangered Species status for the brown pelican does not apply to the species in the state of Alabama

2. State Status in Texas, Louisiana, or Mississippi:

   E = Endangered
   T = Threatened
   \- = Species is not on the state list of endangered or threatened species, or species is not reported to occur within any county or parish in which a proposed SPR structure is located

   State Status in Alabama:

   P = Protected. Species listed in Alabama State Regulation 89-GF-16 (Game and Fish), which prohibits unauthorized take, capture, or kill. These species are included because Alabama to date has not listed any species as endangered or threatened.
   \- = Species is not listed in Alabama State Regulation 89-GF-16, or species is not reported to occur within any county in which a proposed SPR structure is located

3. The two subspecies of peregrine falcon (i.e., American and Arctic) are counted as one species throughout this Appendix. In the following tables, the reported occurrence of the species or subspecies is presented as reported by our sources, which may result in the species and/or one or both subspecies being listed as reported to occur within a particular county or parish. However, in totaling the number of species at the bottom of each table, this species and its subspecies is counted only once.

4. The gulf sturgeon (*Acipenser oxyrhynchus desotoi*) is one of two distinct, geographically separate subspecies of Atlantic sturgeon.[2] The Atlantic sturgeon (*Acipenser oxyrhynchus*), rather than the gulf sturgeon is listed as endangered on Mississippi's state list. Since only the gulf sturgeon subspecies is found in the Gulf of Mexico, we have shown the gulf sturgeon as endangered in Mississippi.

Table D.1-2
Endangered or Threatened Species: Big Hill[1]

Common Name of Endangered or Threatened Species	Big Hill Site	I-10 Pipeline Route and Trinity Bay Pipeline Route		
	Jefferson County	Jefferson County	Chambers County	Harris County
Plants				
Prairie Dawn (Texas Bitterweed)				X (3)
Birds				
American Swallow-tailed Kite	X (2)	X (2)	X (2)	X (7)
American Peregrine Falcon2				X (7)
Arctic Peregrine Falcon2	X (2)	X (2)	X (2)	X (7)
Attwater's Greater Prairie Chicken			X (2)	X (7)
Bachman's Sparrow	X (2)	X (2)	X (2)	
Bald Eagle	X (2)	X (2)	X (2)	X (7)
Brown Pelican	X (2)	X (2)	X (2)	X (7)
Interior Least Tern	X (2)	X (2)	X (2)	
Piping Plover	X (2)	X (2)	X (2)	
Red-cockaded Woodpecker	X (2)	X (2)	X (2)	X (7)
Reddish Egret	X (2)	X (2)	X (2)	X (7)
White-faced Ibis	X (2)	X (2)	X (2)	X (7)
White-tailed Hawk				X (7)
Wood Stork	X (2)	X (2)	X (2)	X (7)
Terrestrial Mammals				
(Louisiana) Black Bear				X (9)
Jaguarundi				X (3)
Rafinesque's Big-eared Bat	X (2)	X (2)		

1 NOTE: Numbers in parenthesis refer to information source; see List of Sources for Endangered Species (p D-19)

Table D.1-2 (continued)

Common Name of Endangered or Threatened Species	Big Hill Site	I-10 Pipeline Route and Trinity Bay Pipeline Route		
	Jefferson County	Jefferson County	Chambers County	Harris County
Red Wolf	X (2)	X (2)	X (2)	X (7)
Terrestrial/Freshwater Reptiles and Amphibians				
Alligator Snapping Turtle	X (2)	X (2)	X (2)	X (7)
Houston Toad				X (7)
Louisiana Pine Snake	X (2)	X (2)		
Northern Scarlet Snake	X (2)	X (2)	X (2)	
Texas Horned Lizard	X (2)	X (2)	X (2)	X (7)
Timber Rattlesnake			X (2)	X (7)
Western Smooth Green Snake	X (2)	X (2)	X (1)	X (7)
Freshwater Fish				
Blue Sucker	X (2)	X (2)		
Creek Chubsucker				X (7)
Paddlefish	X (2)	X (2)	X (2)	X (7)
TOTAL SPECIES	**20**	**28**		

NOTES

1. Numbers in parenthesis refer to the source of information; refer to List of Sources for Endangered Species (p. D-19).

2. The peregrine falcon and its two subspecies (i.e., American and Arctic) are counted as one species.

Table D.1-3
Endangered or Threatened Species: Stratton Ridge[1]

Common Name of Endangered or Threatened Species	Stratton Ridge Site, Crude Oil Spur, RWI, RWI Pipeline, and Brine Pipeline
	Brazoria County
Birds	
American Swallow-tailed Kite	X (2)
Arctic Peregrine Falcon	X (2)
Attwater's Greater Prairie Chicken	X (2)
Bald Eagle	X (1)
Brown Pelican	X (2)
Interior Least Tern	X (2)
Piping Plover	X (2)
Red-cockaded Woodpecker	X (2)
Reddish Egret	X (2)
Rose-throated Becard	X (2)
Sooty Tern	X (2)
White-faced Ibis	X (2)
White-tailed Hawk	X (2)
Whooping Crane	X (1)
Wood Stork	X (2)
Terrestrial Mammals	
Jaguarundi	X (2)
Terrestrial/Freshwater Reptiles and Amphibians	
Alligator Snapping Turtle	X (2)
Texas Horned Lizard	X (2)
Texas Scarlet Snake	X (2)
Timber Rattlesnake	X (2)
Western Smooth Green Snake	X (2)
TOTAL SPECIES	**21**

NOTES

1. Numbers in parenthesis refer to the source of information: refer to List of Sources for Endangered Species (p. D-19).

Table D.1-4
Endangered or Threatened Species: Weeks Island[1]

Common Name of Endangered or Threatened Species	Weeks Island Site and RWI	Brine Pipeline Route		Western Pump Station	Eastern Pump Station
	Iberia Parish	Iberia Parish	Vermilion Parish	St. Mary's Parish	Assumption Parish
Birds					
Artic Peregrine Falcon			X (5)		
Bald Eagle	X (4)	X (4)		X (4)	X (4)
Piping Plover			X (5)		
Terrestrial Mammals					
(Louisiana) Black Bear	X (5)	X (5)		X (5)	X (5)
Red Wolf			X (10)		
TOTAL SPECIES	2	5		2	2

NOTES

1. Numbers in parenthesis refer to the source; see List of Sources for Endangered Species (p. D-19).

Table D.1-5
Endangered or Threatened Species: Cote Blanche[1]

Common Name of Threatened or Endangered Species	Cote Blanche Site and RWI	Pipeline Routes		
	St. Mary's Parish	St. Mary's Parish	Iberia Parish	Vermilion Parish
Birds				
Artic Peregrine Falcon				X (5)
Bald Eagle	X (5)	X (5)	X (5)	
Piping Plover				X (5)
Terrestrial Mammals				
(Louisiana) Black Bear	X (5)	X (5)	X (5)	
Red Wolf				X (10)
TOTAL SPECIES	2	5		

NOTES

1. Numbers in parenthesis refer to the source; see List of Sources for Endangered Species (p. D-19).

Table D.1-6
Endangered or Threatened Species: St. James Terminal and Texas 22" Crude Oil Spur[1]

Common Name of Endangered or Threatened Species	St. James Terminal	Texas 22" Crude Oil Spur
	St. James Parish	Iberia Parish
Birds		
Bald Eagle		X (4)
Terrestrial Mammals		
(Louisiana) Black Bear		X (5)
Marine/Estuarine Fish		
Pallid Sturgeon	X (4)	
TOTAL SPECIES	1	2

NOTES

1. Numbers in parenthesis refer to the source of information; refer to List of Sources for Endangered Species (p. D-19).

Table D.1-7
Endangered or Threatened Species: Richton (Site, Pipeline to Pascagoula, Pipeline to Mobile)

Common Names of Endangered or Threatened Species	Richton Site, RWI, RWI Pipeline, Brine Injection/Blanket Oil Line		Pascagoula Port Facilities Dual-Purpose Line to Pascagoula and Crude Oil Line to Mobile				
	Perry County	Jones County (Brine Injection/ Blanket Oil Line Only)	Perry County	Greene County	George County	Jackson County (Dual-Purpose Pipeline and Pascagoula Port Only)	Mobile County (Crude Oil Pipeline Only)
Birds							
American Oystercatcher							X (12)
American White Pelican							X (13)
Bald Eagle					X (8)	X (8)	X (12)
Bewick's Wren						X (8)	
Brown Pelican						X (8)	
Common Ground Dove							X (12)
Cooper's Hawk							X (12)
Gull-billed Tern							X (12)
Merlin							X (12)
Mississippi Sandhill Crane						X (8)	X (11)
Osprey							X (12)
Peregrine Falcon[a]						X (8)	X (12)
American Peregrine Falcon							X (11)
Arctic Peregrine Falcon							X (11)
Piping Plover							X (13)
Red-cockaded Woodpecker	X (6)	X (18)	X (6)	X (8)	X (8)	X (8)	X (12)
Reddish Egret							X (12)
Snowy Plover						X (8)	X (12)
Wilson's Plover							X (12)
Wood Stork							X (12)
Terrestrial Mammals							
(Louisiana) Black Bear	X (6)		X (6)		X (8)	X (8)	X (13)
Brazilian Free-tailed Bat							X (12)
Florida Panther					X (8)	X (8)	X (11)
Jaguarundi							X (13)

Table D.1-7 (continued)

Common Names of Endangered or Threatened Species	Richton Site, RWI, RWI Pipeline, Brine Injection/Blanket Oil Line		Pascagoula Port Facilities Dual-Purpose Line to Pascagoula and Crude Oil Line to Mobile				
	Perry County	Jones County (Brine Injection/ Blanket Oil Line Only)	Perry County	Greene County	George County	Jackson County (Dual-Purpose Pipeline and Pascagoula Port Only)	Mobile County (Crude Oil Pipeline Only)
Rafinesque's Big-eared Bat							X (12)
Red Wolf							X (11)
Southeastern Bat							X (12)
Terrestrial/Freshwater Reptiles and Amphibians							
Alabama Map Turtle							X (12)
Alabama Red-bellied Turtle							X (12)
Alligator Snapping Turtle							X (12)
American Alligator	X (6)	X (18)	X (6)	X (8)	X (8)	X (8)	X (12)
Black Pine Snake	X (6)		X (6)		X (8)		X (12)
Box Turtle							X (12)
Dusky Gopher Frog							X (13)
Eastern Coachwhip Snake							X (12)
Eastern Indigo Snake	X (6)	X (18)	X (6)				X (12)
Flatwoods Salamander							X (12)
Gopher Tortoise	X (6)	X (18)	X (6)	X (8)	X (8)	X (8)	X (13)
Gulf Salt Marsh Snake							X (12)
Mississippi Diamondback Terrapin							X (12)
Rainbow Snake						X (8)	
Southern Hognose Snake							X (12)
Yellow-blotched Sawback Turtle	X (6)	X (18)	X (6)	X (8)	X (8)	X (8)	
Terrestrial Insects							
American Burying Beetle							X (14)
Freshwater Invertebrates							
Inflated Heelsplitter							X (14)
Freshwater Fish							
Crystal Darter							X (12)

Table D.1-7 (continued)

Common Names of Endangered or Threatened Species	Richton Site, RWI, RWI Pipeline, Brine Injection/Blanket Oil Line		Pascagoula Port Facilities Dual-Purpose Line to Pascagoula and Crude Oil Line to Mobile				
	Perry County	Jones County (Brine Injection/ Blanket Oil Line Only)	Perry County	Greene County	George County	Jackson County (Dual-Purpose Pipeline and Pascagoula Port Only)	Mobile County (Crude Oil Pipeline Only)
Frecklebelly Madtom							X (12)
Marine/Estuarine Fish[3]							
Gulf (Atlantic) Sturgeon,							X (11)
TOTAL SPECIES	7		9			13	42
			15 - Total for Dual-Purpose Pipeline and Pascagoula Port 42 - Total for Mobile Crude Oil Pipeline				

NOTES

1. Numbers in parenthesis refer to the information source; refer to List of Sources for Endangered Species (p. D-19)

2. The peregrine falcon and its two subspecies (i.e., American and Arctic) are counted as one species.

3. The gulf sturgeon is included in this table and the brine diffuser tables (Table D.1-9) because it may be found in estuarine areas that are within county boundaries.

Table D.1-8
Endangered or Threatened Species: Richton (Pipeline to Liberty)[1,2]

Common Names of Endangered or Threatened Species	Crude Oil Pipeline From Richton to Liberty						
	Perry County	Pike County	Walthall County	Marion County	Lamar County	Forrest County	Greene County
Birds							
Red-cockaded Woodpecker	X (6)			X (8)		X (8)	X (8)
Terrestrial Mammals							
(Louisiana) Black Bear	X (6)			X (8)	X (8)		
Florida Panther				X (8)			
Gray Bat						X (8)	
Red Wolf							
Terrestrial/Freshwater Reptiles and Amphibians							
American Alligator	X (6)	X (8)					X (8)
Black Pine Snake	X (6)			X (8)	X (8)	X (8)	
Eastern Indigo Snake	X (6)					X (8)	
Gopher Tortoise	X (6)			X (8)	X (8)	X (8)	X (8)
Rainbow Snake					X (8)	X (8)	
Ringed Sawback Turtle				X (8)		X (8)	
Southern Hognose Snake						X (8)	
Yellow-blotched Sawback Turtle	X (6)						X (8)

NOTE: Numbers in Parenthesis refer to information source; see List of Sources for Endangered Species (p. D-19)

Table D.1-8 (continued)

Common Names of Endangered or Threatened Species	Crude Oil Pipeline From Richton to Liberty						
	Perry County	Pike County	Walthall County	Marion County	Lamar County	Forrest County	Greene County
Freshwater Fish							
Crystal Darter				X (8)			
Frecklebelly Madtom		X (8)	X (8)	X (8)			
Marine/Estuarine Fish							
Atlantic Sturgeon		X (8)	X (8)				
TOTAL SPECIES	17						

NOTES

1. Numbers in parenthesis refer to the source of information; refer to List of Sources for Endangered Species (p. D-19)

2. Although the pipeline goes through Amite county, no endangered or threatened species have been reported.

Table D.1-9
Endangered or Threatened Species: Brine Diffusers in the Gulf[1]

Common Name of Endangered or Threatened Species	Western Gulf[2]	Eastern Gulf[2]
Marine/Estuarine Fish		
Gulf (Atlantic) Sturgeon		X (16)
Marine Mammals		
Atlantic Spotted Dolphin	X (2)	X (15)
Blue Whale	X (2)	X (8)
Dwarf Sperm Whale	X (2)	X (15)
False Killer Whale	X (2)	X (15)
Finback Whale	X (2)	X (15)
Gervais' Beaked Whale	X (2)	X (15)
Goose-beaked Whale	X (2)	X (15)
Killer Whale	X (2)	X (15)
Pygmy Killer Whale	X (2)	X (15)
Pygmy Sperm Whale	X (2)	X (15)
Right Whale	X (2)	X (15)
Rough-toothed Dolphin	X (2)	X (15)
Sei Whale	X (2)	X (15)
Short-finned Pilot Whale	X (2)	X (15)
Sperm Whale	X (2)	X (15)
West Indian Manatee		X (10)
Marine Turtles		
Atlantic Green Sea Turtle	X (2)	X (8)
Kemp's (Atlantic) Ridley Sea Turtle	X (2)	X (17)
Leatherback Sea Turtle	X (2)	X (17)
Loggerhead Sea Turtle	X (2)	X (8)
TOTAL SPECIES	19	21

NOTES

1. Numbers in parenthesis refer to the source of information; refer to List of Sources for Endangered Species (p. D-19)

2. "Western" and "Eastern" Gulf are defined for this table as west or east of the Mississippi River Estuarine System. The brine diffusers associated with Stratton Ridge, Weeks Island, and Cote Blanche would be located in the Western Gulf, while the Richton diffuser would be located in the Eastern Gulf.

Sources for Endangered Species Tables (Tables D.1-1 to D.1-9)

(1) Texas Natural Heritage Program (Texas Parks and Wildlife Department), *Computerized Element Occurrences of Special Concern*, May 15, 1991.

(2) Texas Natural Heritage Program (Texas Parks and Wildlife Department), *Endangered/Threatened Species Data File*, May 9, 1988.

(3) Texas Natural Heritage Program (Texas Parks and Wildlife Department), *Special Plant List*, April 1, 1991.

(4) Personal Communication, *Letter from D. W. Fruge*, Field Supervisor, USDI Fish and Wildlife Service, Lafayette, Louisiana, June 7, 1991.

(5) Personal Communication, *Conversation with K. Mitchell*, USDI Fish and Wildlife Service, Lafayette, Louisiana, March 25, 1992.

(6) Mississippi Natural Heritage Program (Mississippi Department of Wildlife, Fisheries, and Parks), *Special Animals: Perry County*, January 3, 1992.

(7) Personal Communication, *Conversation with D. Sullivan*, Texas Natural Heritage Program (Texas Parks and Wildlife Department), March 24, 1992.

(8) Mississippi Natural Heritage Program (Mississippi Department of Wildlife, Fisheries, and Parks), *Special Animals*, December 12, 1991.

(9) Texas Natural Heritage Program (Texas Parks and Wildlife Department), *Endangered/Threatened Species Data File: Harris County*, May 9, 1988.

(10) Louisiana Natural Heritage Program, Louisiana Department of Wildlife and Fisheries, Habitat Conservation Division, (untitled data), received April 3, 1992.

(11) Personal Communication, *Conversation with M. Bailey*, Alabama Natural Heritage Program, May 15, 1992

(12) Personal Communication, *Conversation with M. Bailey*, Alabama Natural Heritage Program, May 15, 1992, and also found in Mount, R.H., ed., *Vertebrate Animals of Alabama in Need of Special Attention*, Alabama Agricultural Experiment Station, Auburn University, April 1986.

(13) Mount, R.H., ed., *Vertebrate Animals of Alabama in Need of Special Attention*, Alabama Agricultural Experiment Station, Auburn University, April 1986.

(14) Woehr, J.R., Nongame Program Coordinator, State of Alabama Department of Conservation and Natural Resources, *Alabama Federally Listed Endangered/Threatened Species*, October 16, 1991.

Sources for Endangered Species Tables (Tables D.1-1 - D.1-9) (cont.)

(15) Mullin, K., W. Hoggard, C. Roden, R. Lohoefener, C. Rogers, and B. Taggart, *Cetaceans on the Upper Continental Slope in the North-Central Gulf of Mexico*, U.S. Department of the Interior, Minerals Management Service, Gulf of Mexico OCS Regional Office, New Orleans, LA, June 1991, OCS Study/MMS 91-0027.

(16) Gilbert, C.R., *Species Profiles: Life Histories and Environmental Requirements of Coastal Fishes and Invertebrates (Mid-Atlantic Bight)--Atlantic and Shortnose Sturgeons*, U.S. Department of the Interior, Fish and Wildlife Service, Biological Report 82(11.122), U.S. Army Corps. of Engineers TR EL-82-4, 1989.

(17) Personal Communication, *Letter from C. Oravetz*, Chief, Protected Species Management Branch, National Marine Fisheries Service, NOAA, 'Endangered and Threatened Species and Critical Habitats Under NMFS Jurisdiction: Louisiana,' (undated).

(18) Mississippi Natural Heritage Program (Mississippi Department of Wildlife, Fisheries, and Parks), *Special Animals*, Jones County, August 25, 1992.

The remainder of this Appendix presents additional information on the endangered and threatened species reported to occur within the study area. Species are divided into those found predominantly in terrestrial or freshwater areas (section D.2) and those found predominantly in marine or estuarine areas (section D.3).

D.2 Terrestrial or Freshwater Species

D.2.1 Plants

Prairie dawn (Texas bitterweed) is the only endangered or threatened species of plant listed as occurring within the study area.

D.2.2 Birds

Twenty-seven endangered or threatened species or subspecies of birds are listed as being found within the study area. Ten of these species are listed as endangered or threatened at the Federal level: brown pelican, bald eagle, peregrine falcon, Attwater's greater prairie chicken, whooping crane, Mississippi sandhill crane, wood stork, piping plover, interior least tern, and red-cockaded woodpecker. The remainder are listed as endangered or threatened only at the state level.

The majority of these species are most likely to be found in coastal or offshore areas (see section D.3.3 below). Upland/freshwater species include bald eagle, American swallow-tailed kite, white-tailed hawk, Attwater's greater prairie chicken, sandhill crane, wood stork, white-faced ibis, interior least tern, rose-throated becard, red-cockaded woodpecker, Bewick's wren, and Bachman's sparrow.[3] Five of these upland/freshwater species are Federal endangered species: bald eagle, Attwater's greater prairie chicken, interior least tern, Mississippi sandhill crane, and red-cockaded woodpecker.

Of the federally endangered or threatened species, USFWS has expressed some concern about four species: the brown pelican, the bald eagle, the piping plover, and the red-cockaded woodpecker. Detailed information on these four species is provided in Appendix F.

D.2.3 Mammals

Federally endangered species of terrestrial mammals listed as inhabiting the study area include the Florida panther, Jaguarundi, red wolf, and gray bat. The black bear is on the Federal threatened list, while Rafinesque's big-eared bat, southeastern bat, and Brazilian free-tailed bat are endangered or threatened only at the state level. USFWS has expressed some concern about the Louisiana black bear, and detailed information on that species is provided in Appendix F.

D.2.4 Reptiles/Amphibians

Twenty-four species of endangered or threatened reptiles or amphibians are listed as occurring within the study area. These include alligator, Houston toad, Texas horned lizard, eight species of turtles or tortoises, and eleven species of snakes. Alligators, which once were considered endangered, are numerous in the study area, and in many areas numerous nuisance reports concerning alligators are filed each year. Their Federal status is now "threatened due to similarity of appearance (T/SA)", because the alligator closely resembles the American crocodile (*Crocodylus acutus*), a Federal endangered species. Because of its T/SA status, state authorities closely regulate harvesting of the alligator by issuing a limited number of hunting permits and by tracking skins through the manufacturing process. This helps ensure that all "reptilian skin" products (e.g., belts, handbags) are from alligators and not from the endangered crocodile. USFWS has expressed some concern about five species: the Alabama red-bellied turtle, the ringed sawback turtle, the yellow blotched map turtle, and the gopher tortoise and the eastern indigo snake. Additional information on these species is provided in Appendix F.

D.2.5 Fish

Five endangered or threatened species of freshwater fish are listed as occurring within the study area: paddlefish, blue sucker, creek chubsucker, crystal darter, and frecklebelly madtom. None of these species are endangered or threatened at the Federal level.

D.2.6 Freshwater Invertebrates

One Federally threatened freshwater invertebrate is listed as occurring within the study area: the range of inflated heelsplitter, a species of clam, includes the Pearl River and Mobile Bay.

D.2.7 Insects

One Federally endangered insect is listed as occurring in the study area: the range of the American burying beetle includes Mobile, Alabama.

D.3 Marine/Estuarine Species

D.3.1 Fish

Two species of endangered or threatened fish are known to inhabit nearshore waters of the northern Gulf of Mexico. Both are species of sturgeon: Pallid sturgeon, and Gulf sturgeon, a subspecies of the Atlantic Sturgeon. Sturgeon are large (1 to 2.5 meters in length), fish that feed indiscriminately on bottom dwelling animals, insects, and plants. Most species hatch and mature in estuaries or rivers, and then spend the majority of their adult lives in brackish or salt water, returning to rivers and estuaries to spawn. The Gulf sturgeon has been identified by NMFS as a species of concern and is discussed in detail in Appendices E and F.

D.3.2 Sea Turtles

Five species of endangered or threatened sea turtles are known to inhabit the waters of the northern Gulf of Mexico: green, hawksbill, Kemp's Ridley, leatherback, and loggerhead. These turtles have been identified by NMFS as species of concern and are discussed in detail in Appendix E.

D.3.3 Birds

Sixteen endangered or threatened species or subspecies of birds are listed as being found along the northern coast of the Gulf of Mexico: brown pelican, American white pelican, American swallow-tailed kite, American oystercatcher, bald eagle, osprey, Arctic peregrine falcon, reddish egret, whooping crane, Mississippi sandhill crane, Wilson's plover, piping plover, snowy plover, interior least tern, gull-billed tern, and sooty tern. Two additional endangered species, eskimo curlew and roseate tern, also might occur within the study area. The USFWS has expressed concern about three of these species: the brown pelican, the bald eagle, and the piping plover. Additional information on these species is provided in Appendix F.

Of these species, those that feed offshore are the brown pelican, white pelican, least tern, roseate tern, gull-billed tern, and sooty tern. Ospreys feed primarily on fish and nest in coastal areas. Bald eagles feed on fish, birds, and small mammals and do not typically nest on the coast. Swallow-tailed kites are found most commonly in swamps, marshes, river banks, and open forests. Whooping cranes and reddish egrets wade in shallow bays and salt-water flats feeding primarily on crabs, clams, and other invertebrates, while sandhill cranes typically feed in dry fields. The eskimo curlew, snowy plover, piping plover, Wilson's plover, and American oystercatcher feed in intertidal areas on sandy beaches and mudflats. Peregrine falcons congregate along beaches and barrier islands preying primarily on ducks, shorebirds, and sea birds.[4,5]

Brown pelicans, white pelicans, bald eagles, reddish egrets, sandhill cranes, ospreys, and, to some extent, snowy plovers are year-round residents along the northern coast of the Gulf of Mexico, while the other species are present only for a portion of the year (snowy plovers are year-round residents in the eastern portion of the study area but are found in the western part of the study area only in winter). Whooping cranes, piping plovers, Wilson's plovers, gull-billed terns, American oystercatchers, and peregrine falcons are winter residents, swallow-tailed kites, roseate terns, and least terns are summer residents, and eskimo curlews are present only during migration between breeding grounds in the Arctic and wintering grounds in South America. Sooty terns, which have a more tropical distribution, generally are found in the northern Gulf only during hurricanes.[6]

D.3.4 Marine Mammals

Seventeen species of endangered or threatened mammals are listed as occurring in northern Gulf of Mexico waters. These include the West Indian manatee and 16 species of cetaceans (i.e., blue whale, fin whale, sei whale, humpback whale, right whale, sperm whale, dwarf sperm whale, pygmy sperm whale, killer whale, false killer whale, pygmy killer whale, Gervais' beaked whale, goose-beaked whale, short-finned pilot whale, Atlantic spotted dolphin, and rough-toothed dolphin). Of these mammals, NMFS has expressed some concern about four species of baleen whales (i.e., fin, sei, humpback, and right), one species of odontoid whale (i.e., sperm), and the West Indian manatee. Additional information about each of these species is provided in Appendix E. NMFS also has expressed some concern about the bottlenose dolphin, the most abundant and common cetacean species in the Gulf of Mexico, although this species is not currently endangered or threatened. Additional information on the bottlenose dolphin is provided below.

D.3.4.1 Bottlenose Dolphins

Bottlenose dolphins (*Tursiops truncatus*) are the most abundant cetacean in the Gulf of Mexico, inhabiting bays, inland waterways, ship channels, and continental shelf waters. An open water survey, conducted by the NMFS Miami Laboratory, estimated that Gulf of Mexico waters (zero to 183 meters deep) support between 35,000 and 45,000 bottlenose dolphins,[7] while another study, conducted by the NMFS Pascagoula Laboratory, estimated that about 16,500 bottlenose dolphins inhabit U.S. coastal Gulf waters.[8] A separate survey estimated that between 2,000 and 6,000 dolphins inhabit the coastal waters off Mississippi and Louisiana.[9] Density estimates for the various areas along the northern and western Gulf shores include:

- 0.23 dolphins/mile^2 (Mississippi, general);[10]
- 0.7 dolphins/mile^2 (Marsh Island, Louisiana);[11] and
- 0.75 dolphins/mile^2 (Texas, general).[12]

Bottlenose dolphins have a diverse diet, feeding on whatever species are regionally or seasonally abundant. Stomach contents of bottlenose dolphins stranded along the Texas, Louisiana, Mississippi, and Alabama coasts indicate that their diet consists principally of fish, but they also eat cephalopods and shrimp.[13] For much of the year, Gulf of Mexico dolphins follow shrimp trawlers, feeding on items stirred up by the trawl, fish attracted to anchored boats, and trash fish discarded by fishermen.[14] Other feeding strategies include surrounding schools of fish as a group, and trapping schools of fish in shallow waters or against shoals or mud banks. In bay areas, summer populations are about half the size of winter populations, because in the Gulf there are resident populations which remain in nearshore areas year round, and migratory populations that spend the summer months offshore but follow fish into nearshore areas in winter.[15] Observations in Mississippi Sound and Matagorda Bay, Texas suggest that these areas support resident populations of bottlenose dolphins. Resident populations would be likely to switch prey with changing seasonal abundances.[16,17]

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APPENDIX E

BIOLOGICAL ASSESSMENT

for

THREATENED AND ENDANGERED MARINE SPECIES

Submitted

to

National Marine Fisheries Service

by

U.S. Department of Energy
Strategic Petroleum Reserve Office

prepared by

ICF Incorporated
9300 Lee Highway
Fairfax, VA 22031-1207

(Included as Appendix E in the DEIS
on the Expansion of the Strategic Petroleum Reserve)

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E.1 Background

The U.S. Department of Energy's (U.S. DOE) proposed plan to expand the Strategic Petroleum Reserve (SPR) to one billion barrels would require new buried brine and oil distribution pipelines and offshore brine discharge sites. A leaching process is used to create storage caverns in underground salt domes. The resulting brine is disposed either via underground injection or by pumping to the Gulf of Mexico through a buried pipeline and dispersing it into the Gulf. For a more extensive description of the proposed project, see Chapter 3 of the Draft Environmental Impact Statement (DEIS.)

DOE has used a comprehensive three-phased site screening procedure to reduce over 550 onshore and offshore salt domes in the Gulf Coast to specific candidate sites for further environmental assessment under the National Environmental Policy Act (NEPA). Initial site screening was performed in 1988 and resulted in an initial list of 30 and a short list of seven candidate salt domes. Site screening included technical, environmental, and cost criteria and was detailed in DOE's 1989 Report to Congress on expansion of the SPR. In 1990, the initial list of 30 salt domes was re-assessed in terms of the SPR's expansion and distribution objectives, geotechnical characteristics, and environmental aspects. This screening process yielded eight candidate sites for expansion of the SPR to one billion barrels; four in Texas and four in Louisiana, which were discussed in DOE's 1991 Report to Congress.

During the NEPA scoping process, DOE narrowed the number of candidate sites to four based on cost and distribution factors, and then added an additional candidate site to the list for environmental impact assessment. In this DEIS, DOE is assessing five sites: Big Hill and Stratton Ridge in Texas for expansion in the SPR Seaway Complex, and Weeks Island and Cote Blanche in Louisiana and Richton in Mississippi for expansion in the SPR Capline Complex. DOE will choose two sites for expansion.

This biological assessment discusses the possible impacts to marine threatened and endangered species from three components of the proposed SPR expansion plan: (1) offshore pipeline construction; (2) brine discharge into the Gulf of Mexico, system maintenance, and possible brine spills, and; (3) possible oil spill accidents. Twelve federally endangered or threatened marine species and one anadromous fish species are discussed. For the purposes of this biological assessment, there is no difference between the two Louisiana sites (Weeks Island and Cote Blanche), because the same brine pipeline route and diffuser location would be used for either site.

The diffuser locations in the Gulf for the proposed expansion sites are described in Table E.1-1.

The locations of the five candidate sites are shown in Figure E.1-1. The existing brine disposal and proposed oil distribution pipeline routes for Big Hill are shown in Figures E.1-2 and E.1-3, respectively. The proposed brine disposal pipelines for Stratton Ridge, Weeks Island and Cote Blanche sites (the same proposed brine disposal pipeline route for either site), and Richton are shown in Figures E.1-4 to E.1-6.

In March 1980, DOE first began discharging brine from Bryan Mound through a multiport diffuser, which is located in 71 ft (21.6 m) of water, 10.8 nm (20 km) offshore of Freeport, Texas. Additional brine discharge began in May 1981 through the West Hackberry multiport diffuser

Table E.1-1
Diffuser Locations for Proposed SPR Expansion Site Brine Disposal Systems

Site Name	Site Location Lat. - Long.	Depth ft(m)
Stratton Ridge (Offshore Freeport, TX)	28° 56.0' N 95° 13.37'W	36 (11.0)
Weeks Island/Cote Blanche (West of Marsh Island)	29° 24.8' N 92° 16.1' W	25 (7.62)
Richton (Offshore Pascagoula, MS)	30° 10.40' N 88° 37.33' W	47 (14.33)

located in 32 ft (9.8 m) of water, 5.4 nm (10 km) offshore of Holly Beach, Louisiana. Monitoring studies at these two existing sites have provided data to develop an empirical model.

E.2 Assumptions and Methodology

The assumptions and methodology used to prepare this biological assessment are described in this section. First, a summary of the methodology used to predict brine plume dispersion is described. Second, DOE's contacts with Federal agencies and experts (used to determine threatened or endangered species of concern) is described. Third, DOE's strategy for reviewing appropriate literature is discussed.

E.2.1 Empirical Prediction of Site-specific Plume Characteristics

A more extensive description of methods described in detail in Appendix O of the DEIS.

The empirical brine plume prediction model was used to predict the negatively buoyant brine plume characteristics for a range of site-specific scenarios at the proposed Stratton Ridge, Weeks Island/Cote Blanche, and Richton diffuser locations. These scenarios were developed using different sources of information that provide baseline data for areas near the proposed diffuser sites. The following sections describe the data and assumptions used in developing these scenarios for each of the proposed sites.

The brine plume measurements from the Bryan Mound and West Hackberry sites were used to develop an empirical model, which predicts the brine plume areal extent, the vertical extent of the brine jet, and the above-ambient salinity contours. This model has been used to estimate plume concentration and extent the proposed diffuser location for Stratton Ridge, Weeks Island/Cote Blanche, and Richton.

Figure E.1-1
Candidate SPR Storage Sites

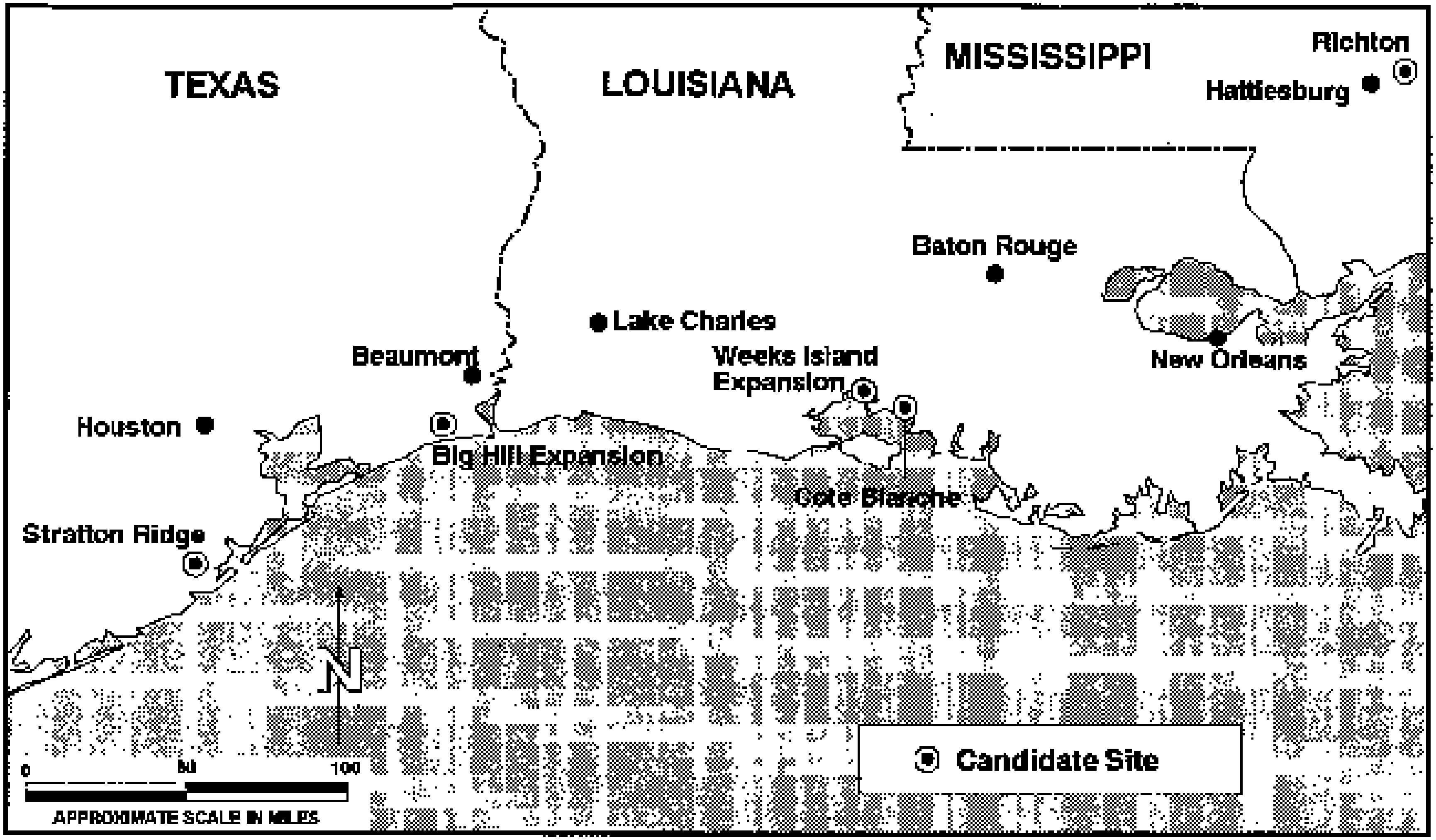
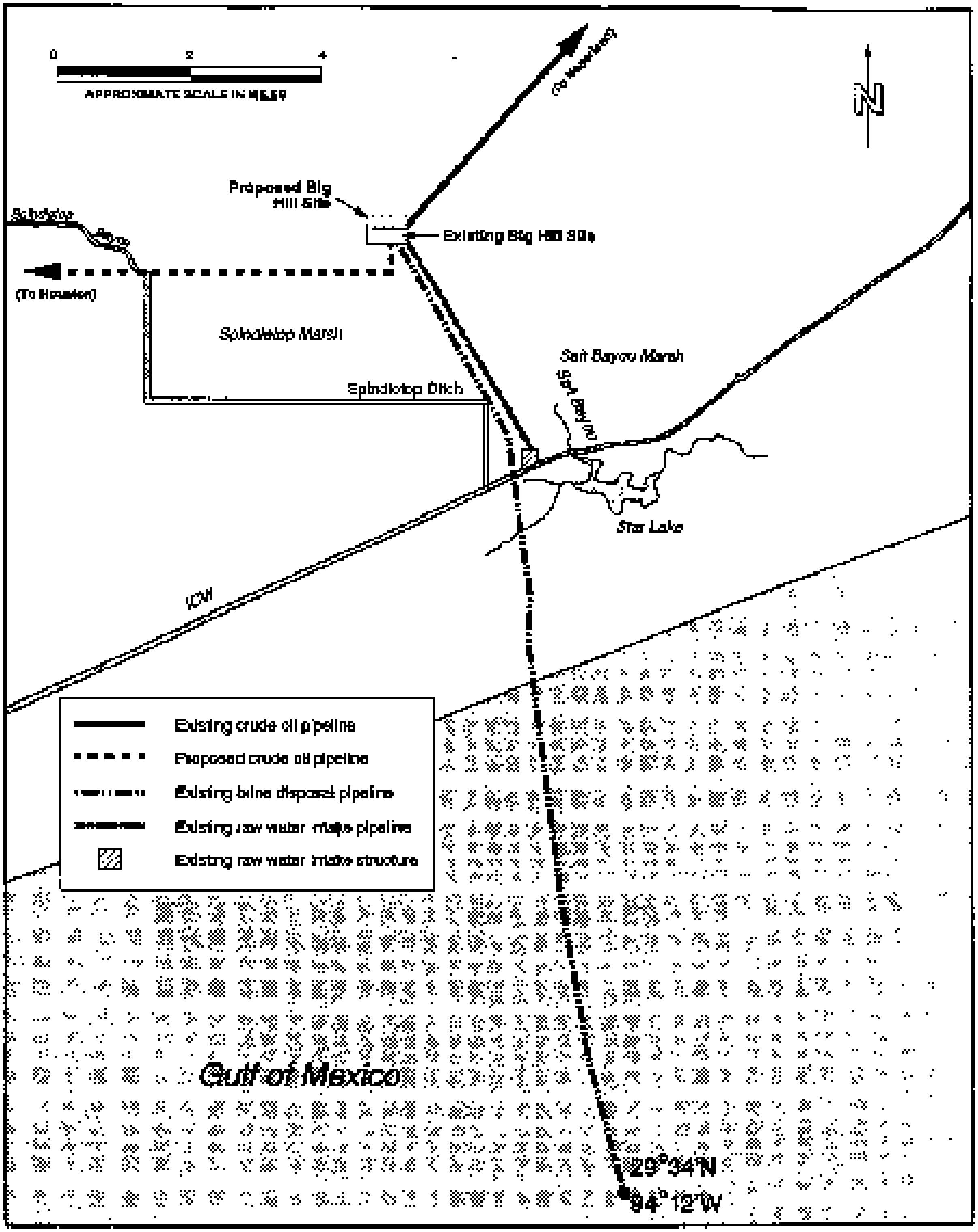


Figure E.1-2
Existing Raw Water Intake and Brine Disposal Systems for Big Hill



Source: Walk, Haydel, & Associates, Inc., *Big Hill Oil Storage Complex*, Jefferson County, Texas – Big Hill to the Gulf of Mexico Raw Water and Brine Disposal Pipelines, Baton Rouge, Louisiana.

Figure E.3-3
Proposed Crude Oil Pipelines for Big Hill

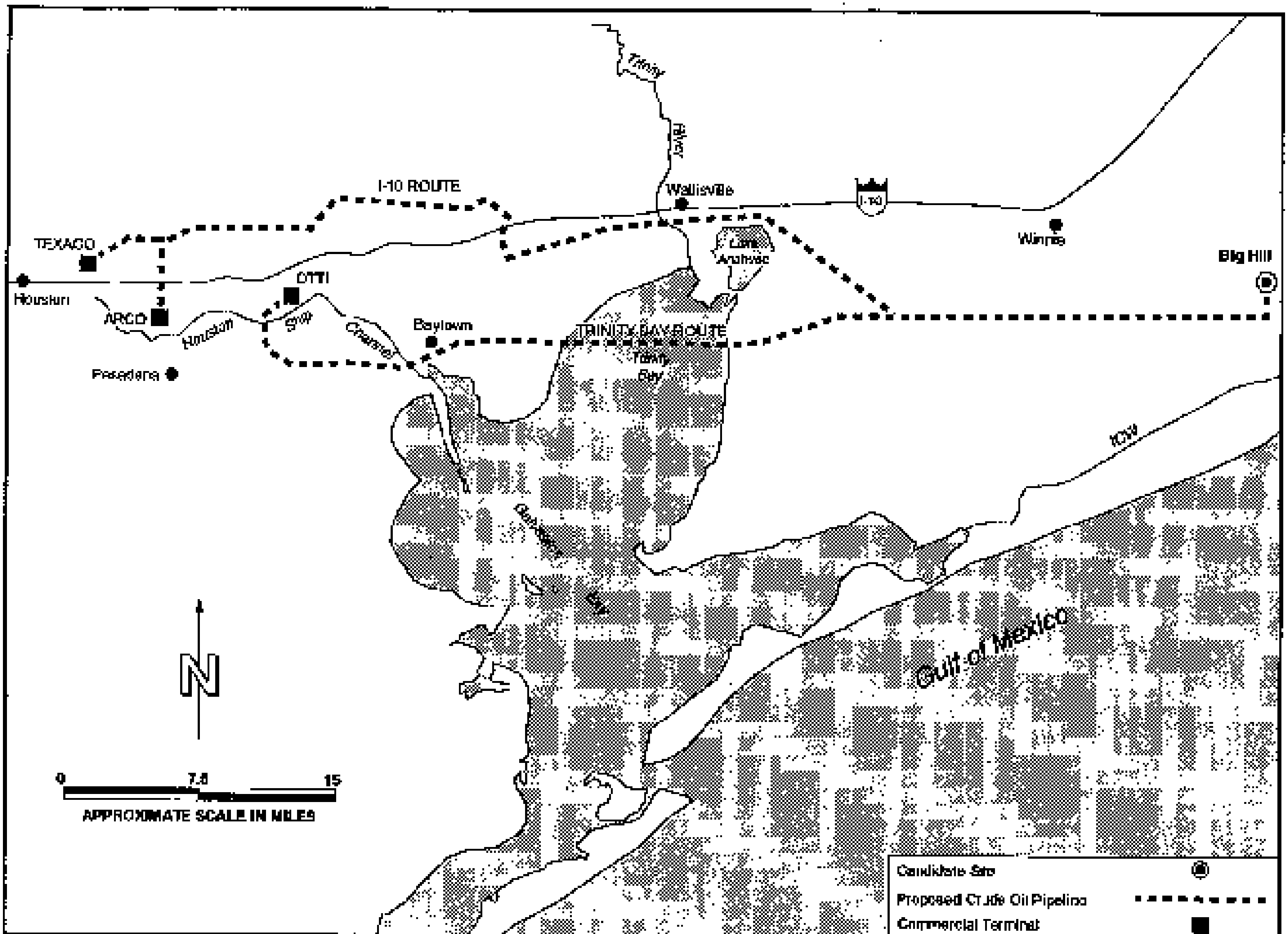


Figure E.1-4
Proposed Brine Disposal, Raw Water Intake,
and Crude Oil Systems for Stratton Ridge

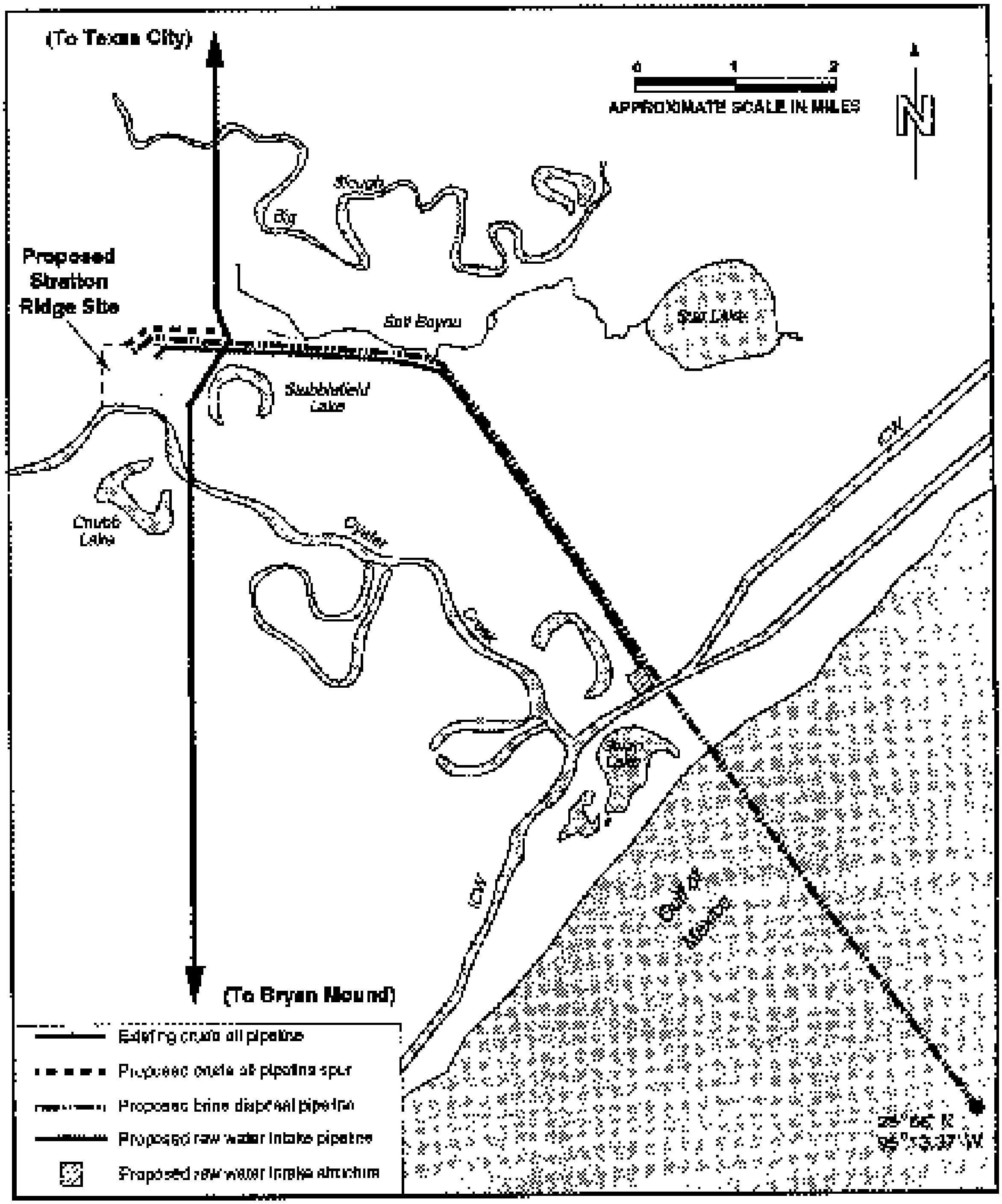
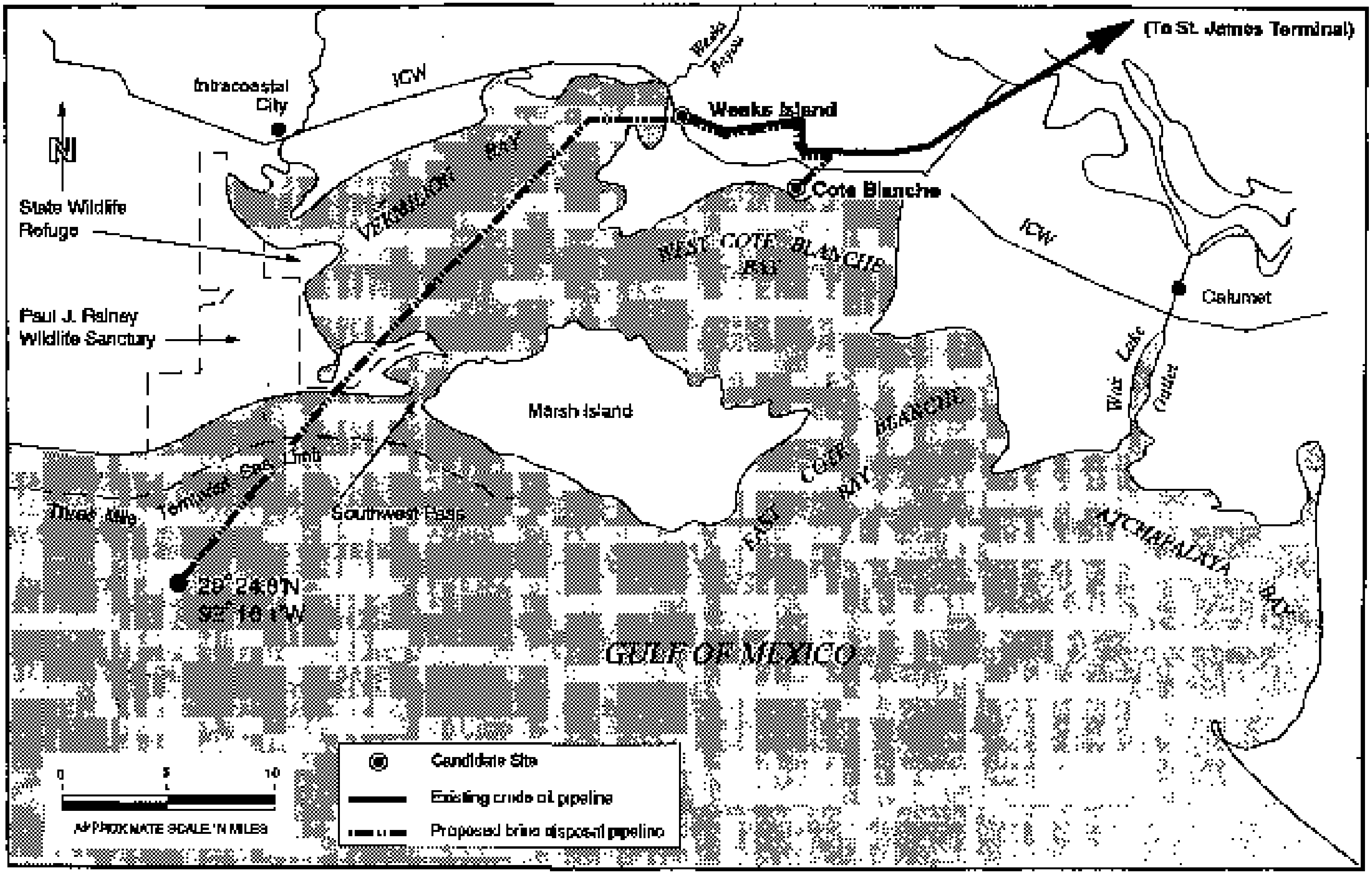
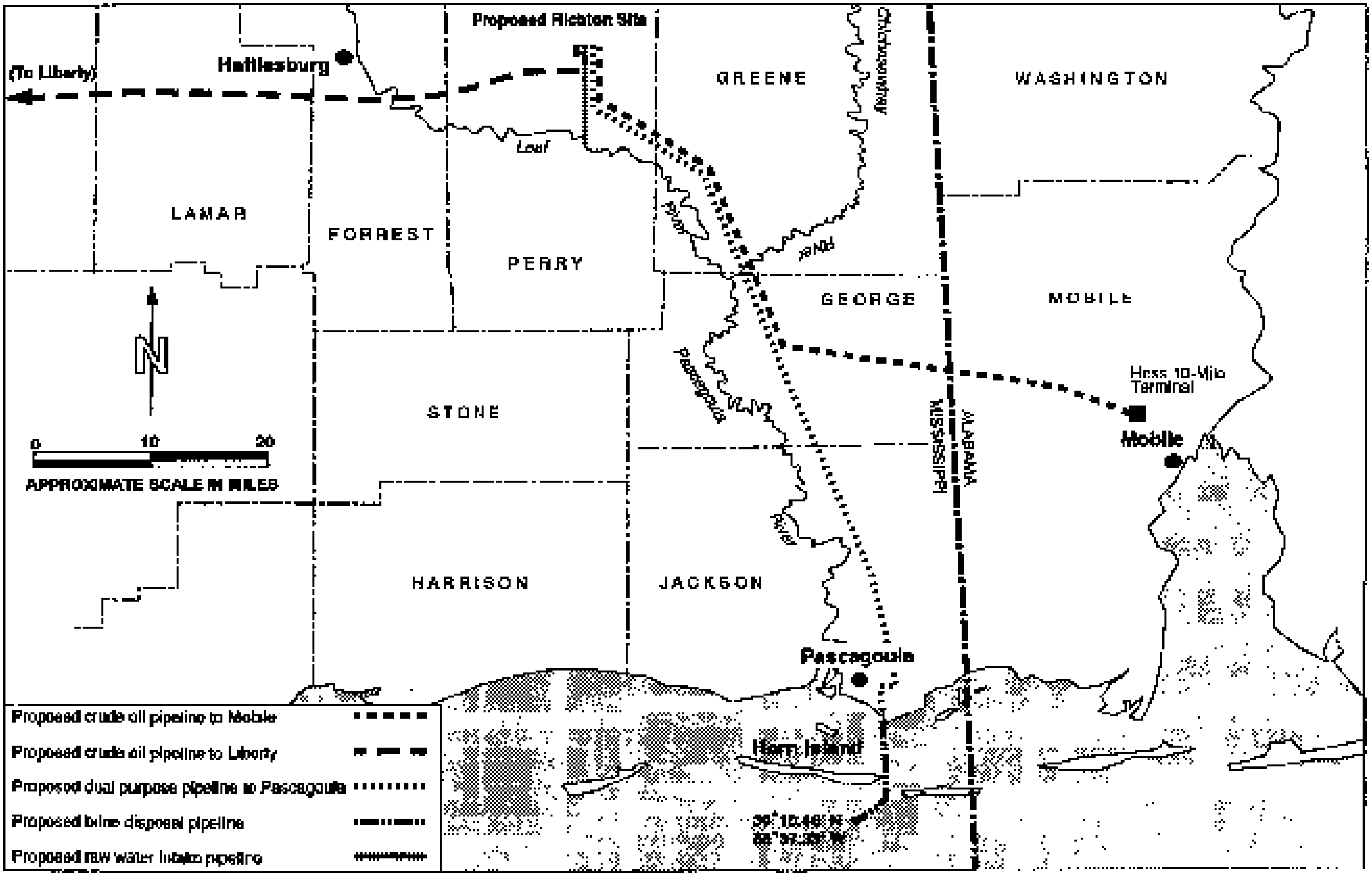


Figure E.1-5
Proposed Brine Disposal System (Diffuser) for Weeks Island/Cote Blanche



Source: PB-KBB Inc., Brine Pipeline Maps of Weeks Island on National Oceanic and Atmospheric Administration nautical charts.

Figure E.1-6
Proposed Crude Oil and Brine Disposal Systems for Richton



Source: 1) PB-KBB Inc., *Richton Dome Pipeline System*, Sheets 1-7, Houston, Texas, 2) Conversation with U.S. Department of Energy

Table E.2-1
Predicted Size of the Brine Plumes

	Predicted Size of the Brine Plumes (nm^2)					
	Maximum Case		Typical-Case		Best-Case	
	1ppt contour	3ppt contour	1ppt contour	3ppt contour	1ppt contour	3ppt contour
Stratton Ridge	23.6	6.9	5.9	1.6	2.6	0.6
Weeks Island/ Cote Blanche	29.3	8.7	6.3	1.7	2.6	0.6
Richton[a]	21.3	6.3	9.1	2.6	6.4	1.7

[a] NOTE: For Richton, "typical" = typical case with 0.06 m/sec bottom current; "best" = typical case with 0.09 m/sec bottom current.

E.2.1.1 Stratton Ridge

This section summarizes the conditions and results for predicted maximum brine plume conditions at Stratton Ridge based on 55 open diffuser ports. For information on conditions and results of other scenarios and a discussion of the modeling process, see Appendix Q of the DEIS. (See Figure E.2-1).

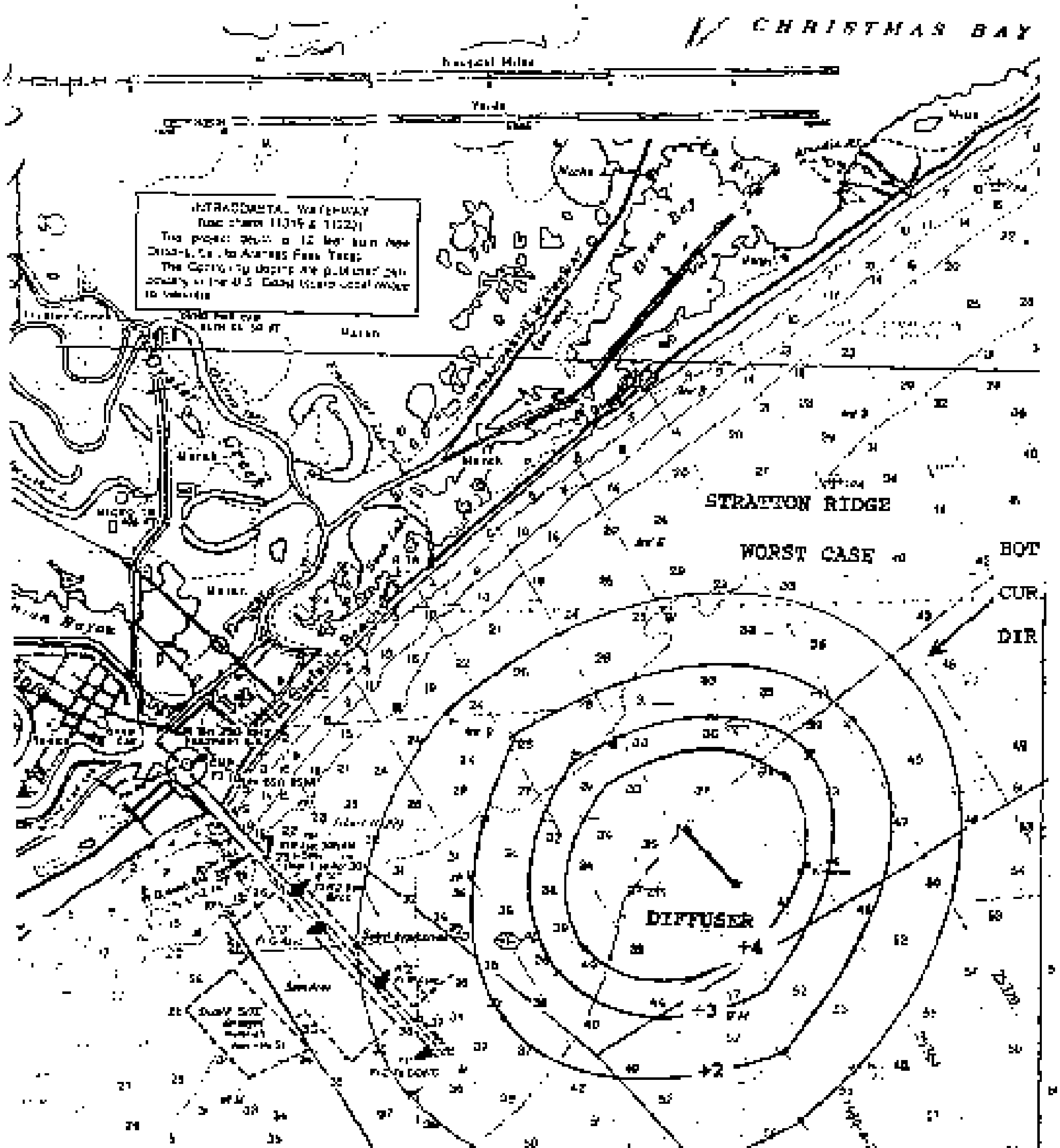
<u>**Maximum-Case Results.**</u> The maximum-case plume occurs at Stratton Ridge with an ambient bottom salinity of 25 ppt, an ambient bottom temperature of 15 °C, and a bottom current of 0.03 m/s. The brine is saturated with a temperature of 20 °C and a salinity of 263 ppt and exits the diffuser vertically through 3-inch diameter ports at 30 ft/s.

Figure E.2-1 presents the maximum brine plume when 55 diffuser ports are open. The maximum above-ambient bottom salinity is predicted to be +4.7 ppt. The ambient bottom current is 3 cm/s in the downcoast direction. The +1 ppt contour extends 3.4 nm from the center of the diffuser and extends to the outer portion of the Freeport ship channel. The +2, +3, +4 ppt contours extend 2.4, 1.8, and 1.5 nm, respectively. The predicted areal extents for the +1 through 4 ppt contours are 23.6, 13.4, 6.9 and 4.2 nm^2, respectively. The widths are 4.5, 3.5, 2.4 and 1.8 nm, and the upstream lengths are 2.0, 1.4, 1.0 and 0.7 nm for the +1 to 4 ppt contours, respectively. The vertical extent (i.e., height) of the brine jet is predicted to reach 18.4 feet above the ocean floor and 17.6 feet below the water surface. Although, the +1 contour reaches within 1 nm of Surfside Beach, the bottom slope is expected to prevent the plume from extending close to shore.

E.2.1.2 Weeks Island/Cote Blanche

This section presents the conditions and results for the three scenarios at the proposed Weeks Island/Cote Blanche brine diffuser location. For information on conditions and results of

Figure E.2-1
Predicted Radial Extent of Large (Maximum-Case) Brine Plume Contours for Proposed Stratton Ridge Diffuser Site



other scenarios and a discussion of the modeling process, see Appendix Q of the DEIS. The predicted brine plumes resulting from disposal through 55 open ports are plotted on bathymetric maps (See Figure E.2-2).

Maximum-Case Results. The maximum-case predicted plume is illustrated in Figure E.2-2 The elliptical shaped contours cover areas of 29.3, 16.7, 8.7 and 5.2 nm^2 for the +1 through +4 ppt contours, respectively. The bottom current direction is alongshore to the west. The plume is about 4.5 nm from the nearest shoreline and does not impact the Freshwater Bayou channel. The +1 through +4 contours have maximum widths of 5.4, 4.3, 2.9, and 2.3 nm and total maximum lengths (downstream plus upstream lengths) of 6.6, 4.6, 3.5 and 2.8 nm, respectively. The vertical extent of the brine jet is predicted to reach 18.2 ft or 6.8 ft below the water surface. This exceeds the recommendation of maintaining a 10 ft clearance between the ocean surface and highest point of the jet.

E.2.1.3 Richton

This section summarizes the conditions and results for the maximum-case scenario at Richton. For information on conditions and results of other scenarios and a discussion of the modeling process, see Appendix Q of the DEIS.

Maximum-Case Results. The maximum-case (large) plume at the Richton site occurs with an ambient bottom salinity of 25 ppt, an ambient bottom temperature of 15°C, and a bottom current of 0.03 m/s. The brine is exiting vertically through 3 in diameter ports at a velocity of 27 ft/s, at a temperature of 20°C, and saturated salinity of 263 ppt.

The maximum above-ambient bottom salinity is predicted to be 5.3 ppt, meaning that there are five above-ambient bottom salinity contours. The bottom areas of these contours are predicted to cover 21.3, 12.1, 6.3, 3.7, and 1.7 nm^2 for the +1 through +5 ppt contours, respectively. The estimated maximum plume widths are 4.3, 3.4, 2.3, 1.7, and 0.9 nm for the respective contours. The +1 through +5 plumes extend 3.2, 2.3, 1.7, 1.5, and 1.2 nm downstream and 1.9, 1.3, 1.0, 0.7, and 0.6 nm upstream from the diffuser center, respectively. The vertical extent of the brine jet is predicted to be 17 ft, which is 26 ft below the water surface.

Figure E.2-3 illustrates the maximum-case brine plume. The maximum above-ambient bottom salinity is 5.3 ppt; the highest above-ambient bottom salinity contour is expected to be +5 ppt. The ambient bottom current is 3 cm/s in the northeast direction. The +1 ppt contour extends 3.2 nm from the center of the diffuser and remains as close as 0.4 nm offshore Horn Island, a barrier island offshore of Pascagoula, Mississippi, and 1.2 nm from the Horn Island Pass Channel entrance. However, the sloping bottom near Horn Island is expected to prevent the plume from actually approaching this point as the model only considers flat bottom areas. In addition, each salinity contour of the predicted brine plume covers the western portion of the designated dredged material disposal area offshore of Horn Island. The predicted plume does not enter Mississippi Sound.

E.2.2 Contact with Federal Agencies and Experts

For this biological assessment, DOE contacted personnel from appropriate Federal agencies as well as other recognized experts familiar with the study areas to determine the species of concern for which there was a possibility of impact. (For a complete list of Federally and State

Figure E.2-2
Predicted Large (Maximum-Case) Brine Plume Contours for the
Weeks Island/Cote Blanche Diffuser Site for Selected Bottom Current Direction

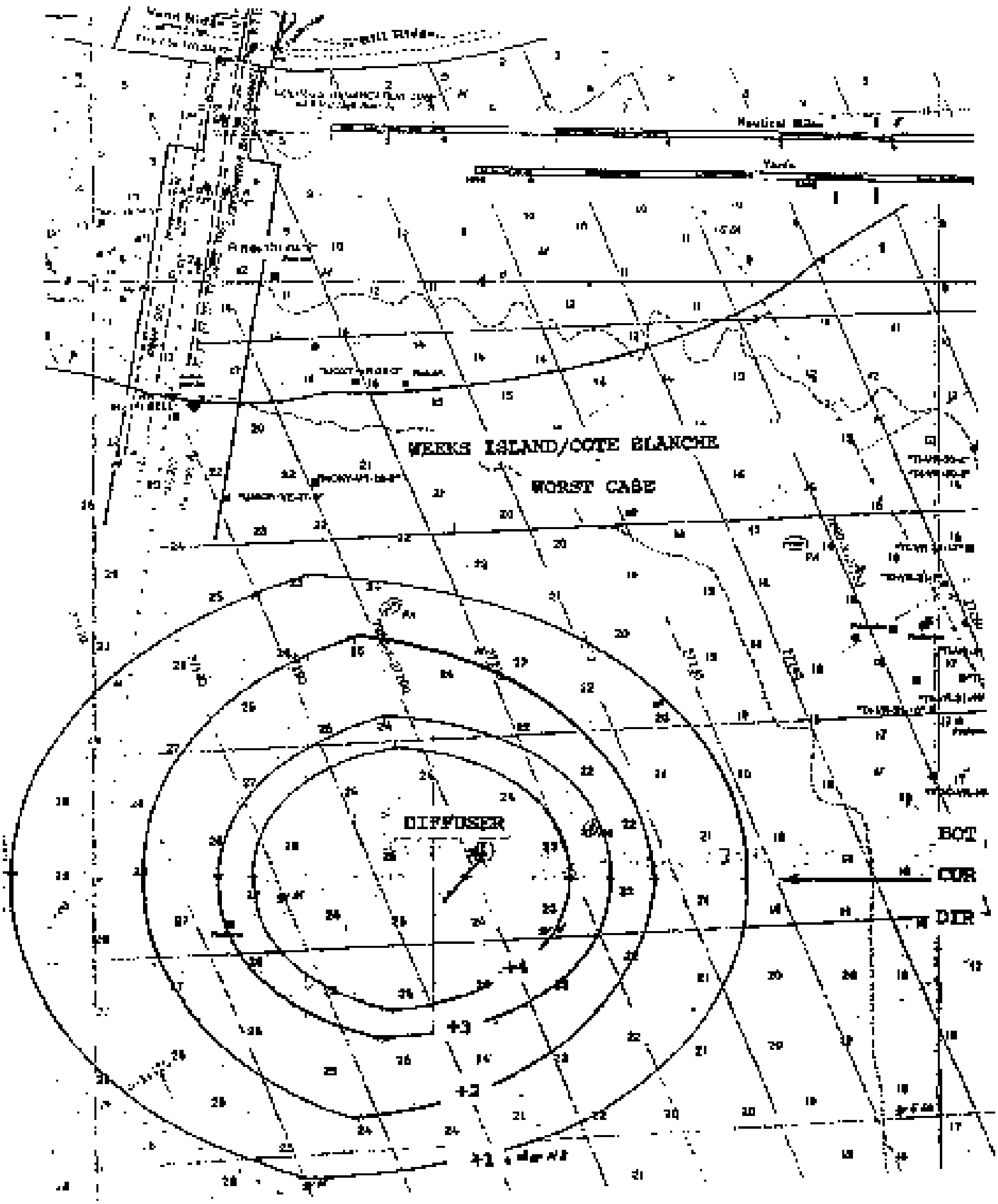
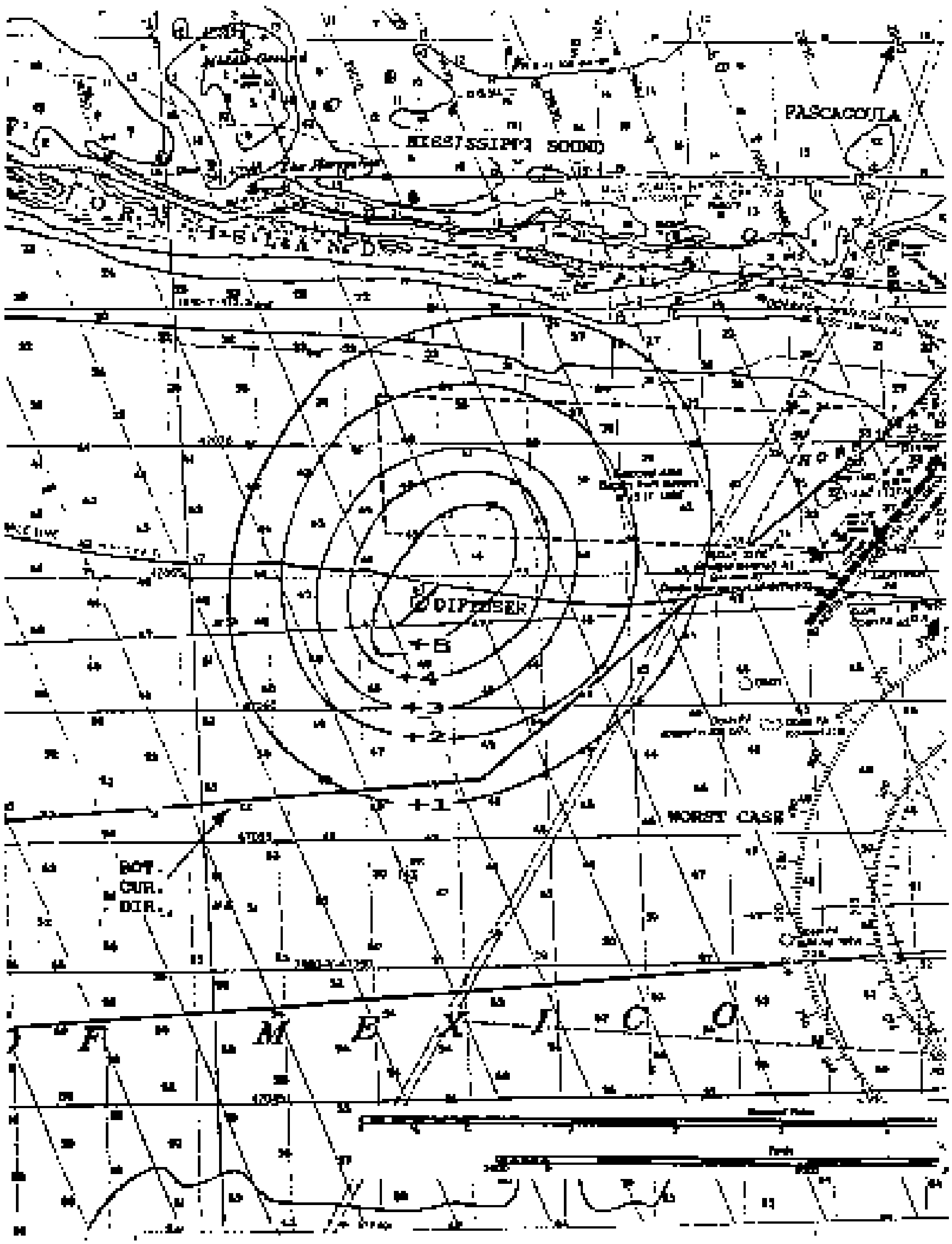


Figure E.2-3
Predicted Large (Maximum-Case) Brine Plume Contours
For Richton Diffuser Site



endangered or threatened species in the study area, see Appendix D of the DEIS.) These contacts are listed in Table E.2-2.

E.2.3 Literature Review

A literature search was conducted to identify site-specific information on each species; the purpose of this search was to identify the most recent published information on each species, especially with respect to population distribution in the Gulf of Mexico and conservation related issues. A selected retrieval was conducted to obtain articles that reflected the most current information that pertained to the species in the Gulf, especially along the coasts of Mississippi, Louisiana, and Texas. Resources were also received from Dr. Keith Mullin (NMFS) and from Dr. Peter Lutz.

E.3 Assessment

The first sections E.3.1, E.3.2, and E.3.3. of this assessment provides an overview of all potential environmental impacts associated with the aspects of the proposed SPR expansion plan that may impact marine habitats. Next, a summary of relevant biological information for each endangered or threatened species of concern is given in section E.3.4, followed by a discussion of potential direct impacts to these specific endangered and threatened species in sections E.3.5, E.3.6, and E.3.7. This is followed in section E.3.8 by a discussion of cumulative impacts that may impact the endangered or threatened species of concern in the Gulf of Mexico. The last section, E.3.9, of this assessment suggests possible steps to minimize any possible impacts to endangered and threatened species through site specific utilization of various construction-related mitigation options.

E.3.1 Potential Impacts Associated With Brine Pipeline Construction

Pipeline construction in the Gulf of Mexico generally would require a trench below the ocean floor. Pipeline construction differs for coastal (i.e., within water depths of twelve to 15 feet) and offshore (i.e., beyond water depths of twelve to 15 feet) waters. In coastal waters, a mechanical dredge (e.g., clam bucket or drag line dredge) is used to excavate the pipeline route. Afterwards, the pipeline is sequentially assembled on a pipelay barge and then pushed off the pipe ramp. Flotation buoys keep the pipeline suspended in the water before it is allowed to descend into the right-of-way (ROW).

In offshore waters, excavation of the pipeline ROW occurs after the pipeline is laid. The pipeline is first assembled sequentially on a lay barge with a conveyor system and lowered to the Gulf floor. A dredging sled, mounted on the stern of the trenching barge, is then lowered to the ocean floor and positioned over the laid pipe. Hydraulic jets on the sled displace the bottom material around the pipe. The pipeline then settles into the trench previously occupied by the displaced bottom material. Depending on the area's environmental sensitivity, the resulting suspended bottom material is either allowed to dissipate in the Gulf water or it is collected and disposed in a spoils area.

As a result of dredging, sediments and associated contaminants become suspended in the water. Dredged material would be held suspended in the water column at the dredging site by wave action or currents, until it was transported by natural forces from the area or biologically fixed. Potential water column impacts in the Gulf might include temporary increases in turbidity,

Table E.2-2
Contacts for Threatened and Endangered Species Information

Source	Agency	Date(s) of Contact
Dr. Jeff Brown, Fishery Biologist	Southeast Regional Office, NMFS	November 5, 1991 August 5, 1992
Mr. Larry Hansen	Miami, NMFS	November 6, 1991
Dr. Ed Klima, Director	Galveston Lab, NMFS	November 13, 1991
Dr. Peter Lutz, Physiologist	University of Miami, Florida	November 12, 1991
Dr. Keith D. Mullin	Southeast Fisheries Center, NMFS	October 22, 1991
Dr. Charles A. Oravetz, Chief	Protected Species Management Branch, Southeast Regional Office, NMFS	July 12, 1991

increases in suspended nutrients, increases in the level of metals and organics (e.g., hydrocarbons) near the project area, and reductions in dissolved oxygen concentrations due to increased oxygen demand as hydrocarbons and other organics are oxidized. These potential impacts are discussed below.

Major increases in turbidity. Moving material either with a bucket or a chain of buckets, mechanical dredges can suspend bottom sediments and significantly increase turbidity.[1] The size and duration of the turbidity plume depend on the number and size of dredges in the area, the skill of the dredging operators, the length of time during which dredging occurs, bottom sediment characteristics, maintenance of the equipment, and water current conditions. Turbidity increases associated with brine pipeline dredging are expected to be confined to areas near the dredging activity and should not persist for long periods. The dredging period itself would be short, and suspended sediments would be expected to settle back to the bottom quickly after the construction ceases.

Increased suspended nutrients. During dredging, the possible release of phosphorus and various forms of nitrogen (nitrates, nitrites, and ammonia) in the sediments could be a concern. Nutrients tend to encourage the growth of aquatic biomass (e.g., algae and plants), accelerating the eutrophication or aging of waters and decreasing the degree to which light can penetrate. In the larger water bodies that have numerous connections with other waters, normal dilution should significantly reduce nutrient levels. However, if bottom sediments are rich in nutrients, adverse effects could occur in bays or estuaries with poor circulation.

Reduced dissolved oxygen concentrations. A decrease in dissolved oxygen concentrations during dredging could take place because many of the materials in sediment are readily oxidized, consuming dissolved oxygen in the water. Problems with low dissolved oxygen would most likely occur in waters with high organic levels in their sediments. It is probable that most sediments would settle out within one or two days, after which only a fraction of the disturbed sediment would exert a significant oxygen demand. This period could be extended somewhat, however, if an affected water body has poor circulation. Additionally, it is likely that suspended sediments would have a significant effect on the dissolved oxygen content of water only in the immediate project area.

Increased concentrations of organic pollutants and trace metals. Because land in areas surrounding the proposed brine pipeline route is used in part for agriculture, industry, and oil and gas production, the bottom sediments in affected water bodies might be contaminated with pesticides, oil, metals, hydrocarbons, and grease. These constituents, along with naturally occurring metals and organics in the sediments, subsequently might be suspended in the water column due to dredging. Heavy metals such as lead are generally less soluble than other metals, and tend to adsorb on suspended solids or combine with sulfides to form insoluble salts which quickly settle to the bottom. However, the lighter metals (e.g., nickel, chromium, and zinc) are more soluble and are less likely to adsorb onto suspended solids. These effects could reduce water quality for several days after completion of the dredging operations.

The combination of effects described above can lead to the destruction of highly productive benthic habitats such as seagrass beds, primarily due to the effects of reduced light penetration to the ocean floor (due to turbid water), and to covering of grasses with dredged materials. Although the vast majority (by area) of seagrass beds in the Gulf of Mexico occurs off the coast of Florida, coastal seagrass beds could possibly be found near the proposed SPR construction activities offshore of Texas, Louisiana, and Mississippi.[2] Seagrasses in the Northern and Western Gulf are found in protected areas such as bays and estuaries.[3] In Louisiana, areas where seagrass beds are found include the bay side of Isle Derniers, Timbalier and East Timbalier Islands, the southeastern shore of Timbalier Bay, and the western side of the Chandeleur Islands.[4] The offshore reaches of Mississippi Sound also support highly productive seagrass communities (i.e., along the northern sides of Horn, Ship, and Petit Bois Islands.)[5] Seagrass beds are among the most productive of marine habitats; they support diverse communities of benthic and pelagic organisms.

Finally, dredging operations can result in direct injury or mortality to marine animals such as sea turtles that get caught in the dredging machinery. The likelihood of this type of accident is quite low considering the relatively small area to be dredged for the proposed SPR brine diffuser pipelines.

E.3.2 Potential Impacts Associated With Brine Discharge

Extensive post-disposal analyses of bioassays and sediment and water samples from the West Hackberry and Bryan Mound diffuser sites determined that impacts associated with brine disposal at these sites have not been significant (Hann and Randall, 1981;[6] 1982;[7] 1983;[8] Hann et al., 1984(a);[9] 1984(b);[10] 1985;[11] DeRoen et al, 1982[12]). These monitoring studies are described in detail in Appendix I of the DEIS. Specifically:

- No significant biological impacts were observed at the two diffuser sites.
- Overall, levels of metals, ions, and other contaminants detected at the diffuser areas were similar to those detected at control stations.

- A general decrease in the abundance of benthic species, the most significantly impacted biological community, occurred within relatively small areas (31 to 2,000 acres at the Bryan Mound and West Hackberry diffuser sites).

- The studies suggest that demersal fish, which are reliant on benthic creatures for food, may move from the diffuser areas to feed in unaffected areas.

E.3.2.1 West Hackberry Studies[13]

Benthos. According to this monitoring study, the unstable and highly variable environment of the benthos made the detection of brine effects on the benthic community very difficult. Essentially, no catastrophic brine-related effects were identified in the study. The primary adverse effect that could be correlated with brine discharge was a general decrease in abundance of dominant species around the diffuser. While this impact was not considered to be significant, the maximum impacted area for benthos was estimated to be between 10 and 15 km^2.

Higher species abundances were found at some control stations; these were attributed to the presence of a few species (e.g., the polychaetes *Owenia fusiformis and Cirratulus hedgpethi*) in very large numbers. On the other hand, species diversity was significantly higher at diffuser stations than at the controls. The brine area had a greater abundance of rare species but in low numbers. The control stations, in contrast, had fewer numbers of rare species but had large populations of a few species.

Abundance and diversity data were compared to the salinity data at each station to determine the relationship between biological variations and the brine plume. The stations with salinities ranging between +4 to +6 ppt above ambient salinity had a slightly greater abundance than stations with other above ambient salinity ranges (+0 to +2, +2 to +4, and +6 to +8 ppt). The stations with above ambient salinities in the +6 to +8 ppt range had significantly greater diversity.

Nekton. Nekton (i.e., free swimming aquatic animals) was assessed to determine the abundance, species composition, diversity, and distribution. An emphasis was placed on commercially and/or recreationally important fish and crustaceans. Nekton was sampled in the diffuser area from May 1982 through October 1982. Afterwards, seven stations were sampled in December 1982, March 1983, and monthly thereafter from June through September 1983. No dramatic lethal effects were identified during any of the sample cruises. Reductions in species abundance and total biomass could not be associated with the brine plume or diffuser.

Zooplankton. Investigations were conducted to determine if brine discharges could be associated with changes in the mortalities of these organisms. In the most recent study at West Hackberry, zooplankton data were collected at the diffuser site from May 1982 through September 1983. In this time period, nine stations were sampled monthly from May 1982 through October 1982, December 1982, February 1983, and monthly thereafter from June 1983 through September 1983. No dramatic lethal effects were identified during any of the sample cruises. However, further observations could not be made because of high data variability and small sample size.

Phytoplankton. Studies were conducted to determine if there were brine-associated changes in phytoplankton biomass. Phytoplankton was sampled from surface and bottom waters at seven locations in June, July, August, September, and November of 1983. The high degree of spatial and temporal variation of the phytoplankton population made it difficult to assess impacts. This natural variation almost precludes the correlation of phytoplankton variables to a point source discharge unless the impacts are very great. The study concluded that no effect to phytoplankton biomass could be attributed to the diffuser or brine.

E.3.3.2 Bryan Mound Studies[14-15]

Benthos. Benthic studies consisted of two years of quarterly samples collected from 26 stations, including 11 samples collected after the diffuser flow rate was increased to one million barrels per day. Analyses indicated that there was no significant difference in diversities observed within any distance "rings" around the diffuser (e.g., 200; 500; 1,000; 2,000; and 4,000 meters or greater from the diffuser). Also, species composition at the diffuser and control stations were similar. A total of 104 different species were found at diffuser stations, and 115 species were found at control stations. When the ten dominant species of each station group were compared, six species were common to both diffuser and control stations.

The overall data show that total species abundance was depressed in the area within 200 meters around the diffuser and that an enhancement ring (i.e., an area with increased abundances that gradually decreased to ambient conditions) existed in the areas between 500 and 1,000 meters from the diffuser. Species distribution results showed that two species played a major role in providing differences in abundance levels between diffuser and control stations: both *K. aequalis* and *Paraprionospio pinnata* showed levels of high abundance in the enhancement ring, but were not found in areas closer to the diffuser.

Nekton. The nekton investigations show that brine disposal at Bryan Mound has resulted in no profound disruption to the overall fish and crustacean community in the are of the diffuser site. The studies concluded that since the inception of brine disposal in 1980:

- No dramatic lethal effects on nekton have been observed during the studies;
- No sharp reductions in total biomass or species abundance occurred in relation to the brine plume;
- No clear or consistent relationship between brine plumes and nekton abundance, biomass, and diversity could be established; and
- Brine effects are a minor source of observed variations.

This low impact is attributed to several factors: the intrinsic dynamism of shrimp and fish populations; the negligible area covered by the brine plume in relation to areas occupied by nekton; and the fact that maximum observed brine salinities are below levels known to cause mortality or evoke avoidance responses in laboratory tests.

Although field data and analysis do not indicate a direct or consistent influence of brine disposal on shrimp and fish, it is conceivable that brine discharge may indirectly impact some nekton species through its effects on the abundance or diversity of benthic organisms. Few dietary analyses have been conducted on nekton common to this diffuser site, but the morphology and epibenthic/demersal habits of some species suggest that they utilize benthos as a primary food source during part or all of their lives.

E.3.3 Potential Impacts Associated With Accidental Oil Spills

Storage of crude oil for the purpose of replacing lost oil imports could lead to releases of oil during marine transport of the oil to the United States, or during transfer of the oil to terminals from tankers and from terminals to the proposed SPR storage sites, via pipelines. If oil stored in the SPR is required during an emergency, the oil would again be transported via pipelines to terminals, from which it may enter the pipeline distribution system or may be loaded onto ships or barges for transport to refineries. Thus, oil spills could occur during the fill or refill of storage caverns, as well as during drawdown and distribution.

Based on the predicted frequency and volume of oil spills, the proposed SPR expansion would be likely to cause only a few small spills of oil to coastal and inland waters (see Section 6.1 of the DEIS). However, depending on when and where these spills occur, they could cause significant adverse impacts in localized areas. Chapter 8 of the DEIS discusses the spill containment equipment, emergency controls, procedures, and contingency/emergency plans that have been developed in order to minimize the potential for spilled oil to impact marine ecosystems. A brief overview of the potential environmental impacts of oil spills are discussed below. These impacts are discussed in detail in Chapter 7 of the DEIS..

An oil spill can negatively impact marine species through toxic external or internal contact, asphyxiation, and habitat destruction. A critical factor affecting the impact of spills on coastal habitats is the fate of oil in these settings. Unlike open ocean spills that are rapidly dispersed, oil spilled near the coast tends to concentrate and mix with nearshore waters. Additionally, the oil deposited in nearshore sediments persists longer than in pelagic sediments.[16] Oil is particularly persistent in low-energy, habitats such as wetlands and protected bay and estuarine areas.[17] Protected areas often support highly productive beds of seagrass; the direct toxic effects of oil, or oil related decreases in light penetration could negatively impact the density or abundance of these seagrasses. Because spawning and hatching of marine animals are generally temporally, as well as spatially, concentrated in coastal estuarine habitats, oil spills that coincide with mating or hatching periods could cause substantial population level impacts. Moreover, because these habitats are rich with sensitive species of plants and animals, and with vulnerable life cycle stages of more resistant species, even small spills could have significant effects.[18]

Oil spills also might temporarily disrupt ecosystem structure and function, which can lead to indirect negative impacts on food supplies used by marine species. Differential rates of animal and plant mortality resulting from spills could shift food web relationships. The result for individual organisms could be changes in resource availability, competition, and predation. On the population level, species that are dependent on impacted prey or habitats would decline, while opportunistic species that are able to take advantage of the loss of a more sensitive species might increase. Sensitive species or life stages, small local populations, or species that are seasonally concentrated in the impacted habitat would be the most likely to decline as a result of an oil spill.

E.3.4 Biological Background Information on Endangered and Threatened Marine Species of Concern

In this section we present biological background data on the endangered and threatened species of concern in the Gulf of Mexico. Species discussed here were identified by one or more of the NMFS contacts listed in Table E.2-2 as being a species of concern; these species are listed in Table E.3-1. Based on conversations with experts and a literature review, the assessment of the effects of the SPR expansion plan on endangered and threatened marine species focuses primarily on two species of sea turtles; the Kemp's Ridley and the loggerhead. Of the eight species of sea turtles, the Kemp's ridley is considered to be the one that is closest to the brink of extinction--and all of the adults and most individuals of the younger life stages are found in the Gulf of Mexico. The loggerhead is important because it is the most abundant sea turtle in the Gulf of Mexico,[19] and as a result is the species likely to have the most contact with environmental impacts related to the construction and brine disposal activities associated with the proposed SPR expansion plan. The Gulf sturgeon is also a species of particular concern, as it may be found in coastal areas near the proposed diffusers in the eastern Gulf of Mexico during the non-breeding season.

As discussed in following biological background section, endangered and threatened whale species of concern are not likely to be impacted by the proposed SPR related activities because they are normally found in offshore, rather than nearshore, waters. Similarly, the manatee is rarely sighted in waters west of Florida, and is not likely to come into contact with any areas potentially impacted by the proposed SPR expansion. The following biological summaries reflect the focus of this assessment, in that the biological requirements of the species most likely to be found in the areas potentially impacted by the proposed expansion are discussed in the most detail.

E.3.4.1 Anadromous Fish

Gulf Sturgeon (*Acipenser oxyrhynchus desotoi*)

One species of endangered or threatened fish is known to inhabit waters of the northern Gulf of Mexico: gulf sturgeon, a subspecies of the Atlantic sturgeon. Gulf sturgeon are large (1.8 to 2.4 meters in length), bottom-feeding fish that hatch and mature in estuaries or rivers, spend the majority of their adult lives in brackish or salt water, and return to rivers and estuaries every year or few years to spawn. The Gulf sturgeon's current range is from Lake Pontchartrain, Louisiana, to Tampa Bay, Florida.[20] In recent years the population of this species has decreased dramatically, primarily due to loss of breeding habitat. Construction of dams on coastal rivers blocks the passage of the gulf sturgeon to their traditional spawning grounds and summer habitat.[21] Overexploitation and decreasing riverine water quality also have been linked to this species' decline. Gulf sturgeon winter in the Gulf of Mexico and adjacent bays, and primarily use this habitat for feeding. In the Gulf, gulf sturgeon feed primarily on invertebrates, including brachiopods, insect larvae, mollusks, worms, and crustaceans,[22] but also eat aquatic plants. Important feeding grounds for this species include sea grass beds and concentrated populations of benthic organisms.

Table E.3-1
Endangered or Threatened Species of Concern in the Gulf of Mexico[1]

Common Name of Endangered or Threatened Species	Western Gulf[2]	Eastern Gulf[2]
Anadromous Fish		
Gulf Sturgeon		X (5)
Marine Turtles		
Kemp's (Atlantic) Ridley Sea Turtle	X (1)	X (6)
Loggerhead Sea Turtle	X (1)	X (2)
Atlantic Green Sea Turtle	X (1)	X (2)
Leatherback Sea Turtle	X (1)	X (6)
Hawksbill Sea Turtle	X (1)	X (6)
Marine Mammals		
Sperm Whale	X (1)	X (4)
Fin Whale	X (1)	X (4)
Sei Whale	X (1)	X (4)
Humpback Whale	X (1)	X (4)
Right Whale	X (1)	X (4)
West Indian Manatee		X (3)

Notes
1. Numbers in parenthesis refer to the source of information; refer to List of Sources for Endangered Species Table.
2. "Western" and "Eastern" Gulf are defined for this assessment as west or east of the Mississippi River Estuarine System. The brine diffusers associated with Stratton Ridge, Weeks Island, and Cote Blanche would be located in the Western Gulf, while the Richton diffuser would be located in the Eastern Gulf.

Sources for Endangered Species Table (Table E.3-1)

(1) Texas Natural Heritage Program (Texas Parks and Wildlife Dept.), Endangered/Threatened Species Data File, May 9, 1988.
(2) Mississippi Natural Heritage Program (Mississippi Department of Wildlife, Fisheries, and Parks). Special Animals, December 12, 1991.
(3) Louisiana Natural Heritage Program, Louisiana Department of Wildlife and Fisheries, Habitat Conservation Division, (untitled data), received April 3, 1992.
(4) Mullin, K., W. Hoggard, C. Roden, R. Lohoefener, C. Rogers, and B. Taggart, Cetaceans on the Upper Continental Slope in the North-Central Gulf of Mexico, U.S. Department of the Interior, Minerals Management Service, Gulf of Mexico OCS Regional Office, New Orleans, LA, June 1991, OCS Study/MMS 91-0027.
(5) Gilbert, C.R., Species Profiles: Life Histories and Environmental Requirements of Coastal Fishes and Invertebrates (Mid-Atlantic Bight)--Atlantic and Shortnose Sturgeons, U.S. Department of the Interior, Fish and Wildlife Service, Biological Report 82(11.122), U.S. Army Corps. of Engineers TR EL-82-4, 1989.
(6) Personal Communication, Letter from C. Oravetz, Chief, Protected Species Management Branch, National Marine Fisheries Service, NOAA, "Endangered and Threatened Species and Critical Habitats Under NMFS Jurisdiction: Louisiana," (undated).

E.3.4.2 Sea Turtles

Five species of endangered or threatened sea turtles are known to inhabit the waters of the northern Gulf of Mexico: Atlantic green, hawksbill, Kemp's Ridley, leatherback, and loggerhead. These turtles spend all of their lives at sea, except for adult females, which come ashore to lay their eggs in the sand at traditional nesting beaches. Sea turtles in the hatchling and post hatchling phases spend at least one and as many as five or more years in the open waters of the pelagic oceanic zone, drifting passively with currents.[23] In the open ocean, these young sea turtles often are found associated with mats of sargassum along driftlines. During this phase, they probably feed on small floating plants and animals, but dietary data are lacking. After this period, several species are thought to migrate to nearshore and estuarine areas, including the coastal Gulf of Mexico, and begin their subadult life stage.[24] Young sea turtles generally are not detected by researchers until they reach eight to ten inches in diameter. It takes between 10 and 50 years for individual sea turtles to grow from hatchlings to sexually mature adults; as a result, populations of these species are expected to recover very slowly from past and future decreases in their numbers.[25] Each species is discussed separately below.

Kemp's Ridley Turtle (*Lepidochelys kempi*)

The Kemp's Ridley turtle, also known as the Atlantic Ridley's turtle, is currently considered the rarest and most endangered sea turtle species. The population of nesting females has dwindled from more than 47,000 in 1947 to approximately 600 today.[26] It is very difficult to estimate the population and seasonal abundance of this species. The Gulf contains their main foraging and only breeding habitat, but their small size and tendency to inhabit murky waters makes counting them using aerial surveys difficult.[27] The Kemp's Ridley turtle is the second most common species found stranded on the coast of Texas; about 225 were found from 1983 through 1985, with stranding peaks in April and June through October. Many of these stranded turtles were post hatchling phase turtles, including a number of tagged turtles that had come into contact with oil or tar.[28]

Almost all nesting occurs on one stretch of beach in the state of Tamaulipas, Mexico, near Ranch Nuevo. Nesting in the U.S. occurs infrequently from May to August on Padre and Mustang Islands in south Texas.[29] Because adults are so rare, information on Kemp's Ridley turtles comes largely from juveniles. Most individuals are found in the Gulf of Mexico, although some are found on the eastern coast of Florida. Adults are found almost entirely in the Gulf, and seem to be equally distributed between the northern and southern Gulf.[30] Tag return data suggest that when adult turtles leave the nesting beaches, they typically move toward feeding grounds in the northern or southwestern Gulf. Juveniles are most commonly found in shallow bays and estuaries and seem to prefer areas characterized by eelgrass beds and shoals. Individuals appear to move along the coast in both directions (i.e., they do not move across the open Gulf from Florida to Mexico). Some hatchlings and juveniles are carried out of the Gulf by currents, and then travel up the east coast in the Gulf Stream.[31] Whether these turtles rejoin the Gulf population is unknown, but they may remain in this pelagic developmental stage long enough to be carried completely around the Atlantic.[32]

In the northern Gulf, the blue crab is the most common item found in stomach contents of adult Kemp's Ridley turtles.[33] This species of crab is found in shallow seagrass beds and shallow mud bottom bays of coastal marshes.[34] The diet of adult, subadult, and juveniles also includes spotted crabs and other benthic crustaceans, shellfish, jellyfish, sea urchins, starfish, and fish.[35] Studies of the gut contents of adults stranded in Texas showed that they were feeding mostly on crabs, including the blue, speckled, calico, spider, and purse crab. The strong presence of blue and speckled crabs in the diet suggests that the Kemp's Ridleys were foraging in the surf zone.[36]

The distribution of juvenile and adult Kemp's Ridleys appears to be associated with the availability of portunid crabs (e.g., blue crabs). The white shrimp and blue crab beds from Marsh Island to the Mississippi delta are the main areas of tag returns in the northern Gulf.[37] All areas with high abundances of crabs are important habitat for the Kemp's Ridley turtle; these areas include the Sabine, High Island, Houston Ship Channel, and Galveston Bay areas of Texas, Grand Isle, Marsh Island and Lake Calcasieu of Louisiana, and the Chandeleur Islands of Louisiana and Mississippi.[38] Shrimp trawl catch reports indicate that large numbers of juveniles inhabit the Sabine River offing in Sea Rim State Park, Texas; Caillou Bay, Louisiana; and Big Gulley, east of the Mobile Bay offing.[39]

Kemp's Ridley turtles generally are found close to shore. A sample of 79 juveniles captured in waters off of northwestern Florida found that 91% were captured in waters 6.1 meters deep or less, and all with a carapace length of less than 25 cm (except one) were collected from waters less than one meter deep.[40] Satellite-tracked adult females migrating north and south following nesting at Rancho Nuevo remained in nearshore waters and spent less than an hour a day at the surface.[41] Radio-tracked Kemp's Ridley turtles travel between Texas and the Florida panhandle.[42]

Loggerhead Turtle (*Caretta caretta*)

Foraging loggerhead turtles are found mainly in shallow subtropical waters such as the continental shelves and estuaries along the edges of the Atlantic, Pacific, and Indian Oceans.[43] Aerial surveys of the waters around eastern and western Florida observed 50 times more loggerhead turtles than did surveys of waters near Texas and Louisiana, and these turtles were less likely to be seen in winter months.[44]

Loggerhead turtles feed on a variety of organisms, but seem to feed primarily on benthic crustaceans and mollusks.[45] Studies of the gut contents of individuals stranded on the Texas coast indicate that loggerhead turtles are primarily benthic feeders, although some jellyfish and floating objects were found. Sea pens (an invertebrate that lives anchored to sandy substrates) and calico, spider, and purse crabs were found to be the major food items taken by adults. The known depth distribution of sea pens and these crab species suggest that the loggerhead turtle forages in nearshore areas.[46]

Nesting occurs in the north and south temperate zones and subtropics. The second largest nesting population utilizes beaches on the eastern shore of Florida. In the Gulf, nesting by loggerhead turtles is rare, although a few nests are regularly found along the Gulf coast of Florida and on the Chandeleur Islands.[47,48] Loggerhead turtles may occasionally nest on other remote barrier islands off of Louisiana and Mississippi.[49] Tagging studies of females nesting on the east coast of Florida suggest that following nesting, some females migrate to the Gulf, often to the turbid, detritus laden, muddy bottom bays and bayous near Louisiana and Mississippi.[50]

Aggregations of winter, dormant (i.e., hibernating) loggerhead turtles, all members of the Cape Canaveral population, have been recorded. This behavior has been seen only when the water was less than 59°F, and not all of the turtles in the area became dormant in response to the low water temperatures.[51] Hibernation does not appear to occur in the northern Gulf of Mexico.[52]

Green Turtle (*Chelonia mydas*)

The green turtle has a circumglobal distribution in tropical and subtropical waters and is found in U.S. waters from Texas to Massachusetts. Important feeding areas in the northern Gulf of Mexico historically have included seagrass beds along coastal Florida and Texas (i.e., Aransas Bay, Matagorda Bay, and Laguna Madre). Adult green turtles are primarily herbivorous, feeding on seagrasses and macroalgae. As a result, foraging green turtles are found primarily in shallow, protected areas. Foraging and nesting areas tend to be far apart, requiring individuals to migrate over long distances.[53] Green turtles nest on the east coast of Florida and in small numbers in the U.S. Virgin Islands and Puerto Rico.

Hawksbill Turtle (*Eretmochelys imbricata*)

Hawksbill turtles are most often found in the Caribbean, but they are occasionally seen in the Florida Keys, the Bahamas, and the southwestern Gulf of Mexico. According to stranding data, the hawksbill is the least common of the five species in the Gulf of Mexico, although from 1983 to 1985 an unusually high number (i.e., twelve juveniles) were found stranded in the vicinity of Mustang Island, Texas.[54] This species is rare in shallow coastal areas with soft bottoms and high turbidity, such as the areas offshore of Louisiana and Mississippi. Adults are benthic feeders and typically forage near rock or reef habitats; they appear to specialize on sponges in areas with clear water that is 20 meters in depth or greater. Juveniles tend to forage for sponges near reefs in shallower waters. Hawksbill nests are found on remote tropical islands and undisturbed tropical continental shores. A few nests have been found in southern Florida, and within the Gulf small numbers of nests have been recorded from the beaches of Campeche, Mexico.[55]

Leatherback Turtle (*Dermochelys coriacea*)

The leatherback turtle, the largest of the sea turtle species, is most often found in deep, offshore areas. This species is sparsely distributed in the Gulf; stranding data from Texas show that it is among the least likely species to be found.[56] Leatherback turtles have been recorded in nearshore areas; they may come close to shore to forage on aggregations jellyfish, their favored prey item.[57,58] Due to its preference for jellyfish, the leatherback turtle is a water column rather than benthic feeder. Leatherback turtles nest almost entirely in the tropics, although a small number of nests are found each year on Florida beaches.[59]

In the sections of this assessment that discuss possible impacts to endangered and threatened sea turtles (Sections E.3.5 to E.3.8), the five species discussed above are at times divided into two groups: (1) coastal sea turtles; and (2) pelagic sea turtles. This distinction is made in order to facilitate discussion of possible impacts that are related to the distance from shore of the habitats utilized by the species. For the purposes of this assessment, the term "coastal sea turtles" refers to the Kemp's Ridley, loggerhead, and green sea turtle species, and the term "pelagic sea turtles" refers to the leatherback and hawksbill sea turtles. This distinction is not meant to imply that the "coastal sea turtles" do not utilize pelagic habitats or vice versa, but is intended to reflect the general tendency of these two groups to utilize different habitats in the areas of the Gulf of Mexico that may be affected by the proposed expansion of the SPR.

E.3.4.3 Marine Mammals

Six species of Federally endangered or threatened mammals are listed as occurring in northern Gulf of Mexico waters. These are the West Indian manatee and 5 species of cetaceans (i.e., fin whale, sei whale, humpback whale, right whale, and sperm whale). Additional information about each of these species is provided below.

West Indian Manatee (*Trichechus manatus*)

The West Indian manatee is one of only five living species of the order Sirenia. Manatees are large, slow-moving, aquatic herbivores which typically inhabit shallow coastal waters and river mouths.[60] In the Gulf of Mexico, their range is usually limited by water temperatures to the coasts of Florida and Mexico;[61] they cannot tolerate water temperatures below 46°F.[62] Since 1975 only eleven sightings have been reported in other portions of the Gulf; two of these animals were dead:

- Two in Texas (probably from Mexico);
- Seven in Louisiana (probably from Florida); and
- Two in Mississippi (probably from Florida).

Resident populations of manatees are only known to occur in Florida, and those sighted elsewhere are considered to be occasional migrants.[63]

Whales

Fin, sei, humpback, right, and sperm whales typically spend summers in high latitude waters feeding on the abundant zooplankton and fish. In fall and winter they migrate south, eating little while they are in the Gulf, living primarily off their fat reserves for several months.[64] Each species is discussed separately below.

Sperm Whale (*Physeter macrocephalus*). This is the most common of the endangered whales found in the Gulf of Mexico, and makes up an estimated 21 to 44% of the total cetacean biomass in the north-central Gulf region.[65] During a recent one-year study of the north-central Gulf of Mexico, NMFS observers sighted 43 herds. Sightings occurred throughout the year but mostly in the fall. Sperm whales were concentrated especially in the area of the continental slope off the Mississippi River delta. In earlier studies, five of seven at-sea sightings were reported off the Mississippi River delta area, but between 1979 and 1981 aerial surveys and opportunistic sightings from ships resulted in 17 sightings of 47 adults and twelve calves, most occurring off the Texas coast.[66,67] Sperm whales occur in waters 300 to 1,200 meters deep, and during the recent NMFS study they distinctly preferred waters 900 to 1,200 meters deep.[68,69,70]

Sperm whales typically feed at great depths, taking medium- to large-sized mesopelagic squids, including giant squids, but they also take significant quantities of large demersal and mesopelagic sharks, skates, and fishes.[71,72] It is thought that sperm whales concentrate near the Mississippi River delta due to the abundance of squid.[73]

Fin Whale (*Balaenoptera physalus*). Numerous fin whale sightings have been documented in deep water areas of the Gulf of Mexico. Most recently the majority of the sightings have occurred south of the Alabama-Florida border in the DeSoto Canyon area, including:

- November 1989; one individual sighted in 143 meters of water;
- July 1985; one individual sighted in about 180 meters of water; and
- Two additional sightings in earlier years near DeSoto Canyon.[74]

Additional records include four strandings on the Louisiana coast. Most fin whales spend the summers at high latitudes, filter feeding on the seasonally abundant fish and krill (i.e., euphausiid crustaceans), but sightings and strandings have occurred throughout the year in the Gulf of Mexico. There is little knowledge of their winter breeding grounds, where mating occurs and calves are born.[75]

Sei Whale (*Balaenoptera borealis*). Some researchers have speculated that a separate Gulf of Mexico/Caribbean stock of sei whales exists, but most are skeptical.[76] In recent years a few sei whale sightings and strandings have been reported in the Gulf of Mexico. In 1990 a possible sighting was made by NMFS, and a live stranding occurred on the Louisiana coast.[77] Two additional strandings have also been reported in the area off of the Mississippi River delta in recent years.[78] Sei whales are filter feeders that prefer copepods, but also will feed on krill and schools of small fish.

Humpback Whale (*Megaptera novaeangliae*). During the winter humpback whales are confined to shallow waters along coasts and oceanic islands, but they are uncommon in the Gulf of Mexico. Only three recent sightings of humpbacks have been reported in the Gulf, two in the central portion near DeSoto Canyon (1952, 1957), and one off of Tampa Bay (1962). Humpback whales are filter feeders, consuming krill, copepods, other pelagic crustaceans, and fish, but during fall and winter they eat little.[79]

Right Whale (*Balaena glacialis*). Right whales are very rare in the Gulf of Mexico. The only reported sightings in the available literature were two individuals sighted off the western coast of Florida, and a stranding in Texas.[80,81] They mate and calve during winter, moving into shallow coastal bays to give birth. This species feeds on copepods and sometimes krill, primarily in Arctic waters.[82]

E.3.5 Potential Impacts to Endangered and Threatened Marine Species Associated With Brine Pipeline Construction

The potential impacts to endangered and threatened marine species associated with the proposed brine pipeline construction are discussed in the following section based on the potential environmental effects associated with the brine pipeline construction (Section E.3.1), and the biological background information provided in Section E.3.4. The potential impacts are summarized in Table E.3-2.

General Impacts of Pipeline Construction

Food Availability. Dredging of the pipeline route for the proposed brine diffusers could result in a temporary decline in food availability for endangered and threatened species, at least in localized areas. Bottom habitat for the prey of endangered and threatened species would be disrupted temporarily along the route of the proposed pipeline by the dredging process. Sessile organisms and other food sources such as seagrasses located directly in or adjacent to the proposed pipeline route would be disturbed either by the physical dredging process or by settling solids in the immediate vicinity of the pipeline. A study on the impacts of navigational dredging

Table E.3-2
Summary of Potential Impacts on Endangered and Threatened Marine Species Due to Brine Pipeline Construction

Species	Site	Concerns	Potential Impact	Rationale of Finding
Gulf sturgeon	Richton	Decrease in available foraging habitat/food supply	None	Loss of foraging area and benthic species would be minor compared to total resources available for feeding; sturgeon would utilize other areas. DOE will attempt to avoid important food source areas (i.e., seagrass beds, oyster beds).
Pelagic Sea Turtles (hawksbill & leatherback)	Stratton Ridge, Weeks Island/Cote Blanche, Richton	Decrease in available foraging habitat/food supply	None	Pelagic turtles do not forage close to proposed dredging areas, which are at most 14 miles from the coast. The hawksbill feeds near coral reefs; the leatherback in deep, offshore areas.
		Elevated contaminant levels and noise associated with dredging	None	Pelagic turtles do not utilize habitat close to proposed dredging areas
Coastal Sea Turtles (Kemp's Ridley, green, & loggerhead)	Stratton Ridge, Weeks Island/Cote Blanche, Richton	Direct mortality/injury due to physical dredging	None	It is very unlikely that turtles would encounter dredging machinery.
	Stratton Ridge, Weeks Island/Cote Blanche	Decrease in available foraging habitat/food supply	None	If seagrass beds are avoided, only minor effects on turtle food would be expected. Any loss of foraging area would be slight compared to total area available for feeding; turtles would utilize other areas. Also, Kemp's Ridley feeds primarily blue and other crabs whose numbers are not expected to decrease.
		Elevated contaminant levels and noise associated with dredging	Impacts Possible	Turtles may go into areas affected by dredging and ingest contaminants, become disoriented, or abandon usual habitat due to disturbance.
	Richton	Decrease in available foraging habitat/food supply	Impacts Possible	If seagrass beds and other important foraging areas are avoided, only minor effects on turtle food would be expected. However, areas near Richton are known feeding habitat for green, Kemp's Ridley, and loggerhead turtles. If food supplies in the area decrease, it may interfere with loggerhead breeding on the Chandeleur Islands.
		Elevated contaminant levels and noise associated with dredging	Impacts Possible	Coastal turtles may travel into areas affected by dredging and could experience effects due to ingestion of contaminants. Disturbance may present a problem at the Richton site, because areas near the Chandeleur Islands provide important feeding habitat for green and Kemp's Ridley turtles, and loggerhead nesting has been recorded in this area.
Marine Mammals Whales	Stratton Ridge, Weeks Island/Cote Blanche, Richton	Decrease in available foraging habitat/food supply	None	The whales are all pelagic and their habitat is in deep water far from proposed pipeline areas.
Manatees	None	Decrease in available foraging habitat/food supply	None	The manatee is found almost exclusively off the coast of Florida.

showed that 75 percent or more of the benthic organisms were removed from a site during channel dredging.[83] These impacts would be temporary and confined to areas close to the proposed pipeline; benthic habitat would be restored and recolonized naturally after construction. Recolonization of the newly dredged area can be fairly rapid and the original biomass can be returned within 2 weeks to 4 months.[84,85,86,87] The loss of benthic food supplies could possibly cause coastal demersal feeders such as Gulf sturgeon, Kemp's Ridley sea turtles, green sea turtles, and loggerhead sea turtles to avoid feeding in areas affected by pipeline and diffuser placement related dredging.

Turbidity and Elevated Contaminant Levels. Dredging and dredged material disposal could affect endangered and threatened marine species through the effects of turbidity and resuspension of toxic contaminants. Physical disturbances, such as solids discharge and noise, could alter the normal behavior of these endangered species by causing them to avoid the areas impacted by the proposed construction activities. Turbidity caused by dredging could cause a decrease in light penetration, reducing primary production and decreasing food availability at lower trophic levels. If bottom sediments have been polluted by light metals (e.g., nickel, chromium, zinc) or organic pollutants (e.g., hydrocarbons, organic pesticides), dredging would increase the concentration of these contaminants in the water column. Increased exposure potential of the animals to these contaminants might result in a variety of behavioral and toxicological effects. For example, the presence of hydrocarbons in sublethal levels in dredged material could interfere with the olfactory senses of the animals and affect food location, selection of feeding, nesting, or spawning habitat, and sex attraction.[88] Significant uptake of contaminants released from the sediments to the water column could cause similar adverse effects, including mortality, if exposures were high.

Direct Injury or Mortality. Dredging can result in direct injury or mortality to individual marine animals that get caught in dredging machinery.[89]

Gulf Sturgeon

The Gulf sturgeon is only found in areas east of the Mississippi River delta, so the only brine pipeline construction activities that could possibly impact this species would be associated with construction of the proposed Richton site.[90] Also, hatchling and juvenile Gulf sturgeon would not be affected by any aspect of the construction of brine pipelines because they inhabit riverine, not marine, habitats. Adult Gulf sturgeon winter in the eastern Gulf, and feed primarily on benthic invertebrates. Adverse effects to this species are likely only if prime feeding areas are destroyed, such as seagrass beds, oyster beds, or other areas of high productivity. These impacts would be minimized or avoided by routing the pipeline to avoid known seagrass and oyster beds to the extent practicable. The sturgeon is a mobile species and will probably avoid the noise and turbidity associated with dredging areas, searching elsewhere for food. If the pipeline construction is located in areas that are of low or marginal quality as foraging areas for the Gulf sturgeon, no significant impacts on this species' food supply are expected.

Due to the noise, disturbance, and lack of food expected in areas affected by the proposed construction, sturgeon will probably avoid impacted areas. As a result, disorientation (and other sublethal effects of turbidity) and toxicity due to contaminants are not expected to significantly impact the Gulf sturgeon. Similarly, if known sturgeon foraging habitat (e.g., seagrass beds) are avoided, incidence of direct injuries or mortality to Gulf sturgeon due to dredging are expected to be few. Since all of this species' breeding activities take place in riverine habitat, this aspect of the gulf sturgeons biology would not be impacted by brine pipeline construction.

Sea Turtles

Dredging of the pipeline routes for the proposed brine diffusers could result in a temporary decline in food availability for endangered and threatened sea turtle species, at least in localized areas. The data available on the diet of hatchling and juvenile sea turtles suggest that they feed on planktonic plants and animals and other small items that accumulate in coastal driftline areas; as a result this discussion focuses on the food supplies available to adult and subadult turtles. Many of the prey items of coastal sea turtles such as the Kemp's Ridley, and loggerhead, are associated with seagrass beds, including the favorite prey of the Kemp's Ridley, the blue crab. Impacts on seagrass beds could indirectly affect both the Kemp's Ridley and the loggerhead sea turtle by decreasing the acreage or density of the seagrass beds that their favored prey items inhabit.[91] The food available to the herbivorous green sea turtle could be more directly reduced; this species feeds primarily on seagrasses. Adverse effects to these turtle species are likely only if prime feeding areas are destroyed, such as seagrass beds or other areas of high productivity. Rerouting the pipeline to avoid known seagrass beds would reduce the possibility of adverse effects. Adult sea turtles are highly mobile animals and will probably avoid the noise and turbidity associated with dredging areas, searching elsewhere for food. If the pipeline construction is located in areas that are of low or marginal quality as foraging areas for the sea turtles, no significant impacts on the food supplies utilized by these species are expected. In addition, even if some blue crab habitat is lost, the blue crab is a hardy omnivorous swimming crab, and individuals of this species would probably be able to relocate to unimpacted areas.

Dredging and other construction-related activities are not expected to affect the pelagic leatherbacks and hawkbills because these species generally feed in deep waters located far from the shoreline. Also, foraging hawksbill turtles tend to be associated with coral reefs, and no coral reefs have been identified in areas near the proposed diffuser pipeline routes.

The potential impacts of dredging the brine pipeline on the Kemp's Ridley, green, and loggerhead turtles are associated primarily with elevated contaminant and turbidity levels. Due to the noise, disturbance, and lack of food expected in areas affected by the proposed construction, foraging sea turtles will probably avoid impacted areas. However, it is possible that migrating or nesting turtles would cross areas of increased turbidity and contaminant levels. Hatchlings of these species could also be affected by contaminants that become resuspended due to dredging if these contaminants were to contact their planktonic food supplies. Again, the more pelagic sea turtle species are not expected to be close enough to shore to encounter areas of increased turbidity or contaminants associated with the proposed construction activities.

A possibility exists for dredging of ship channels and similar types of construction to cause direct injury or mortality to individual sea turtles that get caught in dredging machinery.[92] However, this type of accident is most likely to occur when large scale dredging is done (such as to clear the Port Canaveral Entrance Channel, Florida.[93] Most of the risk associated with dredging has to do with the occurrence of winter dormant (hibernating) turtles partially buried in the mud bottom. Hibernation of turtles in bottom muds does not appear to occur in the northern Gulf;[94] the Army Corps of Engineers has dredged extensively in areas near the proposed expansion sites without ever seeing evidence of a turtle taken during hopper dredging.[95] Direct mortality of endangered or threatened sea turtles due to dredging is not likely.

Marine Mammals

Endangered and threatened whales are not expected to be affected by any aspect of the brine diffuser construction activities because they are generally located much farther from shore than the proposed brine pipeline areas. The species that appears most likely to approach a proposed construction site (due to its abundance in the gulf and tendency to forage near the Mississippi River delta), the sperm whale, generally is located beyond the Mississippi delta and canyon dropoff, which is at least 20 miles offshore. The proposed pipelines would extend only 5 to 14 miles from shore.[96]

The effects of dredging on the abundance of benthic habitat and organisms is not expected to decrease the whales' food supply. Although turbidity caused by dredging might cause a decrease in light penetration, reducing the availability of phytoplankton, which in turn could reduce the numbers of zooplankton that baleen whales such as the fin and humpback whales eat, the dredging would occur in very small area compared to the Gulf as a whole. The sperm whale eats mainly fish and squid; it is unlikely that fish and squid populations would be affected, because these fast moving nekton could feed outside the study area even if plankton populations were reduced in the area of the dredging. Because the whales would not be expected to come near the impacted areas, effects of suspended contaminants and organic materials are not expected to affect the behavior of these animals or have any lethal or sublethal effects.

West Indian Manatees are not known to inhabit any of the coastal areas associated with the proposed plan to expand the SPR, and are not expected to suffer any adverse effects due to any aspect of the brine diffuser construction activities.

E.3.6 Potential Impacts to Endangered and Threatened Marine Species Associated With Brine Discharge

The potential impacts to endangered and threatened marine species associated with the brine discharge are discussed in the following section. First, environmental effects that could impact the endangered and threatened species as a group are presented; these general effects are followed by species-specific discussion of possible impacts of the proposed brine disposal activities. The potential impacts are summarized in Table E.3-3.

General Impacts of Ocean Discharge of Brine

Food Availability. Disposal of highly concentrated brine could result in a slight loss in foraging habitat for coastal endangered and threatened species, at least in localized areas. Sessile epifaunal and infaunal organisms (e.g., polychaetes, mollusks) living in the area very close to the proposed brine diffusers would probably be lost due to the high salinity of the disposed brine or due to low dissolved oxygen conditions, which are exacerbated by high salinity. Many mobile animals would move from the area directly surrounding the diffuser to avoid the salinity or to search for food. Monitoring studies have shown that outside of this zone (estimated at 31 to 2,000 acres at the Bryan Mound and West Hackberry diffuser sites), there are no significant differences between the abundance or species diversity at diffusers and control stations. The studies do suggest that demersal fish and other mobile organisms such as crabs and would be likely to leave the areas directly around the diffuser (due to loss of benthic prey) to feed in other locations.

Table E.3-3
Summary of Potential Impacts on Endangered and Threatened Marine Species Due to Brine Discharge

Species	Site	Concerns	Possible Impacts	Rationale of Findings
Gulf sturgeon	Richton	Decrease in available foraging habitat/food supply	None	Loss of foraging area would be minor compared to total area available; sturgeon would utilize other feeding areas. Also, DOE would attempt to avoid important food source area (i.e., seagrass beds, oyster beds).
		Brine pipeline leaks	Impacts Possible	Additional foraging habitat and food supplies could be lost if a spill were to occur in areas of high prey abundance. Sturgeon would utilize other areas; impacts of sudden changes in salinity are unknown.
Pelagic Sea Turtles (hawksbill & leatherback)	Stratton Ridge, Weeks Island/Cote Blanche, Richton	Decrease in available foraging habitat/food supply	None	Pelagic turtles do not travel close to shore and are not expected to encounter brine plumes.
		Brine pipeline leaks	None	These turtles are all pelagic and their habitat is in deep water far from areas that could be impacted by brine pipeline leaks.
Coastal (Kemp's Ridley, green, & loggerhead)	Stratton Ridge, Weeks Island/Cote Blanche	Decrease in available foraging habitat/food supply	None	If seagrass beds and other important feeding habitat are avoided, only minor effects on turtle food would be expected. Any loss of foraging area would be slight compared to total area available for feeding.
		Brine pipeline leaks	Impacts Possible	Additional foraging habitat and food supplies could be lost if a spill were to occur in areas of high prey abundance. Although sea turtles can tolerate fairly high salinity levels, impacts of sudden changes in salinity are unknown. Juvenile or hatchling turtles could possibly be more sensitive to these changes; these life stages are more likely than adults to be found in low energy bay areas that could be impacted by spilled brine.
	Richton	Decrease in available foraging habitat/food supply	Impacts Possible	If seagrass beds are avoided, limited effects on turtle food would be expected. However, areas around the Chandeleur Islands are known foraging habitat, and a few loggerheads nest in the area. If food supplies in the area decrease, loggerheads may avoid this nesting area.
		Brine pipeline leaks	Impacts Possible	Additional high quality foraging habitat and food supplies could be lost if a spill was to occur in the Chandeleur Island area. Although sea turtles can tolerate fairly high salinity levels, impacts of sudden changes in salinity are unknown. Juvenile or hatchling turtles could possibly be more sensitive to these changes; these life stages are more likely than adults to be found in low energy bay areas that could be impacted by spilled brine.

Table E.3-3 (Continued)
Summary of Potential Impacts on Endangered and Threatened Marine Species Due to Brine Discharge

Species	Site	Concerns	Possible Impacts	Rationale of Findings
Marine Mammals				
Whales	Stratton Ridge, Weeks Island/Cote Blanche, Richton	Decrease in available foraging habitat/food supply	None	The whales are all pelagic and their feeding habitat is in deep water far from proposed diffusers.
		Brine pipeline leaks	None	The whales are all pelagic and their habitat is in deep water far from areas that could be impacted by brine pipeline leaks
Manatees	None	Decrease in available foraging habitat/food supply	None	Manatee feeding habitat is found almost exclusively off the coast of Florida; these areas would not be impacted by any of the proposed diffusers.
		Brine pipeline leaks	None	Manatee habitat is found almost exclusively off the coast of Florida; this species would not encounter any areas impacted by brine pipeline leaks.

Brine Pipeline Spills. If the brine pipeline were to rupture, areas crossed by the pipeline could be seriously impacted. A zone of high salinity similar to the one expected as a result of the diffuser would probably occur; this could be particularly serious in the shallow, low energy bays crossed by the pipeline, because the brine would not be diluted as quickly as it would in the open ocean. Gulf sturgeon, and Kemp's Ridley, loggerhead, or green sea turtles might be found in these bays if the area supported large crab populations, or seagrass beds. As a result, these species might be affected by loss of foraging habitat. No species of whales are expected to be found along the brine disposal pipeline route because these areas are too shallow.

Gulf Sturgeon

The Gulf sturgeon is only found in areas east of the Mississippi River delta, so the only brine pipeline construction activities that could possibly impact this species would be associated with construction of the proposed Richton site.[97] Also, hatchling and juvenile Gulf sturgeon would not be affected by any aspect of the brine disposal because they inhabit riverine, not marine, habitats. According to available sources, the effects of brine disposal or increased ambient salinities on the Gulf sturgeon do appear not been studied directly, but based on the monitoring studies associated with the West Hackberry and Bryan Mound sites, any impacts to the species would most likely be associated with food supplies and feeding habitat. Adult Gulf sturgeon winter in the eastern Gulf and nearby bay areas, and feed primarily on benthic invertebrates. The sturgeon is a mobile species and will probably avoid the high salinity area associated with the diffuser if food supplies in that area are decreased. Adverse effects to this species are likely only if prime feeding areas such as seagrass beds, oyster beds, or other areas of high productivity are destroyed due to the disposal of brine. The Richton brine diffuser would be located at a sufficient distance from shorelines and other environmentally sensitive points to avoid impingement of the brine plume. Given a diffuser location in an area that is of low or marginal quality as foraging habitat for the Gulf sturgeon, no significant impacts on this species food supply are expected.

Due to the lack of benthic food items expected in areas affected by the proposed brine disposal activities, sturgeon will probably avoid impacted areas. As a result, any lethal or sublethal effects that could possibly be related to the fish encountering areas of high ambient salinity would not be likely to occur. Since all of this species' breeding activities take place in riverine habitat, this aspect of the gulf sturgeons biology would not be impacted by brine disposal.

Sea Turtles

The impacts of brine disposal on sea turtles have not been studied directly, but it is likely that the increases in salinity associated with most areas of the proposed brine plumes would be well within the tolerance range of these species.[98] Any potential impacts are most likely to be associated with loss of food supplies and feeding habitat for the coastal species. The Kemp's Ridley and loggerhead feed primarily on benthic organisms, most of which would be lost or would have moved from the high salinity areas close to the proposed diffusers. The green sea turtle feeds primarily on seagrasses, which would probably not survive in areas of extremely high salinities. These sea turtles would probably avoid feeding in the diffuser area and would instead utilize unaffected areas. This impact is expected to decrease the foraging area available to subadult and adult turtles; juveniles and new hatchlings would not be affected because they are pelagic and forage on plant and animal matter that accumulate along open ocean driftlines.[99] Even if currents brought juvenile turtles into the area of a diffuser, they would probably not experience a zone of increased salinity because the predicted brine plumes are not expected to reach the surface of the water.

Slight increases in salinity (i.e., the brine plume contour salinity gradients shown in the maximum-case brine plumes) would not be expected to impact the fitness of sea turtles; they could most likely handle living in waters as high as 40 ppt.[100] It is unlikely that sea turtles would be exposed to the higher concentration portions of the plume because they ingest sea water only when they eat;[101] in the high concentration zones prey items probably would not be present.

It has also been suggested that migrating sea turtles utilizing coastal areas might detect and avoid the brine plume. If so, the plume could pose a barrier to migration.[102] However, sea turtles are known to venture into areas where salinities are 45 ppt or greater, and they have no difficulty in salinities as high as 40 ppt; their salt glands can excrete fluids with salinities as high as 70 ppt.[103] A few loggerhead turtles utilize beaches in the Chandeleur Island area for nesting; if the species is able to detect plumes and avoids them, the plume associated with the proposed Richton site could act as an obstruction between the loggerheads and their nesting habitat.

The pelagic sea turtle species are not expected to experience loss of feeding habitat or areas of increased salinity due to the disposal of brine because they do not generally inhabit the near-shore areas where the proposed diffusers would be located.

Marine Mammals

None of the endangered or threatened whales in the Gulf of Mexico are expected to be impacted by the disposal of brine. This is primarily because all of the species found in Gulf waters are pelagic, inhabiting continental slope and deep oceanic waters. There would also be no effect on the manatees, because they are found almost exclusively off the coast of Florida.

E.3.7 Potential Impacts to Endangered and Threatened Marine Species Associated With Accidental Oil Spills

Gulf Sturgeon

Potential impacts to Gulf sturgeon due to oil spills in the Gulf of Mexico would probably be related to toxic external or internal contact and feeding habitat destruction. Specific information on the sensitivity of sturgeon to oil was not available; however, fish in general are very sensitive to short-term acute exposures, but are able to metabolize sub-lethal intakes. The sensitivity of fish to oil spills varies by species and by age class. Older age classes are able to avoid heavy contamination, and many have a mucous coating that helps them resist contact with toxic oil constituents. It is the youngest age classes that are most vulnerable to oil spills, and for the Gulf sturgeon, these younger age classes are located in riverine habitats.

Sea Turtles

An oil spill can negatively impact sea turtles through toxic external or internal contact, asphyxiation, and habitat destruction. An oil spill would be expected to have the most direct impact on the hatchling turtles, as this part of the population tends to inhabit driftlines where

Table E.3-4
Summary of Potential Impacts on Endangered and Threatened Marine Species Due to Oil Spills

Species	Oil Spills	Concerns	Possible Impacts	Rationale of Findings
Gulf sturgeon	Richton	Decrease in available foraging habitat/food supply	None	Loss of foraging area due to fouling from a small coastal spill would be minor compared to total area available for feeding; sturgeon would and utilize other feeding areas.
		Direct toxicity effects due to encounters with oil	None	The likelihood of encounters with oil is small. Adults would probably not suffer serious effects, and more sensitive (i.e., juvenile) life stages do not utilize habitats in the Gulf of Mexico.
Sea Turtles Pelagic (hawksbill & leatherback)	Stratton Ridge, Weeks Island/Cote Blanche, Richton	Decrease in available foraging habitat/food supply	None	Pelagic turtles do not forage close to shore and are not expected to feed in areas impacted by small coastal oil spills. The hawksbill is usually found near coral reefs and the leatherback in deep, offshore areas.
		Direct toxicity effects due to encounters with oil or contaminated food supplies	None	Pelagic turtles do not travel close to shore and are not expected to encounter small coastal oil spills. Contaminated food supplies and remnants of oil that are washed out to sea are not expected to impact these turtles.
Coastal (Kemp's Ridley, green, & loggerhead)	Stratton Ridge, Weeks Island/Cote Blanche, Richton	Decrease in available foraging habitat/food supply	Impacts Possible	Loss of foraging area due to fouling from a small coastal spill would be minor compared to total area available for feeding; coastal turtles would utilize other feeding areas. However, if bay areas or other low energy habitats utilized by turtles were impacted by oil, impacts could be significant. Also, the Chandeleur Island area contains known feeding grounds for coastal turtles; spills in this area could impact food supplies. If food supplies in the area are impacted by oil, the few loggerheads that nest there may choose other nesting areas.
		Direct toxicity effects due to encounters with oil or contaminated food supplies	Impacts Possible	The likelihood of encounters with spilled oil is small. However, adults do not appear to avoid spills, and do not seem to distinguish tar balls from food. Hatchling and juvenile turtles could contact or consume oil products that accumulate along driftlines. These routes of exposure could lead to toxicity and internal blockage related effects.
Marine Mammals Whales	Stratton Ridge, Weeks Island/Cote Blanche, Richton	Direct toxicity effects due to encounters with oil or contaminated food supplies	None	The whales are all pelagic and their habitat is in deep water far from areas that may be impacted by small, coastal oil spills. Any remnants of the spill that end up in deepwater marine habitats would not be likely to impact whales.
Manatees	Stratton Ridge, Weeks Island/Cote Blanche, Richton	Direct toxicity effects due to encounters with oil or contaminated food supplies	None	The manatee is found almost exclusively off the coast of Florida; small coastal spills in proposed SPR areas would not impact Florida habitats. Any remnants of the spill that end up in coastal Florida habitats would not be likely to manatees.

accumulations of sargassum and other materials occur.[104] Currents would eventually carry the spilled oil to these same driftlines, where the hatchlings would be continually exposed. Behavioral studies suggest that adult sea turtles do not detect and avoid oil slicks.[105] Sea turtles also do not appear to be able to discriminate between tar balls and food; consumption of tar balls can lead to mortality through blockage of the digestive or respiratory systems.[106] The effects of tar ball consumption would have the greatest effect on hatchlings, as this and other types of marine pollution tend to accumulate in the mats of sargassum and other debris where the hatchlings are found.[107] Although adult and juvenile turtles would only be directly exposed when they surfaced to breathe, an oil spill could also lead to the injury and possible mortality of these older animals. Adult loggerhead and green sea turtles exposed for various periods to weathered Louisiana crude have shown evidence of damage to the skin, respiratory system, digestive system, eyelids, and nares.[108] The activity of the turtles' salt gland (the gland that regulates the secretion of salt and the body's concentration of minor ions) was also found to be reduced or delayed following exposure to oil.[109]

Fritts and McGehee (1982)[110] conducted studies on the effects of oil on sea turtle eggs. An analysis of the sand from the Kemp's Ridley nesting beach at Rancho Nuevo indicated that spilled oil can reach the nesting zone as a result of wave action; however, no significant effects on the development or survival of embryos were noted.[111] Laboratory studies on loggerhead eggs using weathered crude resulted in differences in hatchling morphology but not in embryonic mortality. The study did find that fresh oil caused significant embryo mortality and differences in hatchling morphology, suggesting that a fresh spill of oil near nesting beaches (especially Rancho Nuevo) could be serious threat to sea turtle embryos.[112]

Sea turtles could also be indirectly impacted by an oil spill if the spill fouls foraging habitat, such as the seagrass beds of coastal Louisiana and Mississippi. It has been suggested that in the case of an oil spill most species of seagrasses themselves would suffer little permanent damage, but associated organisms would suffer high rates of mortality.[113] These organisms would be expected to return as the seagrass beds recover from the effects of the spill.[114]

Marine Mammals

Because the number of whales found in the Gulf of Mexico is relatively low, the likelihood of one encountering the small, coastal spills of oil predicted to occur as a result of operations related to the proposed SPR expansion plan is relatively remote. If a whale were to encounter one of these small spills, the effects of short-term exposure would probably be limited to mild, reversible effects on the cetacean's skin.[115] Most of the endangered or threatened whale species feed little while in the Gulf, living primarily off of fat reserves, and thus should not be impacted by a reduced or contaminated food supply. Grey whales have been observed to reduce respiration rate and the length of breaths when encountering oil,[116] but several species of whales have been observed traveling through and feeding normally in oil slicks.[117,118] Inhalation of petroleum fumes in the area of a spill can cause inflammation of mucous membranes, lung congestion, or even pneumonia[119] and is probably the only real threat that an oil spill would pose to the health of whales.[120] Inhaled petroleum components could also accumulate in the blood and tissues inducing liver damage or neurological disorders, but prolonged exposure is not expected to occur.[121] The effects of an oil spill on manatees would probably be similar to the above effects on whales, although any SPR-related spill would probably be greatly diluted and dispersed before it reached any areas of manatee habitat.

E.3.8 Cumulative Impacts

In an area as highly developed as the Gulf of Mexico, the potential for cumulative effects with respect to threatened and endangered marine species is an important consideration. Marine species contend with oil drilling and exploration activities, habitat destruction, vessel traffic, marine fishing and shrimping operations, and ocean pollution; these effects can slow or prevent the recovery of depleted populations of endangered and threatened species.

No significant cumulative impacts to the Gulf sturgeon are expected. As discussed in the biological background section (E.3.3), the major threats to the continuation of this species are related to habitat loss in riverine breeding habitat and overexploitation by commercial fishing operations. There is some possibility that individual sturgeon could experience the effects of oil spills, loss of feeding habitat due to construction or operation of the brine diffusers, or effects due to elevated contaminant levels and turbidity in the water column in their Gulf feeding grounds. The overall cumulative impact of these effects is expected to be low.

The potential for cumulative impacts on sea turtles in the Gulf of Mexico is moderate. Sea turtles are exposed to a variety of hazards in the Gulf related to fishing, shrimping, and oil exploration activities, and as a result, cumulative effects may be of concern.[122] Currently the greatest threats to coastal endangered and threatened sea turtle populations in the Gulf are related to accidental drowning in shrimping and fishing gear.[123] The effects of contaminants on sea turtles are not well known, but the potential for cumulative effects in areas where dredging, oil spills, and brine disposal are occurring could have significant impacts on individual turtles. Especially in the proposed dredging areas, elevated contaminant and turbidity levels in the water column due to pipeline construction and maintenance would be added to current water column contaminant levels. Effects may occur in turtles exposed to these elevated contaminant levels that could 1) make sea turtles less effective at life activities (e.g., breeding, feeding); 2) make sea turtles more likely to be caught in fishing or shrimping equipment; or 3) make turtles less tolerant of high salinity brines and/or toxins. Oil spills in coastal areas could have significant impacts on a Gulf-wide scale if important feeding grounds are fouled, or if large numbers of individuals encounter oil or tar balls. Because the Kemp's Ridley turtles breed and spend most of their lives in the Gulf of Mexico, this species is the most likely to experience cumulative impact.

No significant cumulative impacts to the endangered and threatened marine mammals are expected. As discussed in the biological background section (E.3.3), the endangered and threatened whale species are not expected to come close enough to shore to encounter SPR related impacts, or impacts related to most other types of coastal construction activities. Major threats to the continuation of whale species have historically been related to overexploitation by the whaling industry; however, it is possible that in the future, increased contaminant levels and other types of ocean pollution will be shown to have significant effects on individuals or species. Similarly, significant cumulative effects on manatees are not expected; the most important threats to this species are probably loss of seagrass habitat in Florida, and direct impacts with vessel traffic in Florida.

E.3.9 Mitigation

The main focus of efforts to minimize potential impacts associated with the proposed expansion of the SPR to endangered and threatened marine species would be to prevent unnecessary habitat destruction. The most important habitat types to avoid include seagrass beds, oyster beds, other areas associated with high concentrations of benthic food supplies, and areas near historical sea turtle nesting sites. Preliminary routing of brine diffuser pipelines avoids known seagrass beds; this would have to be confirmed by surveys before filing an application for construction permits. If seagrass beds cannot be avoided, DOE would utilize construction techniques to minimize damage, such as removal of dredged sediment from the area. If damage cannot be avoided, DOE would consider appropriate restoration measures in consultation with appropriate agencies.

Because the gulf sturgeon is only found in the eastern Gulf, any impacts could be minimized by conducting dredging operations in this area (i.e., Richton) during the summer when the adult sturgeon are utilizing estuarine and riverine habitats.

Mitigation measures related to oil and brine spill prevention and control are discussed in Chapter 8 of the DEIS. The spill containment equipment, emergency controls, procedures, and contingency/emergency plans that have been developed should be effective in minimizing the potential for spilled oil or brine to impact marine ecosystems and threatened and endangered marine species.

In order to further minimize the very slight possibility of direct injury to endangered and threatened marine species from dredging activities, areas to be dredged would be surveyed for turtles prior to the start of pipeline channel construction. Any turtles in the area could be captured and removed from the vicinity or displaced from the area in a less stressful manner, if feasible.

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110. Fritts, T.H. and M.A. McGehee, *Effects of Petroleum on the Development and Survival of Marine Turtle Embryos*, U.S. Fish and Wildlife Service, Denver Wildlife Research Center, Belle Chase, LA., 1982, FWS/OBS-81/37, 41 pp.

111. Fritts, T.H. and M.A. McGehee, *Effects of Petroleum on the Development and Survival of Marine Turtle Embryos*, U.S. Fish and Wildlife Service, Denver Wildlife Research Center, Belle Chase, LA., 1982, FWS/OBS-81/37, 41 pp.

112. Fritts, T.H. and M.A. McGehee, *Effects of Petroleum on the Development and Survival of Marine Turtle Embryos*, U.S. Fish and Wildlife Service, Denver Wildlife Research Center, Belle Chase, LA., 1982, FWS/OBS-81/37, 41 pp.

113. *Gulf of Mexico Sales 131, 135, and 137: Central, Western, and Eastern Planning Areas, Draft Environmental Impact Statement*, U.S. Department of Interior, Minerals Management Service, Gulf of Mexico OCS Region, OCS EIS/EA, MMS 90-0003, New Orleans, March 1990.

114. *Gulf of Mexico Sales 131, 135, and 137: Central, Western, and Eastern Planning Areas, Draft Environmental Impact Statement*, U.S. Department of Interior, Minerals Management Service, Gulf of Mexico OCS Region, OCS EIS/EA, MMS 90-0003, New Orleans, March 1990.

115. Geraci, J.R., and D.J. St. Aubin, *Study of the effects of oil on cetaceans*, U.S. Department of the Interior, Bureau of Land Management, Washington, DC, Contract AA-551-CT9-29, 1982, 274 pp.

116. Kent, D.B., S. Leatherwood, and L. Yohe, *Responses of migrating gray whales, Eschrichtius robustus, to oil on the sea surface*, unpublished M.S. thesis, Hubbs-Sea World Research Institute, San Diego, CA, 1982.

117. Goodale, D.R., M.A.M. Hyman, and H.E. Winn, 1981, "Cetacean responses in association with Regal Sword oil spill," *A Characterization of Marine Mammals and Turtles in the Mid and North Atlantic Areas of the U.S. Outer Continental Shelf*, R.K. Edel, M.A. Hyman, and M.F. Tyrell (eds), Chapter XI, pp 1-15, Cetacean and Turtle Assessment Program Annual Report 1979, University of Rhode Island.

118. Geraci, J.R., 1990, "Physiologic and toxic effects on cetaceans," *Sea Mammals and Oil: Confronting the Risks*, J.R. Geraci and D.J. St. Aubin (eds), Academic Press, San Diego, CA.

119. Hansen, D.J., 1985, *The potential effects of oil spills and other chemical pollutants on marine mammals occurring in Alaskan waters*, U.S. Department of the Interior, Minerals Management Service, Alaska Outer Continental Shelf Region, Anchorage, AK, Rep. MMS 85-0031.

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122. Personal communication, *Conversation with J. Brown*, U.S. Department of Commerce, National Marine Fisheries Service, Miami, FL, August 5, 1992.

123. National Academy of Sciences, *Decline of the Sea Turtles: Causes and Prevention*, Committee on Sea Turtle Conservation, Board on Environmental Studies and Toxicology, Board on Biology, Commission on Life Sciences, and National Research Council, National Academy Press, Washington, DC, 1990.

APPENDIX F

BIOLOGICAL ASSESSMENT

for

THREATENED AND ENDANGERED SPECIES

Submitted

to

Fish and Wildlife Service
U.S. Department of Interior

by

U.S. Department of Energy
Strategic Petroleum Reserve Office

prepared by

ICF Incorporated
9300 Lee Highway
Fairfax, VA 22031-1207

(Included as Appendix F in DEIS
on the Expansion of the Strategic Petroleum Reserve)

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F.1 Background

The U.S. Department of Energy's (DOE) proposed plan to expand the Strategic Petroleum Reserve (SPR) capacity to one billion barrels requires the addition of sites and buried pipelines (brine, raw water, and oil pipelines). A leaching process is used to create storage caverns in underground salt domes. The resulting brine is disposed of by ocean discharge in the Gulf of Mexico and/or by underground injection wells.

In the Draft Environmental Impact Statement (DEIS), DOE is assessing five sites: Big Hill and Stratton Ridge in Texas for expansion in the SPR Seaway Complex and Weeks Island and Cote Blanche in Louisiana and Richton in Mississippi for expansion in the SPR Capline Complex. DOE will choose two sites for expansion.

This biological assessment discusses the possible impacts to inland threatened and endangered species from four aspects of the proposed SPR expansion: (1) site construction, (2) pipeline construction, (3) site operations, and (4) pipeline right-of-way maintenance. Eleven federally endangered or threatened coastal, inland terrestrial, or aquatic species and one anadromous fish species are discussed considering possible impacts of the proposed expansion plan.

The following section provides a brief overview of each proposed site and its associated distribution and brine disposal configurations. Information presented includes locations of the candidate sites and construction requirements and options for site development or expansion. A map showing the locations of all five sites is provided in Figure F.1-1. Detailed information on each site, its surrounding environment, and options is presented in the body of the DEIS.

F.1.1 Big Hill Expansion (Seaway Complex Site)

Big Hill is an existing SPR facility located in Jefferson County, Texas, approximately 17 miles southwest of Port Arthur. An additional 150 acres would be developed. Under the Big Hill expansion alternative, DOE would construct:

- Up to ten additional caverns with the capacity to store 100 million barrels (MMB) of oil; and
- A new sacrificial anhydrite pond.

DOE also may construct:

- A new crude oil distribution pipeline connecting Big Hill to East Houston. (Two routes are being assessed; one crosses Trinity Bay and one generally follows I-10.)

The right-of-way (ROW) required for the pipeline crossing Trinity Bay would include 39.7 miles of uplands, approximately 12 miles of open water, and 6.5 miles of wetlands. The ROW required for the I-10 route would involve 49 miles of uplands, approximately one mile of open water, and 13 miles of wetlands. Maps of the proposed site and pipeline locations are shown in Figures F.1-2 and F.1-3.

Figure F.1-1
Candidate SPR Storage Sites

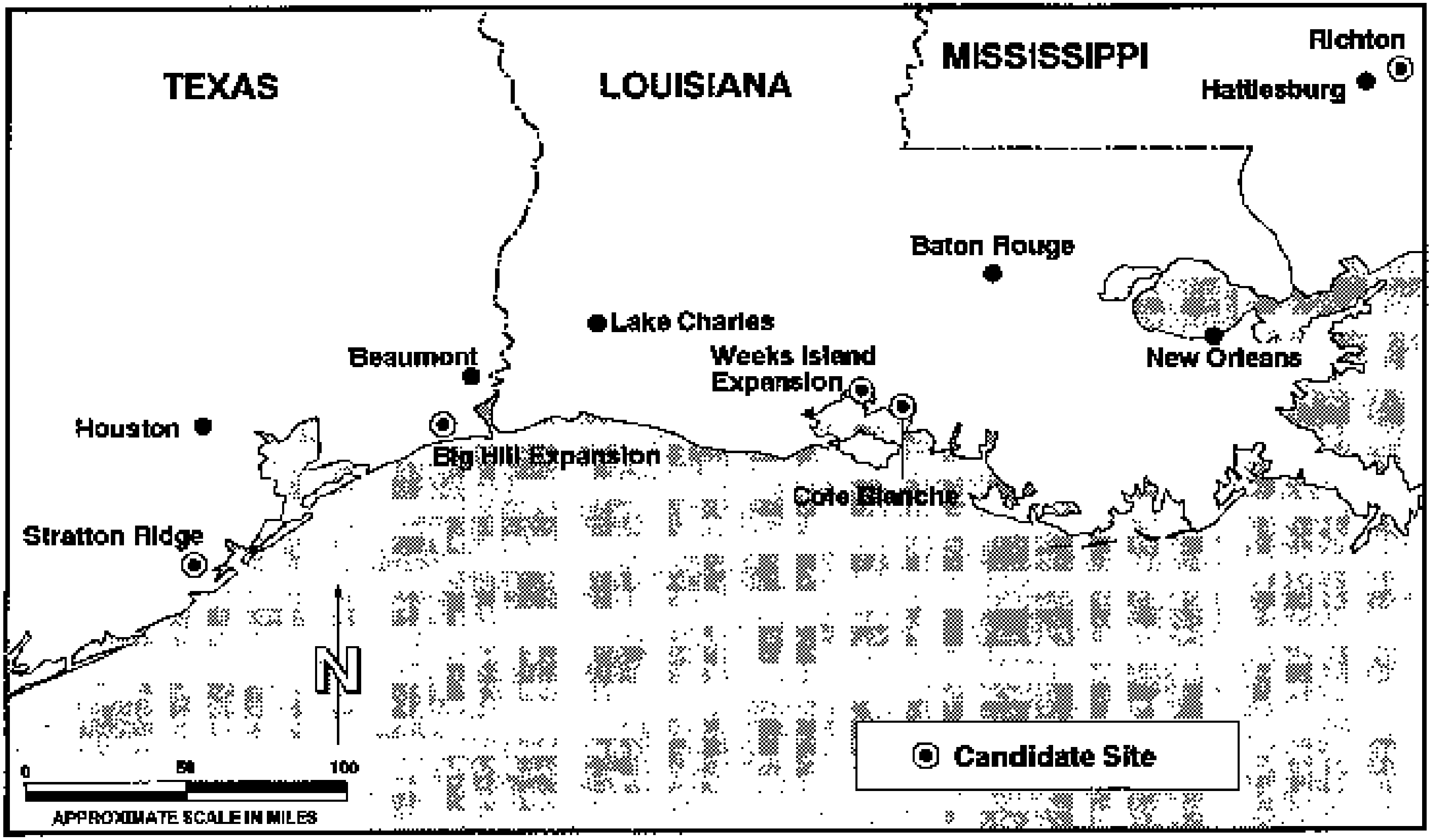
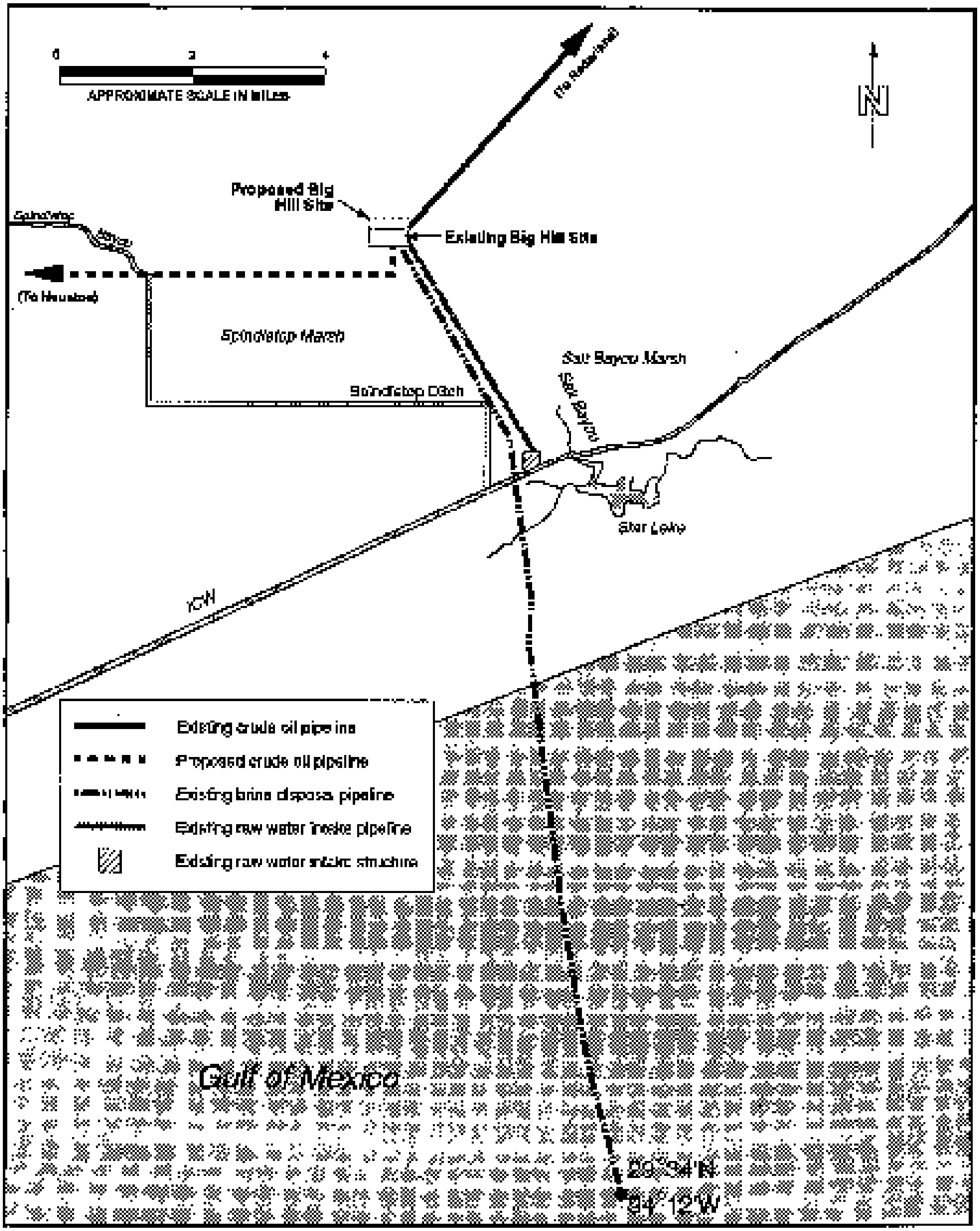
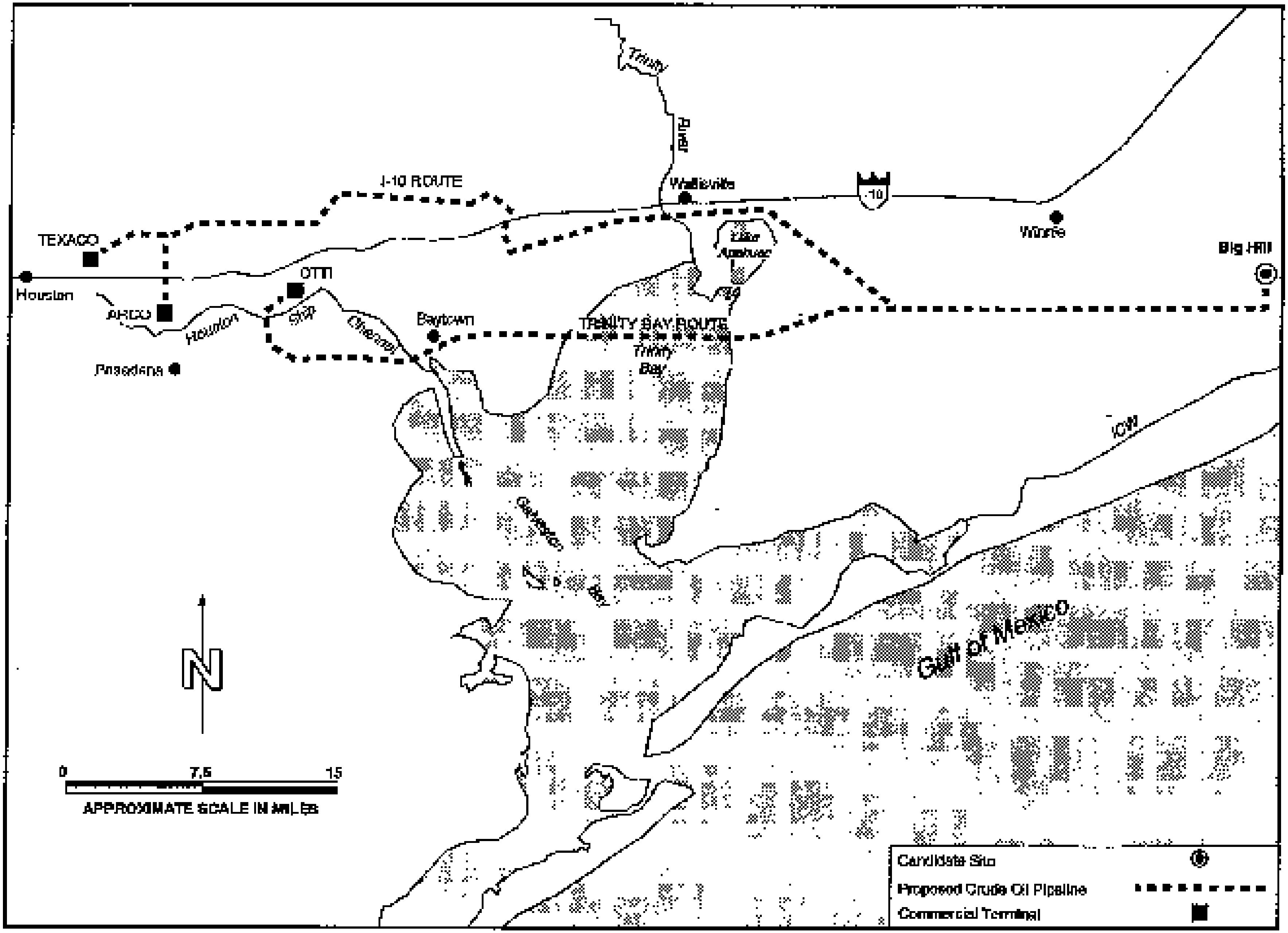


Figure F.1-2
Existing Raw Water Intake and Brine Disposal Systems for Big Hill



Source: Walk, Haydel, & Associates, Inc., *Big Hill Oil Storage Complex*, Jefferson County, Texas – Big Hill to the Gulf of Mexico Raw Water and Brine Disposal Pipelines. Baton Rouge, Louisiana.

Figure F.1-3
Proposed Crude Oil Pipelines for Big Hill



F.1.2 Stratton Ridge (Seaway Complex Site)

The proposed Stratton Ridge site is in Brazoria County, Texas, three miles east of Clute and Lake Jackson and six miles north of Freeport. The proposed site would be located on approximately 200 acres. Under this alternative, DOE would construct:

- Operation, maintenance, and security buildings;
- Ten storage caverns;
- A leaching/drawdown system;
- An offsite raw water intake (RWI) structure on the Intracoastal Waterway (ICW) and associated pipeline;
- A brine settling and disposal system with a pipeline to a diffuser about 3.5 miles offshore in the Gulf of Mexico; and
- A crude oil distribution system including a one-mile pipeline spur from the site to the existing Bryan Mound-Texas City pipeline.

Figure F.1-4 shows the location of proposed pipelines.

F.1.3 Weeks Island Expansion (Capline Complex Site)

The existing Weeks Island SPR facility was developed on the southwest slope of the island and occupies about 1.8 surface acres of the Weeks Island salt dome. The proposed expansion would be located on approximately 270 acres. Under the Weeks Island expansion alternative, DOE would construct:

- Up to 16 storage caverns, with a total storage capacity of 160 MMB;
- An RWI structure on the ICW; and
- Up to two pump stations on the existing Weeks Island-St. James crude oil pipeline.

DOE also may construct:

- A seven-mile spur to the existing Texas 22" pipeline to Clovelly.

DOE is considering two brine disposal systems at Weeks Island. DOE would construct either:

- A 48-inch, 41-mile brine disposal pipeline and diffuser system extending to the 25-foot water depth contour in the Gulf of Mexico that would share a common ROW with the RWI pipeline from the site to the ICW; or
- A deep underground injection system close to the site as a brine disposal alternative.

Figures F.1-5, F.1-6, and F.1-7 provide maps of the proposed site and pipeline locations.

Figure E.1-4
Proposed Brine Disposal, Raw Water Intake, and Crude Oil Systems for Stratton Ridge

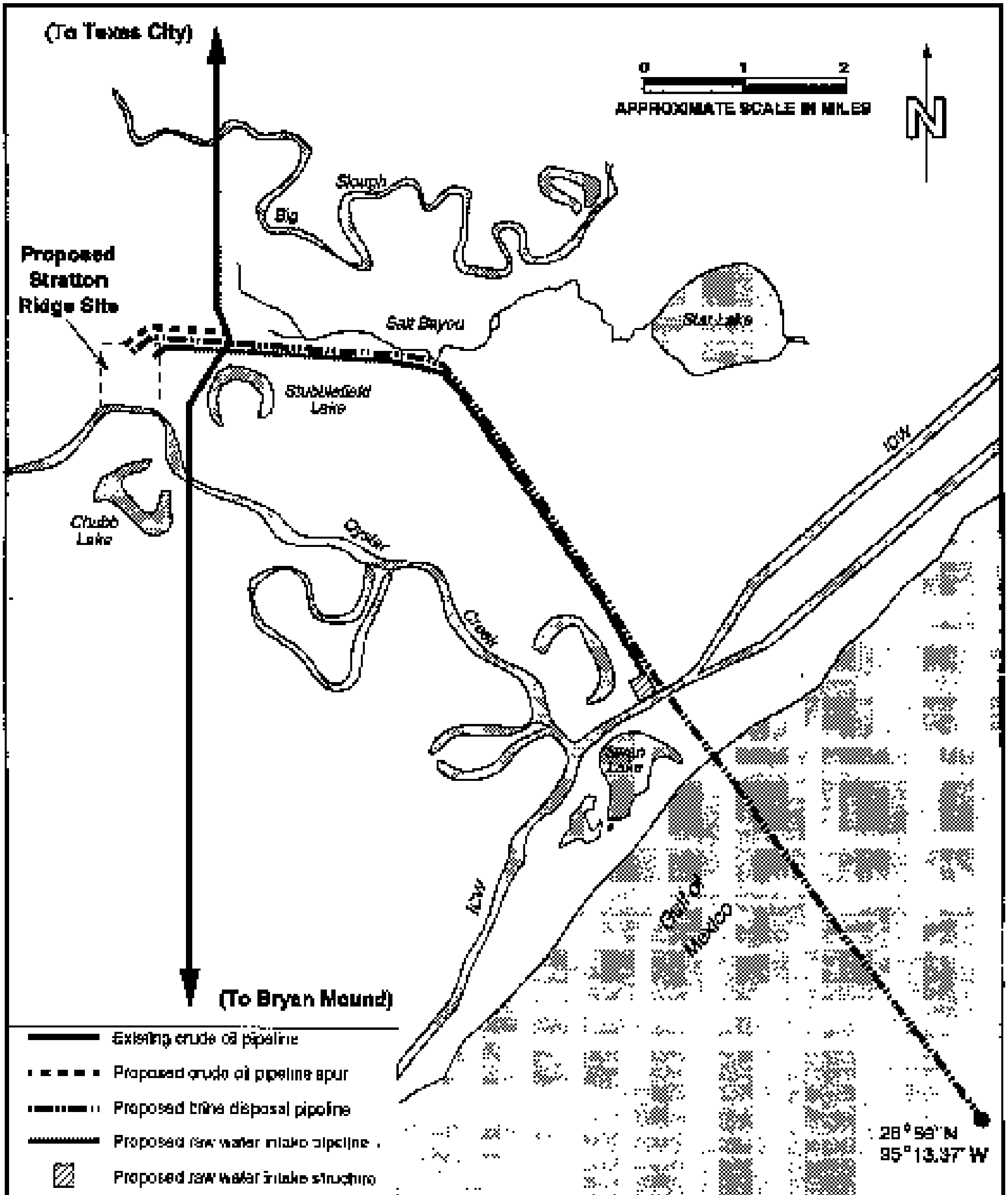


Figure F.1-5
Proposed Brine Disposal (Underground Injection) and Raw Water Intake Systems for Weeks Island

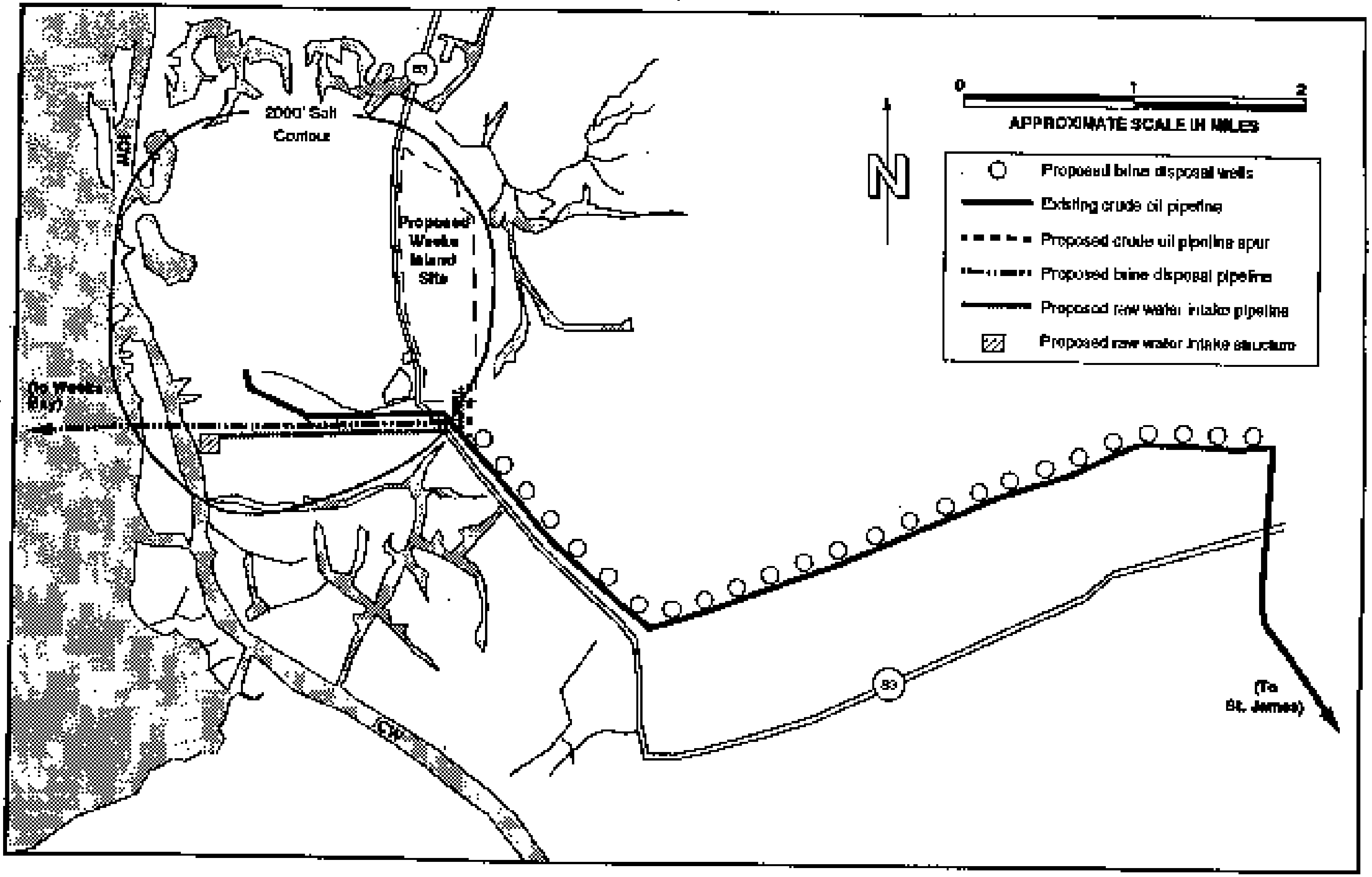
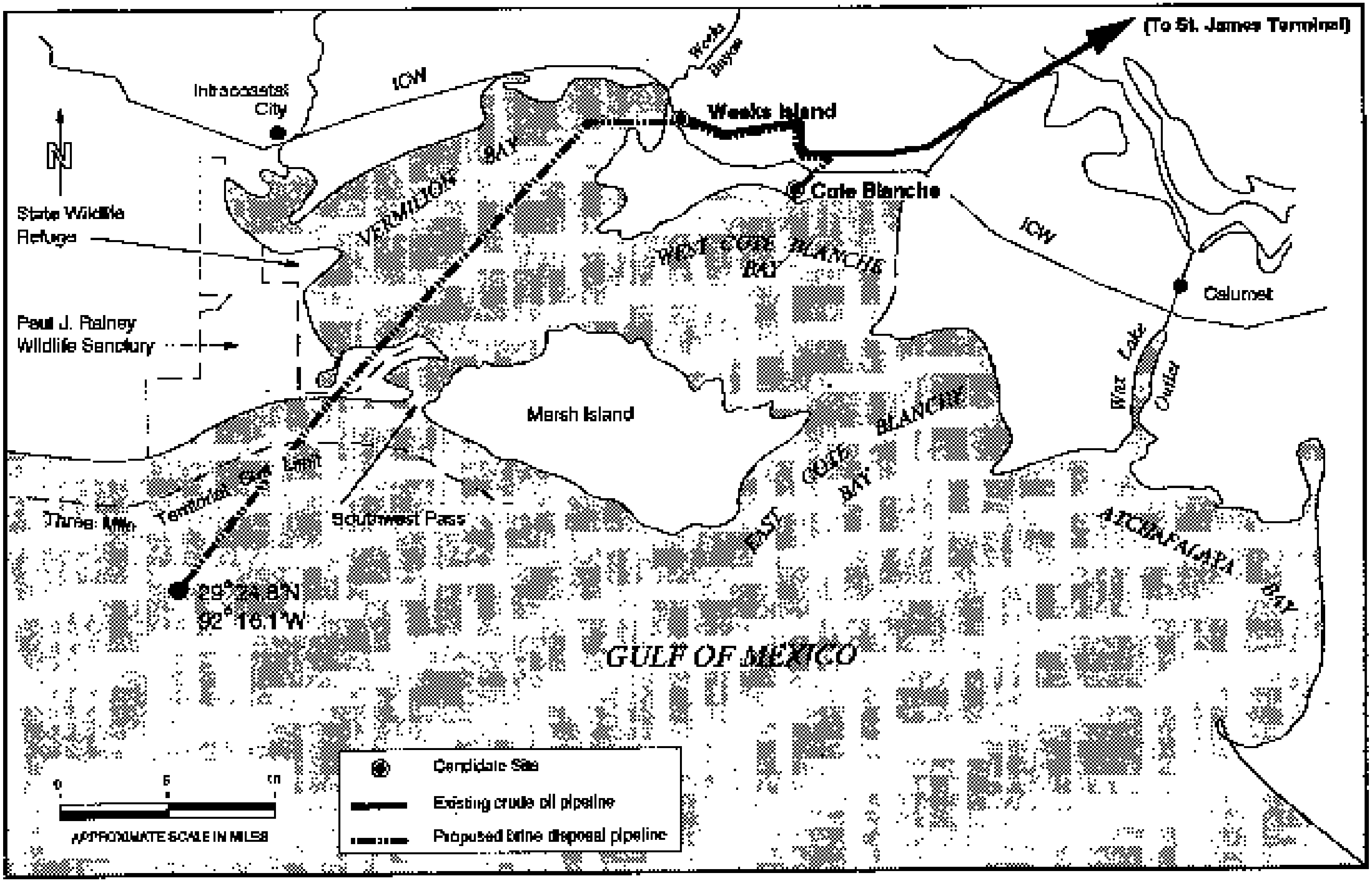
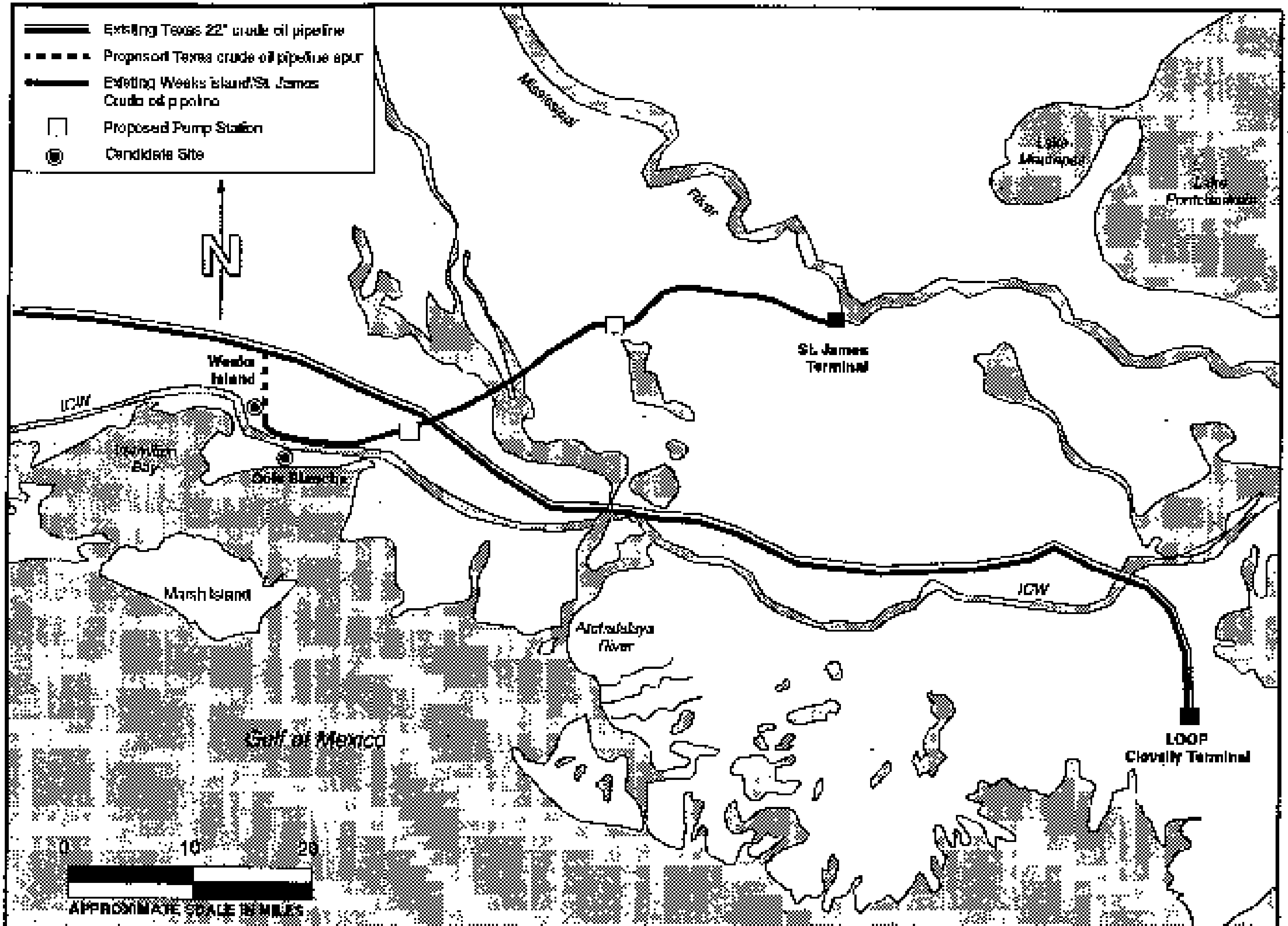


Figure F.1-6
Proposed Brine Disposal System (Diffuser) for Weeks Island/Cote Blanche



Source: PB-KBB Inc., Brine Pipeline Maps of Weeks Island on National Oceanic and Atmospheric Administration nautical charts.

Figure F.1-7
Proposed Crude Oil System for Weeks Island/Cote Blanche



F.1.4 Cote Blanche (Capline Complex Site)

The Cote Blanche salt dome is located in St. Mary Parish, Louisiana, on the northern edge of West Cote Blanche Bay, about eleven miles southwest of Franklin. It is one of the three DOE candidate sites for SPR development in the Capline Complex. The proposed site would be located on approximately 300 acres. Under this alternative, DOE would construct:

- Up to 16 storage caverns, with a total storage capacity of up to 160 MMB;
- A raw water-handling system for leaching and drawdown;
- A brine settling and disposal system;
- A crude oil fill and drawdown/distribution system;
- Operations, maintenance, and security buildings;
- Access roads and a bridge over the ICW; and
- An off-site RWI structure on the ICW located about one mile north of the proposed site and associated pipeline.

For brine disposal, one of the following would be constructed:

- A pipeline passing to the west of Marsh Island and extending more than 40 miles from the site to a diffuser located in at least 25 feet of water in the Gulf of Mexico; or
- A deep well injection system that would inject brine into deep saline aquifers.

Oil distribution pipeline options include:

- A two-mile spur to the existing pipeline to St. James Terminal and one booster station; or
- A pipeline upgrade with two pump stations and a seven-mile spur from Weeks Island to the Texas 22" pipeline.

See Figures F.1-6, F.1-7, and F.1-8 for site and pipeline locations.

F.1.5 Richton (Capline Complex Site)

The Richton salt dome is located in northeastern Perry County, Mississippi, approximately 18 miles east of Hattiesburg and approximately three miles from the town of Richton. It is an alternative to the candidate sites at Weeks Island and Cote Blanche. Under the Richton alternative, DOE would construct:

- Up to 16 storage caverns totaling 160 MMB capacity on approximately 300 acres with associated operations and maintenance facilities;
- A 10-mile pipeline to a RWI structure on the Leaf River;
- A terminal at Pascagoula with about 9 miles of pipeline connections to:
  - the Chevron Refinery,
  - the Cal-Ky Pipeline terminus, and
  - up to 4 docks of the Port of Pascagoula on Bayou Casotte;
- A brine clarifier and disposal system utilizing both underground injection and ocean discharge and featuring two dual-purpose oil/brine pipelines:
  - a 10.6-mile connection to a Hess 10" oil pipeline with a 2.8-mile extension to 15 brine disposal wells; and

- an 82-mile pipeline to the Port of Pascagoula with a 15-mile brine-only extension to a brine diffuser 14 miles offshore in the Gulf of Mexico to a depth of 47 feet.

Other oil distribution options include:

- A 70-mile pipeline to Mobile with one pump station; or
- A 118-mile pipeline to the Capline Pipeline at Liberty with the following:
  - one pump station;
  - 1.2 MMB of tankage at Liberty; and
  - one dock and one 0.4-MMB tank at St. James.

See Figures F.1-9, F.1-10, F.1-11 for maps of proposed pipelines.

F.2 Assumptions and Methodology

F.2.1 Site Visits

Walk-through surveys were conducted by ecologists at each of the sites. The proposed Big Hill, Stratton Ridge, Weeks Island, and Cote Blanche sites were surveyed in June 1991. The Richton site was visited in November 1991 and April 1992, and an aerial survey was conducted in December 1991. Detailed descriptions of the ecology at each site, including any signs of threatened or endangered species, are described in Chapter 5 of the DEIS. No surveys along proposed alternate pipeline routes have been conducted.

F.2.2 Contacts with Federal Agencies and Experts

For this biological assessment, we began with the list of Federally-listed threatened and endangered species. Representatives of USFWS and State agencies with statutory responsibility for protection of threatened and endangered species were provided with maps of the proposed pipeline routes. These representatives identified species of concern (i.e., threatened and endangered species for which appropriate habitat may be located at or near proposed site areas or pipeline routes). Table F.2-1 lists threatened and endangered species that were considered species of possible concern. See Appendix D of the DEIS for a complete list of threatened or endangered species in the study area (i.e., counties and parishes in which the proposed sites, pipeline routes, and structures are located).

Agencies then marked known locations of the listed species on detailed maps of the proposed sites and pipelines. Only the black bear (Louisiana) and the yellow-blotched sawback turtle (Mississippi) actually are known to inhabit areas near the proposed sites or pipelines. Agency representatives suspect there is some possibility that the nine other threatened and endangered species may be affected by SPR activities, although sightings of these species have not been recorded.[1] These nine species are included in this biological assessment because it is possible that:

- Suitable habitat for the species may be near the proposed pipeline routes (based on maps of the pipelines and species habitat information); or

- Suitable habitat for the species may be close enough to SPR construction or spills to experience some impact.

Figure F.1-8
Proposed Brine Disposal, Crude Oil,
and Raw Water Intake Systems for Cote Blanche

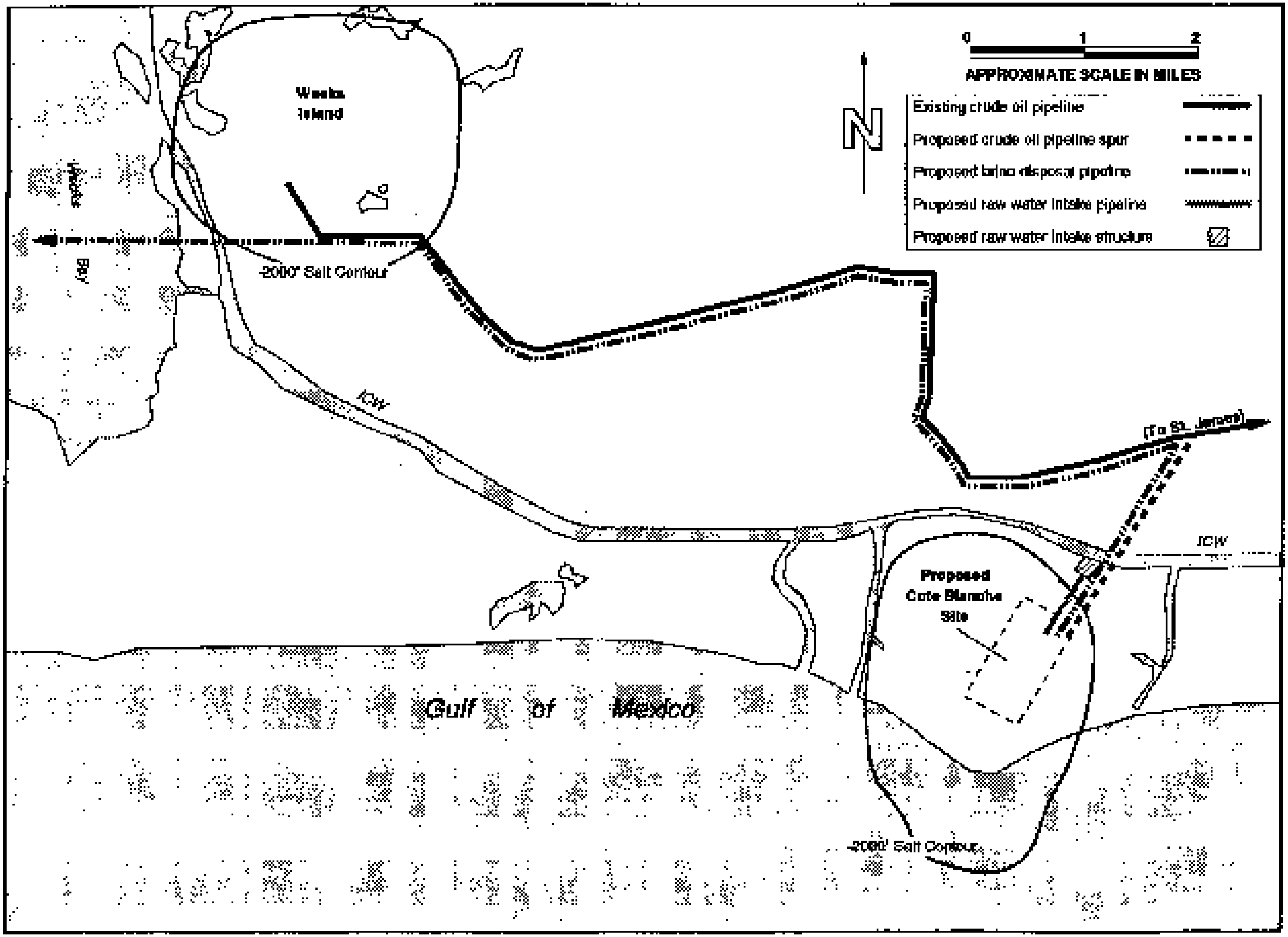
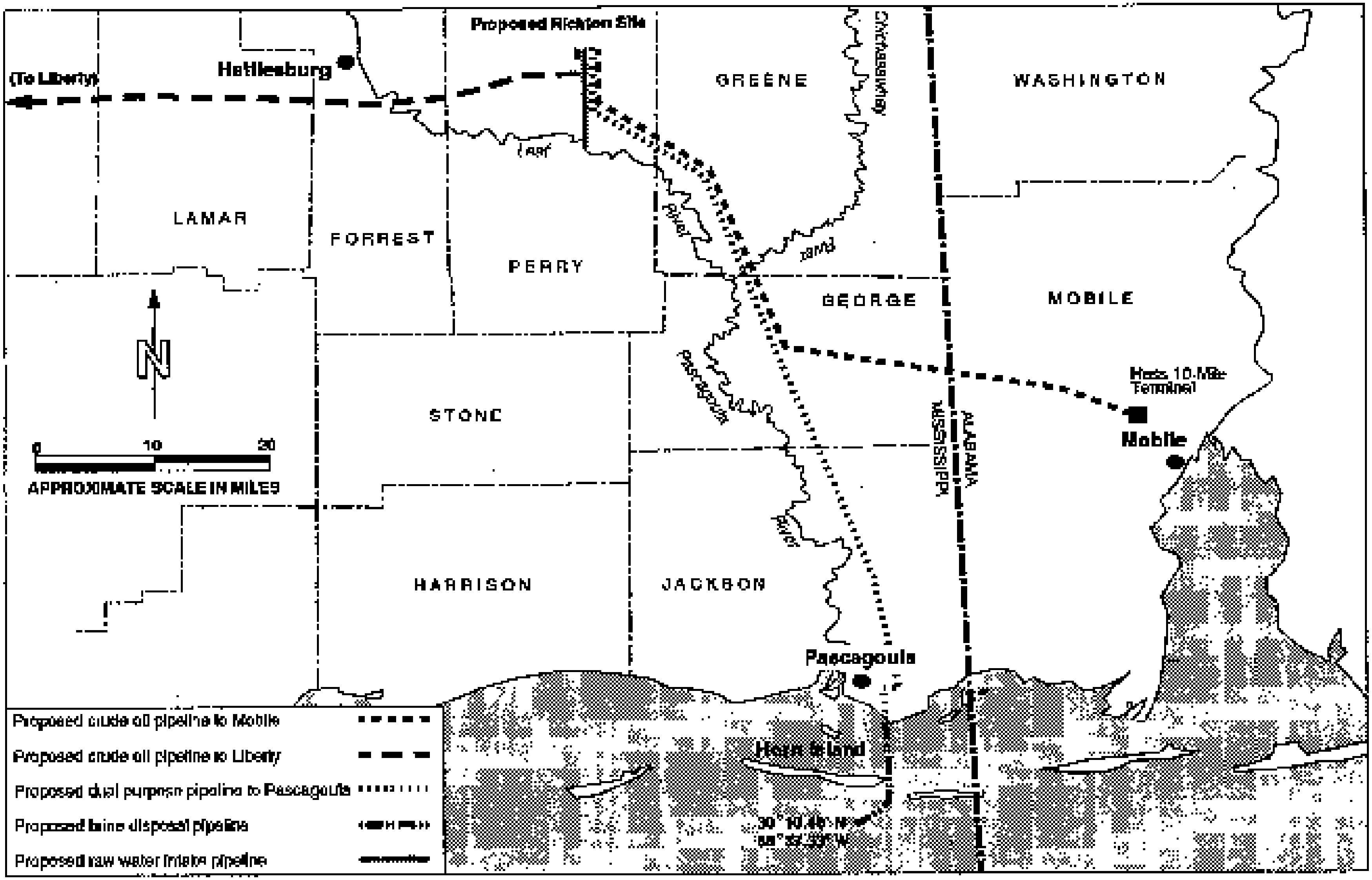
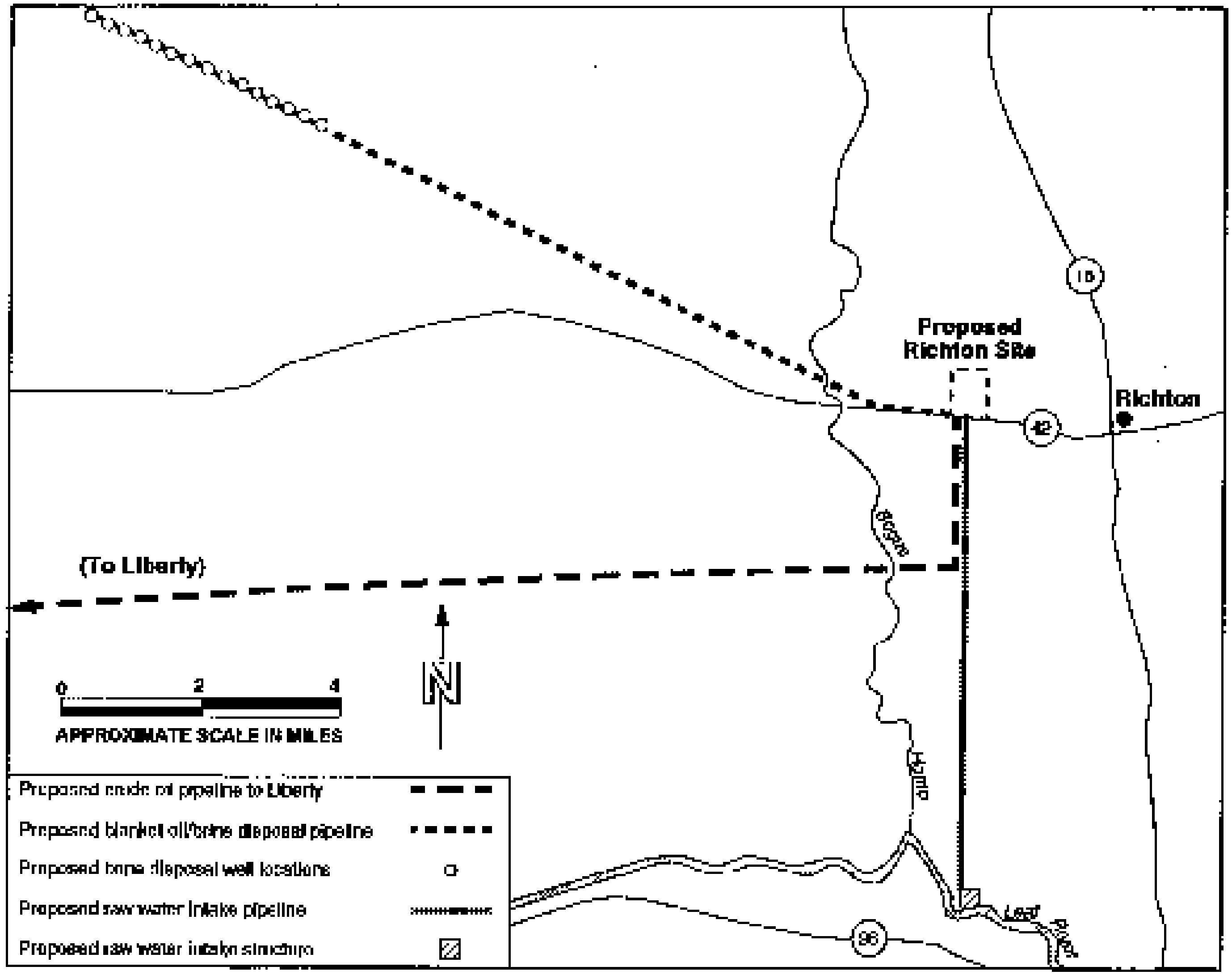


Figure F.1-9
Proposed Crude Oil and Brine Disposal Systems for Richton



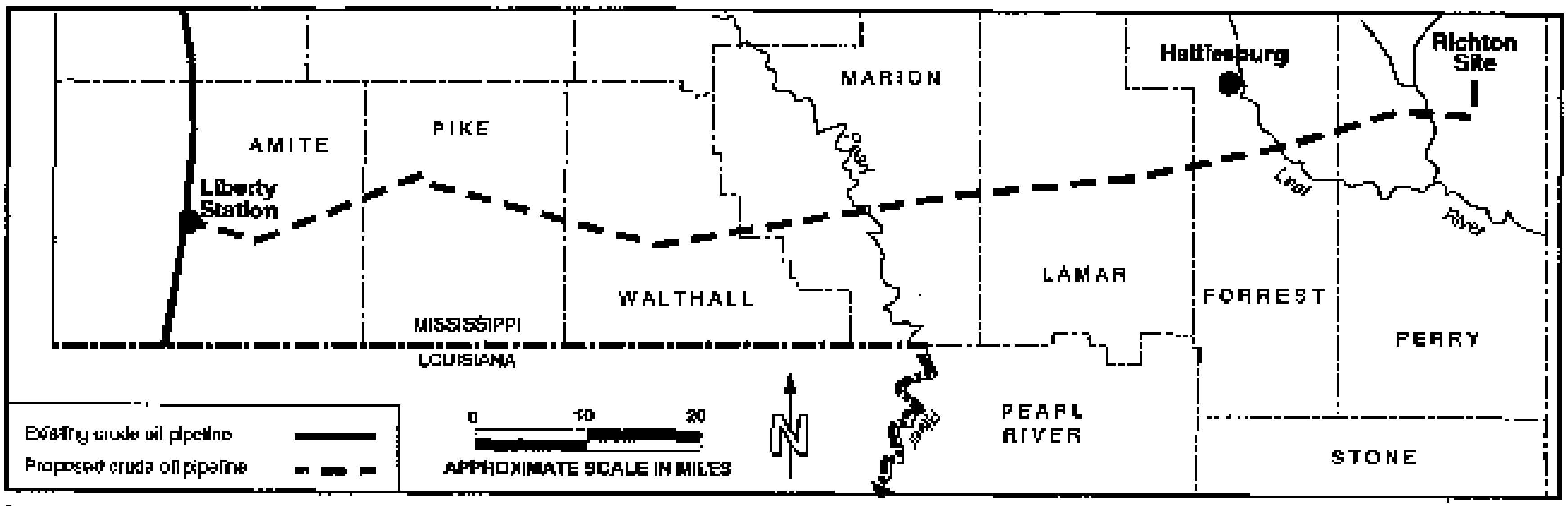
Source: 1) PB-KBB Inc., *Richton Dome Pipeline System*, Sheets 1-7, Houston, Texas; 2) Conversation with U.S. Department of Energy

Figure F.1-10
Proposed Raw Water Intake and
Underground Injection Systems for Richton



Source: PB-KBB Inc., *Richton Dome Pipeline System*, Sheets 1-7. Houston, Texas.

Figure F.1-11
Proposed Crude Oil Pipeline to Liberty



Source: U.S. Department of Energy

Table F.2-1
Threatened or Endangered Species of Possible Concern

Common Name of Threatened or Endangered Species	Sources
Big Hill, Texas	
NONE	(1)
Stratton Ridge, Texas	
Bald Eagle	(1)
Brown Pelican	(2)
Piping Plover	(2)
Weeks Island/Cote Blanche, Louisiana	
Black Bear	(3)
Richton, Mississippi	
Alabama Red-bellied Turtle	(5), (6), (7), (8)
Bald Eagle	(4), (5), (6), (7), (8)
Eastern Indigo Snake	(4), (5), (6), (7), (8)
Gopher Tortoise	(4), (6), (7), (8)
Gulf Sturgeon	(9)
Red-cockaded Woodpecker	(4), (5), (6), (7), (8)
Ringed Sawback Turtle	(4), (7), (8)
Yellow-blotched Sawback Turtle	(4), (7), (8)
TOTAL SPECIES	11

Sources

(1) Texas Natural Heritage Program, (Texas Parks and Wildlife Department), _Computerized Element Occurrences of Special Concern_, May 15, 1991.
(2) Texas Natural Heritage Program (Texas Parks and Wildlife Department), _Endangered/Threatened Species Data File_, May 9, 1988.
(3) Personal Communication, _Conversation with K. Mitchell_, USDI Fish and Wildlife Service, Lafayette, Louisiana, March 25, 1992.
(4) Mississippi Natural Heritage Program (Mississippi Department of Wildlife, Fisheries, and Parks), _Special Animals and Special Plants_, January 3, 1992.
(5) Personal Communication, _Conversation with M. Bailey_, Alabama Natural Heritage Program, May 15, 1992.
(6) Mount, R.H., ed, _Vertebrate Animals of Alabama in Need of Special Attention_, Alabama Agricultural Experiment Station, Auburn University, April 1986.
(7) Personal Communication, _Correspondence from Larry E. Goldman_, Field Supervisor, U.S. Fish and Wildlife Service, Daphne, Alabama, February 26, 1992.
(8) Personal Communication, _Correspondence from Larry E. Goldman_, Field Supervisor, U.S. Fish and Wildlife Service, Daphne, Alabama, June 9, 1992.
(9) Gilbert, C.R., _Species Profiles: Life Histories and Environmental Requirements of Coastal Fishes and Invertebrates (Mid-Atlantic Bight)—Atlantic and Shortnose Sturgeons_. U.S. Department of the Interior, Fish and Wildlife Service, Biological Report 82(11.122), U.S. Army Corps. of Engineers TR EL-82-4, 1989.

Inclusion in this biological assessment does not necessarily indicate that the species (a) is currently found sufficiently close to any proposed SPR site or pipeline to be potentially affected by the proposed SPR activities, or (b) actually would be adversely affected if located nearby. To gain a more precise understanding of the possibility that the SPR expansion alternatives would adversely affect these species, more detailed site-specific information may be required. Such information might include additional more precise information about habitat (e.g., if no mature pine stands are crossed by a pipeline, red-cockaded woodpeckers are unlikely to be adversely affected) or walk-through surveys (e.g., to look for gopher tortoise burrows).

The agencies listed in Table F.2-2 identified and provided information on species of concern.

F.2.3 Literature Review

The *Federal Register (FR)* notice reporting the determination of each species as either Federally endangered or threatened was obtained for most species,[a] and species-specific information was reviewed. These were used as a source of basic biological information and to identify conservation priorities and possible impacts. If the *FR* notice was fairly recent (i.e., 1985 or later), it was also used to identify other relevant reference materials. For example, most of the references for the Gulf sturgeon (listed in 1991) and the gopher tortoise (listed in 1987) were selected from those listed in the *FR* notice.

U.S. Fish and Wildlife Service Recovery Plans were obtained for all species for which plans have been completed. Many of these were provided by regional offices of USFWS. Recovery plans are not yet available for species that only recently have been listed (e.g., Louisiana Black Bear).

A computerized literature search was conducted to identify articles, reports, and other materials on each species; the purpose of this search was to identify the most recent published information of each species, especially with respect to population distribution in Mississippi, Louisiana, and Texas and with respect to conservation-related issues.

F.3 Potential Environmental Impacts

As noted in section F.2.2, only the black bear (Louisiana) and the yellow-blotched sawback turtle (Mississippi) actually are known to inhabit areas near the proposed sites or pipelines. It is unknown whether the other nine species are close enough to proposed SPR activities to be adversely affected.

This section describes general potential impacts that could directly or indirectly affect the threatened and endangered species listed in Table F.2-1, assuming individuals are close enough to the proposed project to be affected. These potential impacts can be divided into three major categories: (1) those due to site construction and maintenance; (2) those due to pipeline construction and maintenance; and (3) those due to accidental oil and brine spills. Information on other types of environmental impacts that might occur as a result of the SPR proposed project

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[a] Because the red-cockaded woodpecker was listed early in the ESA program, no species-specific information was contained in the Federal Register notices.

Table F.2-2
Agency Contacts for Threatened and Endangered Species Information

Source	Agency	Date(s) of Contact
M. Bailey	Alabama Natural Heritage Program	May 15, 1992
Bob Butler	Fish and Wildlife Service, Alabama	July 29, 1992 August 17, 1992
Brigitte R. Cliburn Data Assistant	Mississippi Natural Heritage Program, Mississippi Department of Wildlife, Fisheries, and Parks	January 3, 1992
Clifton Eakes	Mississippi Natural Heritage Program, Mississippi Department of Wildlife, Fisheries, and Parks	August 5, 1992
David W. Frugé Field Supervisor	Fish and Wildlife Service, Louisiana	June 7, 1991
Larry E. Goldman Field Supervisor	Fish and Wildlife Service, Alabama	February 26, 1992 June 9, 1992
Ken Gordon	Mississippi Natural Heritage Program, Mississippi Department of Wildlife, Fisheries, and Parks	August 6, 1992
Cheri Jones	Mississippi Natural Heritage Program, Mississippi Department of Wildlife, Fisheries, and Parks	January 8, 1992
B.D. King	Fish and Wildlife Service, Texas	July 28, 1992
Kim Mitchell	Fish and Wildlife Service, Louisiana	July 29, 1992
Mark Mitchell	Texas Parks and Wildlife Department	August 4, 1992
Terri Rabot	Fish and Wildlife Service, Louisiana	July 29, 1992

(but are not expected to affect threatened or endangered species of concern) is provided in Chapters 6 and 7 of the DEIS.

F.3.1 Potential Impacts Due to Site Construction and Maintenance

Inland Surface Waters and Aquatic Ecology

Erosion could result in increased sedimentation to surrounding waters, possibly affecting the sturgeon and aquatic turtles. Also, pollutants (e.g., gasoline, diesel oil) from construction activities could run into nearby water bodies and affect the threatened and endangered aquatic (e.g., sturgeon, turtles) or piscivorous species (e.g., bald eagles).

Terrestrial Ecology

The most significant predicted ecological impacts would be those of habitat loss associated with site construction. The primary impacts to vegetation from construction of the site are destruction of on-site vegetation and impacts to off-site vegetation from soil erosion and sedimentation. The Weeks Island site is comprised of a combination of agricultural land and mature live oak and magnolia forest; the threatened Louisiana black bear inhabits the island. The proposed site locations at Big Hill, Cote Blanche, and Richton are located in areas with few, if any, unique ecological communities. At Stratton Ridge, there are several diverse ecological communities, including emergent and forested wetlands, open parkland forest, and abandoned farmland and orchards, but no known threatened or endangered species inhabit the proposed site area.

Potential impacts to wildlife from construction of the proposed sites could include destruction of individuals of smaller or less mobile species of wildlife, displacement of wildlife, and disruption of behavior due to increased traffic and human activity. Weeks Island is increasingly heavily used for industrial purposes, and available black bear habitat on the island is already limited.

F.3.2 Potential Impacts Due to Pipeline Construction

Inland Surface Waters and Aquatic Ecology

The pipeline construction method used would differ depending on the size and depth of the water bodies to be crossed. Waterways less than 500 feet wide would be crossed by digging a trench with a barge- or bank-mounted dragline. Original material excavated from the streambed would be used for backfill, while excess excavated material would be deposited on upland areas authorized by a permit. In deep marshes, "floatation canals" may be dredged to accommodate barges that are used to construct and bury the pipe. Floatation canals are typically 80 to 100 feet wide and are not backfilled. A less damaging method for use in marshes is modified push ditch construction, in which shallow barges excavate a pipeline trench. The pipeline is then floated into the trench from a stationary construction barge, and dredge spoil is returned to the pipeline trench. For waterways that are more than 500 feet wide, pipelines often are constructed using the directional drilling method. In this technique, a trench is not excavated in the streambed. Instead, a pilot hole is drilled on one side of the crossing using a slanted drill rig. The pilot hole proceeds under the waterway, eventually emerging on the opposite bank, and the pipeline is then pulled through the hole.

At least temporarily, pipeline construction would result in degradation of water quality and aquatic habitat in water bodies that are crossed. Water quality impacts might include increased turbidity levels, increased concentrations of suspended nutrients, salt water intrusion, reduced dissolved oxygen levels, and, depending on the composition of sediments, increased levels of metal and organic contaminants. Organisms that live in the water might, in turn, experience adverse toxicological and behavioral effects. Benthic organisms and habitat directly within and near the pipeline corridor also would be unavoidably destroyed. All of these impacts would be temporary, however, and would be confined to areas close to the pipeline ROW. Suspended sediments are expected to settle back to the bottom, benthic habitat is expected to be restored and recolonized, and free swimming fish that avoided the disturbance are expected to return to the area soon after construction ceases.

Pipeline construction can also cause adverse ecological impacts, either directly due to the dredge activity itself or indirectly due to the degradation of water quality. Construction of the pipeline could minimally impact organisms in the region but could significantly affect the organisms in a concentrated area along the 100 to 170-foot wide ROWs. Particular biological/ecological impacts that might be associated with dredging and dredged material disposition include:

- Adverse effects due to increased turbidity and sedimentation. Dredging will be conducted when pipelines cross water bodies that are less than 500 feet wide. Dredging and dredged material disposal could cause disorientation in aquatic fauna (e.g., aquatic turtles, sturgeon) due to the confusion of organic smells and alteration of normal behavior due to physical disturbances, such as solids discharge and noise. Turbidity caused by dredging might cause a decrease in light penetration, reducing primary production. This, in turn, could decrease availability of some fish foods (e.g., small invertebrates that feed on plants or algae). Laboratory tests indicate, however, that turbidity levels created by dredging are not likely to cause direct mortality.[2] Sedimentation of dredged material could have a strong negative impact on benthic invertebrates, which are an important food source for sturgeon and aquatic turtles.

- Adverse effects due to chemical exposure. Depending on the chemical composition of dredged and suspended sediments, there could be a potential for exposure to a variety of contaminants, which might result in a variety of behavioral and toxicological effects in aquatic fauna (e.g., sturgeon and turtles). For example, the presence of hydrocarbons in sublethal levels in dredged material could interfere with the olfactory senses of these animals and affect food location, escape from predators, selection of habitat, and sex attraction.[3] Significant uptake of PCBs, pesticides, or metals released from the sediments to the water column could cause similar adverse effects, including mortality, if exposures were great enough.

Terrestrial Ecology

The primary impact to terrestrial threatened and endangered species from pipeline construction would be destruction, loss, and fragmentation of habitat in the 150-foot construction ROW if pipelines are routed through suitable habitat for these species. Clear-cutting ROWs through forested areas could permanently destroy and fragment black bear and red-cockaded woodpecker habitat. ROWs would be maintained with herbicides to prevent forest regrowth. Pipeline construction through dry, grassy areas could temporarily disrupt gopher tortoise habitat.

Potential impacts associated with operation and maintenance of the sites and pipelines would include continued loss of habitat for wildlife due to restricted access and lack of vegetation on the site; disruption of wildlife surrounding the site due to increased traffic, noise, and human activities; loss or impairment of vegetation and wildlife from leaks or spills; and disruption and temporary displacement of wildlife during inspections.

F.3.3 Potential Impacts Due to Accidental Oil and Brine Spills

An overview of the potential impacts of oil and brine spills is provided below. The chances of an oil or brine spill occurring and the related impacts are discussed in detail in Chapters 6 and 7 of the DEIS.

Oil Spills

Accidental oils spills could affect threatened or endangered species in one of two ways. Inland spills (e.g., due to pipeline leaks or transfer spills at terminals) could damage terrestrial, freshwater, or estuarine habitats. Marine spills (e.g., tanker spills due to incremental increase in Gulf oil traffic) could damage coastal habitats. Since oil traffic is already extremely heavy in the Gulf, any increase in activity due to the SPR expansion would be comparatively small.

The sensitivity of fish to oil spills varies by species and by age class. In general, fish are very sensitive to short-term acute exposures, but are able to metabolize sub-lethal intakes. Older age classes are able to avoid heavy contamination, and have a mucous coating that helps them resist contact with toxic oil constituents. It is the youngest age classes that are most vulnerable to oil spills. Oil may smother eggs, interfere with hatching success, or cause developmental abnormalities.[4] Because spawning and hatching are generally concentrated temporally as well as spatially, oil spills that coincide with mating or hatching periods could cause substantial population level impacts. Many physiological, histological, and behavioral abnormalities caused by exposure to crude oil have been documented.[5]

Coastal birds, such as plovers and pelicans, are highly vulnerable to oil spills in coastal and estuarine areas. Feathers that become coated with oil become water-logged and lose their insulative properties. As a result, birds may drown or die of hypothermia. Oil is also ingested by birds as they preen. It has recently been discovered that birds suffer stress-related effects as they attempt to detoxify the ingested oil.[6] Disturbance of high-quality habitat or resources also could indirectly affect birds through increased competition.

Brine Spills

Although chloride is essential to life, it is toxic to most organisms at the high concentrations found in brine. EPA has established ambient water quality criteria for chloride for freshwater aquatic life (860 mg/l acute toxicity, 230 mg/l chronic toxicity). There is an extensive body of literature on the biological effects of elevated salinity.[7] Many species have evolved means of surviving in conditions of high or highly variable salinity.[8] An undiluted brine spill could expose biota in freshwater or estuarine areas to chloride concentrations well above natural levels and well above the acute and chronic criteria for aquatic life. A brine spill also could cause a significant, but temporary and localized, disruption of ecological structure and function, though long-term impacts to surface water or sediment quality, or to biota would not be expected. In many respects, the ecological disruption caused by a brine spill would be similar to the disruptions caused by an oil spill. In the impacted area a change in community compositions would occur. The affected area would initially be repopulated by heartier, salt-tolerant species. Pioneer species (i.e., species not occurring at the site prior to the spill) might colonize the site.[9] In time, species succession would generally return the community to its previous composition. Only in the most heavily disturbed areas would habitat restoration be necessary to facilitate ecological recovery. The severity of impacts in the affected habitats would be directly related to the amount of freshwater flushing. The most heavily impacted areas would probably be poorly drained wetlands, and mitigation may be required to stimulate revegetation in these areas.

F.4 Biological Background Information for Threatened and Endangered Species of Concern

Biological background information for the eleven threatened and endangered species of concern (listed in Table F.2-1) is provided below. Discussions for each species include population distribution, range and habitat, food habits, and breeding and nesting habits.

F.4.1 Bald Eagle (*Haliaeetus leucocephalus*)

Population

The bald eagle population of the United States has been declining over the past 200 years and has suffered an extremely rapid decline since the late 1940's.[10] The bald eagle (below the 40th parallel) has been listed as a Federally endangered species since 1967. The primary causes of this decrease have been extensive loss of habitat (from logging, housing developments, and recreation), mortality from human-related activities (e.g., shooting, lead poisoning, pesticide bioaccumulation and poisoning), and nesting failure from loss of nest trees.[11] Population declines are due more to low adult survival rates than to low reproductive rates.[12] Recent population survey data show that there has been a significant increase in bald eagle nesting pairs in the U.S. from approximately 500 in the early 1960s to nearly 1,500 in 1982.[13] However, many biologists believe that this increase is a result of more extensive survey efforts; thus, actual population increases are unknown.

Survey data from 1982 indicate that there were 18 occupied eagle nests (and 18 young raised) in Louisiana, 14 occupied nests (and 16 young raised) in Texas, and no occupied nests in Mississippi.[14] Survey data from 1987-88 indicate that there were 37 eagle nests in Louisiana, located primarily along the Mississippi River Valley, the Gulf Coast, the Sabine River, and the Toledo Bend Reservoir. In the 1987-88 breeding season 20 eagle nesting areas were found in Texas.[15] In Mississippi, only two occupied breeding sites were found in 1988.[16]

The essential nesting habitats located in counties of concern (i.e., counties that the proposed pipeline route crosses) in Texas include the Brazos River drainage (Matagorda and Brazoria Counties) and the San Bernard River drainage (Brazoria County).[17] No essential nesting habitats, however, are located in the other counties of concern in Texas: Jefferson, Chambers, and Harris. The nearest nest to Oyster Creek (Brazoria County, Texas) is 25 miles away.[18] The only known eagle wintering habitat in a county of concern in Texas is Warren

Lake (Harris County).[19] There are no known essential nesting or wintering habitats in the counties of concern in Mississippi (George and Jackson Counties).

Geographic Range and Habitat

The range of the bald eagle covers most of North America, but it is more abundant in Canada. In the northern Gulf states, nesting is less common and is found mostly in peninsular Florida and along the coast of Louisiana, Mississippi, and South Carolina.[20] The key feature of bald eagle nesting habitat is water, as almost all nests are within two miles of a coastal area, river, marsh, or lake.[21] Eagles prefer to nest in tall trees, either living or dead, that have an open structure for easy approach and that have a clear view of the surrounding area.[22] They will not use trees that are adjacent to excessive human activity; the highest eagle population densities are found in undisturbed areas. The dominant species of tree utilized by the eagle varies in different regions of the continent.

Wintering habitat for the bald eagle is somewhat different. In the winter, after nesting and migration has occurred, eagles search for sites with readily available food sources and are not as limited to areas near water.[23] The winter habitat also consists of night roost sites, commonly occupied communally by two or more eagles and characterized by a warmer microclimate; these roosts are usually found in the oldest and largest trees within a stand.[24]

Food Habits

Bald eagles are opportunistic feeders, and the primary component of their diet is fish (e.g., catfish, carp, gizzard shad, white perch, yellow perch), either live or dead.[25] Because they are opportunistic, the amount of fish in the eagle's diet depends on food availability. Eagles will also scavenge on birds and mammals, including Canada geese, mallard, lesser scaup, white-tailed deer, black racer, opossum, and grey squirrel.

Breeding and Nesting

Bald eagles are monogamous, mating with the same individual from several years to life.[26] The breeding season (in southern states) takes place in the winter.[27] In Florida and Texas, courtship and nest building occurs from late September through November.[28] In general, egg-laying in the southeast occurs most often in December, but can vary from October to March, depending on the latitude.[29] Breeding areas are mostly along the coastlines.[30] Clutch size is usually one to three eggs.[31] Eagles do not begin breeding until at least five years of age.

F.4.2 Brown Pelican (*Pelecanus occidentalis carolinensis*)

Population

The brown pelican is one of the few species to have achieved some of the recovery goals established for it under the Endangered Species Act. In 1985 the brown pelican was removed from the list for much of its range on the southeastern coast of the United States. However, it remains on the endangered species list throughout the rest of its range, including in Mississippi, Louisiana and Texas. Historically there have been as many as 5,000 pelicans in Texas along the coast from Freeport to Galveston Bay, but by 1963 only about 100 birds were observed annually, and through 1974 only about 50 remained.[32] Since 1974 the numbers have been slowly increasing, but recruitment remains low.[33] Texan populations in winter still tend to be small (less than 100 annually between 1970 and 1981), but during the spring and summer the numbers increase. Five hundred were reported along the Texas coast during the spring and summer of 1979.

Originally, pelicans experienced a major decline through direct mortality and failed recruitment as a result of organochlorine pesticide pollution. Their recovery has been severely hampered by loss of suitable habitat, human disturbance (lowers productivity), parasitic infection, commercial and recreational fishing activity, pesticide pollution, sedimentation (lowers water clarity, making fish prey difficult to see), and coastal oil/gas development.

Geographic Range and Habitat

Pelicans nest and winter in Texas, although not necessarily in the same areas. While some populations present are native, it is thought that pelicans from Mexico and other areas also can be found there. Wintering pelicans tend to be concentrated on the central and southern coasts of Texas. Colonies, however, can be found as far north as Matagorda Bay,[34] and they are infrequently sighted in the Freeport-Galveston Bay area (Brazoria Co.) within their historical range.[35] Nesting colonies have been established in eight locations along the coast, beginning only as far north as San Antonio. In 1980 and 1981 one pair nested on the upper Texas Coast in Cedar Lakes in the San Benard National Wildlife Reserve.[36]

Food Habits

Brown pelicans dive to capture their prey, usually by flying at the surface and then scooping fish up off the surface and to a depth of one meter. They feed predominantly on fish and must consume more than 25% of their body weight daily.[37] Pelicans are at the top of the marine food web. They are adapted to go without or with low levels of food for extended periods; however, reproductive success generally is affected if low food availability persists for several years in a row.[38] Pelicans can live up to 25 years.

Breeding and Nesting

Pelicans begin breeding at three years or older. The breeding season begins from mid-February to early March and requires approximately eight months. Nesting is fairly prolonged in the lower latitudes of the pelican's range. Clutch size is generally three eggs, although productivity depends on how many fish the adults can catch. Additional clutches are laid (after nest or egg destruction) in up to 26% of wild colonies.[39] Postfledging survival is low (24-31%), but once the young learn the skills necessary to catch fish, its chances of survival increase (>86% annual survival rate). Recruitment problems in its Texas range included the adults not nesting and a high nest mortality, documented from 1964-74.[40] Since then, an increase has been recorded; from 1964-71 46 young (total) were fledged, from 1975-81 this number increased to 264 (total).[41] By 1982 there were 96 breeding adults in Texas.[42]

Their present breeding distribution extends from North Carolina through the Gulf of Mexico. They nest almost exclusively on islands; depending on the location of the colony pelicans nest in trees, small shrubs, and on the ground. Preferred island types are often human-made dredge spoils and natural sand spits slightly above sea level that are small enough to be uninhabited by humans and far enough from the mainland so there are no mammalian predators.[43] Pelicans also use sandbars and dredge islands as habitat for roosting and loafing.[44] Pelicans are colonial in nesting and feeding.[45] Colony size is often dependant on the amount of nesting site available. Although pelicans are occasionally found outside of the barrier islands (usually not further than 20 miles off-shore), their primary habitat is within the various estuarine bay systems.[46]

E.4.3 Piping Plover (*Charadrius melodus*)

Population

The piping plover is a migratory shorebird that has been listed as threatened on the Federal Endangered Species List since January, 1986. There are currently two subspecies recognized, the Atlantic or eastern piping plover (*Charadrius melodus melodus*) and the interior piping plover (*Charadrius melodus circumcinctus*). Both subspecies are considered as threatened, however, their status and recovery are assessed separately. In addition, the species has been listed separately for its breeding and wintering ranges. For the purposes of the SPR expansion, it is predominantly the interior piping plover that is of interest. There is not much historical information on the plover, but enough to show a substantial decline.[47] It is estimated that the total number of both subspecies is less than 4,500 including 697 breeding pairs of interior piping plovers located in the Great Lakes (17 - endangered) and Northern Great Plains (680 - threatened).[48]

Habitat loss and destruction and coastal oil activities have been the primary threats to the plover in its wintering habitat. Dredging activities and other development that destroys or alters beaches and muddy sandflats results in habitat loss, as does coastal oil activity.

Geographic Range and Habitat

Despite the fact they are in their winter range for most of the year, the majority of field studies on plovers have focused on their breeding and nesting habits and habitat: relatively little is known about their wintering ecology. This is problematic for the recovery of plovers since it has been suggested that winter may be an important part of the annual cycle affecting mortality of migratory shorebirds.[49] The interior piping plover breeds in the Great Lakes and Northern Great Plains regions of the U.S. and Canada from March until August. The remaining eight months are spent wintering along the Gulf Coast from Florida to Northern Mexico.[50] Impacts to the plover in its wintering range still need to be examined (relative to impacts occurring in the breeding areas). In particular, loss and modification of habitat has been indicated to be a potential problem, as it has been suggested that specific sites may have importance for both breeding and non-breeding birds.[51] Because adult plovers are relatively site-faithful, loss or alteration of habitat is a particular problem.[52]

Recent studies have begun to investigate the plover more thoroughly in its winter range. Plovers have been sighted mainly on large areas of intertidal flats, typically ephemeral sandflats and sandy mudflats, more often than the open, sandy beaches they use during nesting and breeding. This may be because much of their time is spent foraging for food; few birds have been sighted roosting.[53] However, in the past plovers have been more strongly associated with beach areas;[54] it has been suggested that due to the increased urban and industrial expansion on beaches, plovers have been forced to find new habitat.[55]

Christmas bird count data from 1978 until 1988 indicate that plovers utilize most coastal beaches and barrier islands in Texas as wintering habitat.[56] A survey of 89% of the Texas coast showed 55% of all the plovers wintering in the Gulf (20% of the entire plover population), and the highest density.[57] Censuses taken from 1983 to 1985 noted high concentrations of plovers occurring in a number of Texas counties, including Jefferson, Chambers, and Brazoria.[58] Recreational and commercial/industrial development in the area has led to increased recreational activities, fixation of water levels, stabilization of ephemeral habitat and, consequently, a decline in plover winter habitat, estimated at as much as a 30% loss, with more coastal development imminent.[59]

Due to the high amount of human and habitat disturbance in northern breeding and nesting areas, the reproductive success of plovers is still very low and highly variable,[60] meaning the continued survival of breeding and non-breeding birds during the winter is critical to the maintenance of the population.

As part of the recovery plan for plovers, much of their habitat, breeding and wintering, is to be Federally protected.[61] This can be difficult because ephemeral habitat by its very nature is difficult to designate. Essential habitat sites, required because of complete plover dependency for food and nesting, have been established to help meet the recovery objective and have been described and mapped.[62] Essential areas (coastal beaches, mudflats, and sandflats) designated in Texas include Sea Rim State Park (Jefferson Co.), Brazos Island State Park, and San Benard NWR (Brazoria Co.).

Food Habits

Relatively little is known about the diet or the foraging behavior at any point during the annual cycle. Their diet seems to contain organisms mainly from the intertidal area and is thought to include marine worms, crustaceans, molluscs, other small marine animals and their eggs, and insects.[63] During the winter, plovers use open beaches, muddy sandflats, and dunes of the Gulf and the adjacent offshore (barrier) islands for feeding.[64]

Breeding and Nesting

No breeding occurs in Texas, Louisiana, Mississippi, or Alabama.

F.4.4 Louisiana Black Bear (*Ursus americanus luteolus*)

Population

The Louisiana black bear is a Federally-designated threatened species. Black bear populations have suffered serious declines as a result of suitable habitat destruction and fragmentation, illegal shooting, and loss of genetic purity via cross-breeding with other species. Population density of the Louisiana black bear can range up to 1-2 individuals per square mile.[65] One study estimated a population of 60 bears in 70,000 acres of timberland in the Tensas River Basin, but the reliability of this figure is unknown.[66] There are no population data for the Atchafalaya River Basin.

Geographic Range and Habitat

The bear historically inhabited eastern Texas, Louisiana, and southern Mississippi,[67] but more than 80% of its suitable habitat has been damaged by human activities, particularly land-clearing for agriculture.[68] As a result of habitat fragmentation, the black bear's habitat is currently limited to the bottomland hardwood forest habitats of Louisiana in the Tensaw River Basin (northeast Louisiana) and the Atchafalaya River Basin (southeast Louisiana).[69]

Three primary viable populations of the Louisiana black bear are found in the Tensaw (388,000 acres) and Atchafalaya River Basins (1.5 million acres); one in the Tensaw and two in the Atchafalaya.[70] The latter two are located in Iberia and St. Mary Parishes, which contain the highest black bear populations in the state.[71] The primary and required habitat for the black bear is a large area of isolated, undisturbed forest.[72] The bears utilize areas of high habitat diversity, as they forage in both the timbered areas of the forest and the succulent vegetation of forest openings.[73] The bears utilize hollow cypress trees, hollow tupelo gum trees, and brushpiles located in thick vegetation and dense understory areas for winter dens.[74] Areas of thick cover also serve as "escape cover"—an important component of bear habitat that allows bears to avoid human encounters in an increasingly fragmented environment.[75] The switchcane/palmetto/shrub understories as well as the vegetative regrowth of briars, vines, saplings provide escape cover and daybed resting sites.

The black bear is very mobile and can cover large distances during daily foraging activities.[76] Trails and small roads do not disrupt bear movements or habitat use in the Tensas River Basin.[77] Home range size for adult males is up to 40,000 acres and for adult females is up to 18,000 acres.[78]

Food Habits

The black bear, an omnivore, feeds primarily on vegetation.[79] Understory plants in timbered areas found in the black bear's spring and summer diet include blackberries, pokeweed, elderberry, devil's walking stick, French mulberry, red mulberry, grapes, dogwoods, and paw paw.[80] Edge plants and plants in forest openings eaten by bears include oats and wheat. Bears also eat beetles, grubs, and other invertebrates found in decomposing logs. In the late fall and early winter, prior to denning, Tensas Basin bears feed on oak acorns, beechnuts, and nuts of pecan (hard mast crops) in order to build fat reserves.[81] During this time, the bears move extensively and forage continuously.[82] Hard mast food is a critical food source during this time of the year.[83]

Breeding

Black bear mating takes place during the summer months, and cubs are born in the winter dens after a seven to eight month gestation period. Lack of food can decrease litter size, which normally ranges from one to five.[84] Females generally give birth every other year, as the cubs stay with the mother for a full year. Females utilize brushpiles and hollow cypress trees as natal dens.[85]

F.4.5 Alabama Red-Bellied Turtle (*Pseudemys alabamensis*)

Population

The Alabama red-bellied turtle, also known as the red-belly, is listed as a Federally endangered species and is protected in Alabama. Total population size of this species is unknown, but age class data for the turtle suggest a serious declining trend.[86] Of the twenty-four turtles caught between 1968 and 1970, ten were juveniles, and of 20 turtles collected between 1971 and 1983, only one was a juvenile.[87] Relatively little historic and ecological information about the red-belly has been collected.

The factors contributing to the decline of this species include: egg predation by both natural predators (e.g., fish crows, fire ants, and humans) and nest disturbance within the nest area; capture for the pet trade; predation on the turtles themselves by alligators; and reduction of aquatic vegetation in turtle habitat from herbicides and storms. A combination of these factors has led to low recruitment rates and an overall small population size. It is likely that these factors have had similar effects on the closely-related Mississippi red-bellied turtle.

Geographic Range and Habitat

The Alabama red-bellied turtle is considered by most experts to occur only in the lower portion of the Mobile Bay drainage system in Mobile and Baldwin counties beginning at the confluence of the Mobile and Tensaw Rivers.[88] It is most abundant in the Tensaw River (Baldwin Co.). There have been other reports, current and historic, for Little River State Park Lake (Monroe Co.) and Dauphin Island (Mobile Co.). Sightings have also placed the turtle in the Tchoutacabouffa River, the Pascagoula River, drainage system, and Horn Island in Mississippi.[89] However, the turtles found there have been tentatively placed in a new taxon.[90]

Studies prior to 1985 attempted to establish the range of the red-belly outside of the Mobile River system.[91] With emphasis on the Pascagoula, Escambia, Choctawhatchee, and Apalachicola Rivers, twelve drainage systems and the lakes on St. Vincent Island were sampled. Despite the similarity of habitats to those found in the Mobile River system, no Alabama red-bellies were found, supporting the conclusion that the red-belly was endemic to the Mobile River system.

The turtles found in the lower Pascagoula system, currently labeled as the Mississippi red-belly, are thought to be closely related to the Alabama red-belly and a formal identification is in preparation.[92] It is not known how long this species has been in existence. Unconfirmed sightings of red-bellies in Mississippi Sound prior to 1950 have been suggested to be both the Alabama and the Mississippi red-belly. The apparent low numbers of this new species indicate that it is endangered. However, protection under Endangered Species Act is not possible without formal identification and recognition of this alleged new taxon. It is reasonable to expect that the turtles found there are vulnerable to the same problems as those in Mobile.

The red-bellied turtle inhabits fresh to moderately brackish waters of streams, channels, lakes and sloughs. It prefers broad, densely vegetated expanses of shallow water that provide substrate for cover, predator avoidance, food, and basking. Substantial decreases in the aquatic vegetation occurring as a result of storms and the spraying of aquatic herbicides have had correspondingly detrimental effects on the turtle populations.[93]

Food Habits

Red-bellied turtles are primarily, if not exclusively, herbivorous.[94] Elodea (*Anacharis* sp.) and other aquatic vegetation are believed to be a primary food source; it has recently been depleted, however, perhaps as a result of herbicide application.[95]

Breeding and Nesting

Open, sandy areas are required for nesting. There is only one known primary nesting site for the Alabama red-belly located on Gravine Island (Baldwin Co.) although it has been suggested that turtles may nest elsewhere.[96] The turtles return every year to nest at the same site during a three month period. Clutches generally contain four to nine eggs, and average clutch size is six eggs. This habit, combined with the high concentration of nests in a small area has left turtle eggs vulnerable to both recreational and predatory human activity, in addition to predation by fish crows, alligators, and fire ants.[97] Studies of nests in 1978 and 1985 have shown mortality has been as high as 100%.[98] The ecology of other closely related species suggests the red-belly females nest more than once per year. Disturbance and predation of nesting areas was the most likely cause of the suspected low of the recruitment rate the red-belly decline.

F.4.6 Eastern Indigo Snake (*Drymarchon corais couperi*)

Population

The eastern indigo snake has been listed as threatened under the Federal Endangered Species Act since 1978. Other names for the snake are blue indigo snake, gopher snake, and blue bull snake. It is considered endangered in Mississippi and is protected in Alabama. Although no data are available concerning the numbers in the population, it is thought that the snake may be relatively abundant in parts of its range in Florida and Georgia. Serious declines have been observed throughout the range, and the snake has been extirpated from many areas. Several experimental restockings have been attempted in Alabama, Georgia, South Carolina and Mississippi.[99] Restocking projects were conducted in Harrison County in 1981 and Marion County in 1986.[100]

Natural limiting factors for the snake are unknown. The most serious cause of the snake's decline has been destruction of suitable habitat due to housing developments, agriculture, and forestry practices. In addition, the snake is in great demand by the pet trade. Gassing of gopher tortoise burrows in order to drive out rattlesnakes has also been detrimental because the indigo snake (which is harmless) frequently uses these burrows. Habitat loss or degradation is probably the most important factor limiting the indigo snake.[101]

Geographic Range and Habitat

At present, the indigo snake occurs naturally only in southern Georgia and Florida. Its former range is thought to have extended from southern Mississippi to South Carolina and Florida. There are some historic reports of its occurrence in South Carolina and Mississippi, but sightings have not been documented for some time.[102] In Mississippi, no confirmations have been made since the 1950's (Wayne Co.), however, there was a reported sighting in Stone County in 1977 and Jones County in 1985.[103] It has been suggested that the snake may still be present in southern Mississippi in longleaf pine areas, where the gopher tortoise occurs.[104]

The habitat preference of this snake varies somewhat by region. In portions of its range outside of Florida this snake is strongly associated with xeric sandridge habitat, more commonly referred to as a longleaf pine-scrub oak association.[105] Typically associated with this habitat is the gopher tortoise, also a Federally-listed threatened species. The indigo snake uses the tortoise burrows for refuge, overwintering, nesting, foraging, and denning. In the summer, the snake tends to move to agricultural fields and stream-bottom thickets,[106] sometimes migrating large distances.[107]

Food Habits

The indigo snake is active during the day and preys upon many small animals, including other snakes, frogs, toads, lizards, small mammals, and birds. They are probably at the top of the food chain in the xeric sandridge habitat.[108]

Breeding and Nesting

The breeding season begins in late October and continues into February, with a peak in December. Eggs, averaging nine per clutch, are laid in May and hatch within 90 to 120 days.

F.4.7 Gopher Tortoise (*Gopherus polyphemus*)

Population

The gopher tortoise decline has been the result of several factors. First, land use and development has been detrimental because of destruction of habitat and because fire exclusion prevents the creation of suitable habitat in the area that is left; tortoises utilize relatively open areas that get enough light for basking and maintaining the plants and grasses required for food. Like the indigo snake, the tortoise has suffered as a result of capture for the pet trade. Both tortoise eggs and young hatchlings are highly vulnerable to predation. As a result of a very low recruitment rate the current population is quite small and therefore is impacted more severely by the other factors.

Geographic Range and Habitat

The western population of the gopher tortoise (defined as the population found west of the Tombigbee and Mobile Rivers in Alabama) is listed as Federally threatened. Because of rapid habitat destruction from current tree harvesting and reforestation methods, tortoises are now limited to a small region in southeastern Mississippi.[109] The extensive upland areas west of the Pearl River in Mississippi appear to lack gopher tortoises.[110] The dominant tree species associated with the gopher tortoises' range in Mississippi is the longleaf pine; other associated tree species include the loblolly, shortleaf, and slash pine.[111] In Marion and Lamar counties, tortoises are found in two general habitats: on top of steep-sided hills in gravelly sands, where turkey oak and longleaf pine occur; and on the sides of hills in sandy clay areas, with shortleaf pines, and blackjack oak.

This colonial species is found in xeric sandy habitats from South Carolina through Florida and west to the southeastern edge of Louisiana; within these habitats, the range of the gopher tortoise closely matches the original range of the longleaf pine.[112]

Three characteristics define the most suitable habitat for gopher tortoises: well-drained, sandy soils, allowing for easy burrowing; an abundance of herbaceous ground cover; and an open canopy with sparse shrub cover that allows sunlight to reach the forest floor.[113]

The habitat requirements of juveniles are assumed to be similar to those of the adults. Although the habitats of western gopher tortoises mostly consists of longleaf pine-scrub oak communities located on sand ridges, the tortoises may also be found in field edges, pastures, and along power lines.[114] The ecology of the gopher tortoise's habitat is in part fire-dependent. In areas that have been utilized for timber production, most fires have been quickly controlled. This, along with other forestry related practices, result in less herbaceous ground cover, more shrub growth, and a more closed forest canopy.[115]

The burrows of adult gopher tortoises average about 4.5 meters in length, with a depth of 1.8 meters,[116] and a single tortoise often excavates more than one burrow.[117] Juvenile gopher tortoises dig smaller burrows that may be as shallow as a few inches below the surface.[118]

Food Habits

Gopher tortoises are herbivores, feeding primarily on grasses, grass-like plants, and legumes, and availability of these foods appear to determine the carrying capacity of an area.[119] Wild legumes, which are high in protein, appear to be especially important in the juvenile tortoises' diet.[120] In one study, 95 percent of all feeding activity took place within 30 meters of the burrow being used.[121] The availability of food supplies probably has a major influence on foraging distances and home range sizes.

Breeding and Nesting

Gopher tortoises breed sometime between February and September, depending upon location; the peak time for breeding activities seems to be in May and June.[122] The tortoise's mean clutch size is seven eggs (range 4 to 12).[123] Females on average lay eggs twice every three years. Nests are excavated in sunny bare spots, normally in the mound of excavated sand at the burrow entrance,[124] and tend to be about 15 to 25 cm beneath the surface.[125] When the burrow entrance is shaded, nests may be excavated in open areas such as firelanes or roadsides.[126] Although gopher tortoises live for approximately 40 to 60 years, they do not mature until they are about twenty.

F.4.8 Gulf Sturgeon (*Acipenser oxyrhynchus desotoi*)

Population

The Federally threatened Gulf sturgeon is a large (1.8 to 2.4 meters in length), bottom-feeding fish that hatches and matures in estuaries or rivers, and then feeds mainly in brackish or salt water, returning to rivers and estuaries to spawn. In recent years the population of this species has decreased dramatically. Construction of dams on coastal rivers blocks the passage of the Gulf sturgeon to their traditional spawning grounds and summer habitat.[127] Gulf sturgeon winter in the Gulf of Mexico and adjacent bays, and primarily use this habitat for feeding.

Commercial fisheries have been the major contributor to the decline of the sturgeon population, both through direct catch (now illegal) and as by-catch. Dredge and fill activities and waste disposal in sturgeon spawning and nursery areas have resulted in habitat loss and deterioration of water quality, chronic problems. Lastly, coastal oil and gas activities have been detrimental because of spillage that tends to impact the sturgeon in its early life stages.

Geographic Range and Habitat

The Gulf sturgeon's current range is from Lake Pontchartrain, Louisiana, to Tampa Bay, Florida.[128] The type of habitat preferred by Gulf sturgeon in the Apalachicola River during the late spring and early summer had a mean depth of 8.4 meters (range: 6.0 to 12.0 meters) and a mean flow velocity of 64.1 cm/sec (range: 60.0 to 90.0 cm/sec).[129] This may not reflect the historically preferred habitat, but rather the best available to the Apalachicola sturgeon, whose migration has been blocked by dam construction.[130] Fall migration begins in late September and continues through October and early November; the yearly migrations involve a number of "stopovers and retreats" that the fish use to adjust their osmoregulatory balance.[131]

Protection of riverine habitats is critical to the survival of this species.[132] Of special importance are known or suspected spawning habitat and rocky areas, especially those associated with deep holes, and areas adjacent to and downstream from spring runs. These areas should also be managed in a way that prevents alteration of sediment, water flow, and water quality.[133]

Juvenile and subadult Gulf sturgeons are not uncommon in the first 30 to 50 river miles in the Pascagoula and Pearl Rivers.[134] In general, adults venture further upstream and their abundance becomes progressively smaller the farther they go, making the estimation of their abundance difficult.[135] Adults seem to be more common in the Pearl River than in the Pascagoula, and it is possible that they move as far north as the Ross Barnett Dam during highwater.[136] In 1984, a 160 lb. female was caught in the Pearl River just south of Jackson, Mississippi.[137]

Reports of mature sturgeon in the Pascagoula's main tributaries, the Leaf and Chickasawhay, are limited; one was caught in Chickasawhay near Waynesboro.[138] In one study one subadult was caught during 30 net nights in June 1987.[139] Historically, Gulf sturgeon populations have inhabited both of these river systems.[140]

Food Habits

Gulf sturgeon live and feed in fresh to brackish water from the time they hatch until about age three, when they begin to follow a migration pattern similar to that of the adults.[141] Currently, information is lacking on the types of habitat and food sources used by hatchling and juvenile sturgeons.[142] After they have reached five or six years of age, they probably feed almost entirely in marine or estuarine waters during the winter, and then live primarily off of stored fat while in their riverine summer habitat (March to October).[143] In the riverine areas, the diet of the sturgeon is probably dominated by plant material and debris.[144] Gulf sturgeon in estuarine/marine waters feed primarily on invertebrates including brachiopods, insect larvae, mollusks, worms, and crustaceans.[145]

Breeding and Nesting

Migration from the Gulf or bay areas to riverine spawning grounds begins in late February.[146] Limited studies suggest that Gulf sturgeon return to spawn in the stream where they hatched.[147] Sturgeons do not spawn every year; males spawn at intervals of one to five years, and females at intervals of three to five years.[148] Non-spawning adults often participate in the annual spring migrations.[149] Male Atlantic sturgeon in South Carolina first spawn at an average age of eight years (range 5 to 13), and females spawn at 11 years (range 7 to 19).[150] Each female produces between 1 and 2.5 million eggs.[151] Spawning takes place over hard bottomed areas, and in pools below waterfalls.[152] The eggs are demersal and sticky, and will adhere to rocks, gravel, aquatic plants, and other objects that come into their path. Spawning has been reported in water temperatures of 13 through 23 °C.[153] Incubation period ranges from 94 to 168 hours, depending on the temperature of the water.

F.4.9 The Red-cockaded Woodpecker *(Picoides borealis)*

Population

The red-cockaded woodpecker has been on the Endangered Species List since 1970. Once abundant in the open pine ecosystem throughout the southeastern United States, this species of woodpecker has declined due to clear-cutting of the southern pine forests. Although only rough estimates on population size are available, it is known that this species of woodpecker has been disappearing precipitously in the last few decades.[154] In 1978, estimated populations included between 1,500 and 3,500 colonies and from 4,500 to 10,000 birds.[155]

The main causes of the decline of the woodpecker have been habitat loss and fragmentation, and mismanaged forest-use practices in the mature, open pine forest that the woodpecker requires for survival. This has led to very small, reproductively isolated, highly endangered populations.

Geographic Range and Habitat

The red-cockaded woodpecker was once widely distributed and abundant throughout the southeastern United States from southeastern Maryland and Kentucky west to Missouri and south to eastern Texas and South Florida. Today the range of the red cockaded woodpecker includes portions of 13 southeastern states extending from east Texas and southeastern Oklahoma eastward throughout the Gulf States, south to the Big Cypress Preserve of south Florida, and north as far as Tennessee, south-central Kentucky, and eastern Virginia.[156] The range of this woodpecker probably once included all of Mississippi, exclusive of the loess hills and major river flood plains. Recent data show that the red-cockaded woodpecker has been sighted in the southern two-thirds of the state. It has not been found in the Mississippi Delta and only sporadically in the northern counties.[157]

An average home range size for the red-cockaded woodpecker is 200 acres of undisturbed mature pine forest. Loss or fragmentation of mature pine stands within the range will negatively affect this woodpecker, disrupting both its feeding and breeding patterns.[158]

Food Habits

The red-cockaded woodpecker specializes in scaling loose bark from pines to capture insects, centipedes, and spiders hidden beneath. Loose bark of older pines provides optimum foraging conditions; the bark of younger pines and of hardwood trees adheres more tightly.[159] This woodpecker needs a large foraging area. Males dominate females and usually take the best foraging sites (i.e., the upper trunk and occasionally on larger limbs). Typically neither sex will forage below the level of dense forest midstory. Thus, male dominance further enhances the need for older, larger pines. In younger stands an encroaching midstory may result in inadequate foraging for the female.[160]

Breeding and Nesting

The red-cockaded woodpecker lives in "clans" and exhibits communal nesting. The average age of the pines that this woodpecker uses to excavate cavities is about 95 years for longleaf pine and 75 years for loblolly and other southern pines. These older pines are better for excavating cavities because, typically, heartwood fungus makes them softer than hardwood trees. Furthermore, although the gum sap from the pine is critical to the red-cockaded woodpeckers defense against pine climbing predators, these older pines do not have an overflow of sap that could potentially trap the woodpecker inside the newly excavated cavity.[161]

The red-cockaded woodpecker is a clan bird.[162] Each clan typically includes a breeding pair, their young of the year, plus additional male young from previous breeding seasons. Clans with additional males acting as helpers fledge more young than those without. Thus it is important that the colony site and foraging habitat be adequate to support these helpers as well as the breeding pair.

The clans utilize and defend a cluster of nesting and roosting sites.[163] Territory stability is enhanced by increased numbers of useable cavities. Cavities are known to be used in excess of 50 years. A clan may have from one to thirty cavity trees, including trees with completed cavities, trees with cavities under construction, and trees with abandoned cavities.[164] These provide alternatives when competing species are present. They also provide roost sites for helpers, increasing the chances that helpers will survive to assist with the rearing of the young. Breeding and nesting activity takes place in the spring. Females lay from two to five eggs in late April through early May or later. The eggs hatch in about ten days and the young are able to fly in 24 to 29 days.[165]

F.4.10 Ringed Sawback Turtle (*Graptemys oculifera*)

Population

The ringed sawback turtle has been listed as a Federally threatened species since 1986. Habitat availability has become the primary limiting factor for this species as a result of extensive habitat modification for flood control, navigation, and reservoir construction (e.g., Ross Barnett Reservoir) and has threatened the survival of the ringed sawback turtle.[166] Much of the habitat required for nesting, basking, and predator avoidance is altered detrimentally by these practices. Floodplain clearing and construction have affected 21 percent of the turtle's range and threaten most of its remaining habitat.[167] In addition, the turtle is adversely affected by the runoff and increased siltation that occur as a result of continued channelization in the Pearl River

System and by pesticide runoff from agricultural fields.[168] These practices adversely impact the turtles' food sources and can lead to the bioaccumulation of toxic substances. Collecting for commercial purposes and hunting also have caused declines.

Geographic Range and Habitat

The species currently is found only in the main channels of the Pearl and Bogue Chitto Rivers of Mississippi and Louisiana.[169] The turtles prefer unpolluted river habitats with narrow channels, moderate current, and abundant, floating or emerging logs or debris in deep water for basking in the sun.[170] Basking may in fact be necessary for the turtle's survival, and the stream thus should receive sufficient sunlight.[171] They also prefer wide beaches with large sand and gravel bars for their nesting habitats.[172] The turtle is only marginally adaptable for survival in pond or lake habitats.[173]

Food

The primary components of the turtle's diet are snails and other mollusks, which require high water quality in order to thrive.[174] Juveniles and small males may eat insects.[175]

Breeding and Nesting

The turtles build nests (approximately 15 cm deep) on high sand bars of the rivers; the eggs are covered with packed sand to the top of the cavity.[176] The turtle's egg incubation period is unknown. A very important factor in reproductive success is egg mortality, which can exceed 90% as a result of predatory activities.[177] Data on clutch size are scarce; one study reported that a turtle produced seven eggs during the breeding season.[178]

F.4.11 Yellow-blotched Sawback Turtle (*Graptemys flavimaculata*)

Population

The yellow-blotched sawback turtle has been listed as a Federally threatened species since 1991. It faces many of the same problems as the ringed sawback turtle. It has also been threatened by many factors such as habitat modification, hunting, commercial collecting, water quality degradation, hunting, and high nest predation.[179] Channel modifications, flood controls, and navigation measures have resulted in the destruction or alteration of habitat required for nesting, basking, and predator avoidance. Gravel mining has increased turbidity and sedimentation in the rivers of interest.[180] Pollution has resulted in bioaccumulation of toxic chemicals that has depleted the turtle's food supply.[181]

A mark and recapture study done by Fish and Wildlife Service and the Mississippi Department of Wildlife, Fisheries, and Parks estimated that about 336 turtles per mile were in existence in the lower Pascagoula River.[182] Population density for this turtle is greater near Wade (Jackson County), and the higher densities continue downstream for approximately 18 miles; the highest densities occur between Wade and Vancleave (also in Jackson County).[183] The species also occurs in short tributaries near the Pascagoula River.[184] Turtle populations in the Chickasawhay River were found to be smaller than in the Leaf and Pascagoula Rivers.[185]

Geographic Range and Habitat

The yellow-blotched sawback turtle is currently endemic to the Pascagoula River system in Mississippi, and can be found in the Leaf, Chickasawhay, and Escatawpa Rivers and other tributaries.[186] It prefers rivers that are wide enough to receive at least several hours of sunlight per day for basking and will avoid small streams and creeks that are shaded by bank vegetation.[187] It requires rivers with moderate current, sand or clay substrate, sand bars or beaches for nesting, and snags or logs for basking.[188] The turtle also needs rivers with plentiful food supply of mollusks and insect larvae. The population distribution of this turtle includes the following counties of concern (i.e., counties that the Richton pipelines crosses): Perry (Leaf River, Tallhala Creek), Greene (Leaf River, Chickasawhay River), George (Pascagoula River), and Jackson (Pascagoula River, Escatawpa River, Red Creek, Black Creek). The highest population densities occur in Jackson County.

Food Habits

The diet of the turtle consists of large quantities of mollusks as well as insects.[189] The turtle may also eat plant materials, algae, bryozoans, and sponges.[190]

Breeding and Nesting

Nesting occurs from May through July on sandbars or beaches well above the water level and close to the vegetation line.[191] Egg mortality has been found to be very high as many nests are destroyed by predators.[192] Males probably reach maturity at about three to four years of age, while females mature at about eight to ten years of age.[193]

F.5 Potential Impacts on Threatened and Endangered Species of Concern and Possible Mitigation

Section F.5 provides examples of specific impacts that potentially could affect each species of concern, assuming the individuals are close enough to proposed project areas to be affected. Examples of specific mitigation options for each species also are provided. Mitigation activities fall into three categories:

- Avoidance of habitat currently used by the species (e.g., rerouting pipeline routes, selection of alternatives);
- Minimization by using least damaging construction, operation, and maintenance techniques (e.g., directional drilling, spill prevention, careful choice of herbicides) if it is not feasible to avoid habitat currently used by the species; and
- Mitigation of unavoidable adverse effects on habitat currently used by the species, using restoration techniques (e.g., planting a particular trees species along ROW edges).

Species-specific mitigation options are provided below for each species of concern.

F.5.1 Big Hill

For the Big Hill alternative, including the proposed oil pipeline routes to Houston, no species of concern have been identified by USFWS.

F.5.2 Stratton Ridge

Bald Eagle

Brine pipeline construction and maintenance may disturb roosting eagles if roosting areas exist near the ROW. The pipeline construction and maintenance is not expected to disturb nest activity. The bald eagle is most vulnerable to nest disturbance, and no existing nests would be disturbed (the closest known eagle nest to the Stratton Ridge pipeline ROW is at least 20 miles away).[194]

If site facilities and the pipeline are built at least ¼ mile from eagle nesting or roosting sites,[195] and if potentially suitable eagle foraging and roosting habitats are avoided, eagle populations should not be affected. To accomplish this, important winter habitat and potential breeding habitat would need to be identified. The pipeline could be routed to avoid roosting trees and potentially suitable habitat (e.g., areas where old-growth timber encloses an open and discontinuous canopy).

Brown Pelican

Brine pipeline construction and maintenance are not expected to affect the brown pelican because known populations are south of the proposed project area.[196] Inland oil spills also should not affect this species because they would not be near pelican habitat. However, if SPR expansion increases oil tanker traffic or the likelihood of a major spill in the Gulf, there is some chance of direct and sub-lethal impacts to pelicans due to oil pollution.

Because of their gregarious behavior, feeding habits, and preference for shallow coastal waters, pelicans are highly vulnerable to oil pollution. Oil, from both small chronic spills and large spills, decreases primary productivity and thus fish availability, destroys pelican habitat, and may harm or kill pelicans by oiling the feathers. However, because the increased chances of marine spills due to the SPR proposed project are minimal (see Chapter 6 of the DEIS), and the brown pelicans are not located in the immediate vicinity of the proposed project, impacts on pelicans should be minor.

DOE will comply with all relevent regulations and can use appropriate technology to prevent and clean up oil spills.

Interior Piping Plover

Brine pipeline construction and maintenance are not expected to affect the piping plover. Although plovers are highly sensitive to any kind of human disturbance,[197] known plover populations are south of the proposed project area.[198] As long as pipeline ROW routes avoid plover nesting areas, and construction does not disturb or alter the interior piping plover's habitat (i.e., sandflats and sandy mudflats), populations should not be impacted by pipeline construction. Inland oil spills also should not affect this species because they also would not occur near plover habitat. However, if SPR expansion increases oil tanker traffic or the likelihood of a major spill in the Gulf, there is some chance of direct and sub-lethal impacts to plovers due to oil pollution could occur.

Oil spills in the Gulf could destroy plover habitat. However, because the increased chances of marine spills due to the SPR proposed project are minimal (see Chapter 6 of the DEIS), and the plovers are not located in the immediate vicinity of the proposed project, impacts on plovers are not expected.

Areas inhabited by the plover can be identified and avoided. DOE will comply with all relevant regulations and can use appropriate technology to prevent and clean up oil spills.

F.5.3 Weeks Island/Cote Blanche

Louisiana Black Bear

Pipeline ROW construction and maintenance may affect black bears if it fragments suitable habitat. Site construction may permanently destroy black bear habitat. Black bears are known to live on Week's Island, but their presence on Cote Blanche is not confirmed. A survey would be required to determine (1) if and where bears are present on Cote Blanche, (2) which parts of Weeks Island are suitable black bear habitat, and (3) whether proposed SPR components would be located in this habitat.

To mitigate adverse effects to black bears due to any potential habitat fragmentation, cypress seedlings could be planted along the edges of ROWs, and thick understory growth could be maintained in these areas so bears can quickly find escape cover.[199] "Travel corridors" (e.g., drainage ditches lined with trees and bushes) also could be built across clearings to facilitate movement of bears from one point to another if habitat fragmentation occurs from pipeline construction.

F.5.4 Richton

Alabama Red-bellied Turtle

Construction of the pipeline alternative to Mobile could impact the Alabama red-bellied turtle if water quality degradation reaches downstream to the Mobile River system, which is the turtle's habitat. The closely related Mississippi red-bellied turtle, a potentially endangered species that also inhabits fresh to moderately brackish streams, channels, lakes, and sloughs, but probably would not be affected by construction because it inhabits the lower Pascagoula River, and the proposed pipeline routes lie east or north of that area. If the Mississippi red-belly becomes listed as a Federally threatened or endangered species, possible impacts from low water flow and water quality degradation as results of RWI could be investigated further.

If it is determined that the Alabama red-belly's habitat would be affected, construction techniques that minimize water quality degradation could be used to mitigate impacts.

Bald Eagle

Brine and oil pipeline construction and ROW maintenance may disturb roosting eagles if roosting areas exist near the ROW. The pipeline construction and maintenance is not expected to disturb nest activity. The bald eagle is most vulnerable to nest disturbance, and no known nests would be disturbed (no known nests exist within at least a mile of the pipeline ROW[200]).

If site facilities and the pipeline are built at least ¼ mile from nesting or roosting sites of the eagle, and if potentially suitable foraging and roosting habitats for the eagle are avoided, eagle populations should not be affected. To accomplish this, important winter habitat and potential breeding habitat would need to be identified. The pipeline could be routed to avoid roosting trees and potentially suitable habitat (e.g., areas where old-growth timber encloses an open and discontinuous canopy).

Eastern Indigo Snake and Gopher Tortoise

Potential impacts on the indigo snake and the gopher tortoise are discussed together because these two species share a common habitat (i.e., the indigo snake often lives in gopher tortoise burrows).

The presence of indigo snakes and gopher tortoises near proposed SPR activities at Richton is unknown, but there is no record of a sighting within at least one mile of the proposed sites or ROWs in Mississippi. However, if these species are present along any of the pipeline ROWs, construction could destroy the burrows that both species use. Conversely, after construction, pipeline ROWs in some areas may actually create new habitat for these species. (Young tortoises are found in field edges and along power lines.) However, regular spraying of these areas with certain pesticides could harm the animals. Also, cleared areas created by the maintenance of a ROW provide attractive routes for all-terrain vehicles. These vehicles could be very destructive to any future burrows along the ROW.

To determine if gopher tortoises and indigo snakes are present along proposed pipeline ROWs, surveys for gopher tortoise burrows would need to be conducted. Pipelines could be routed to avoid these burrows. In general, pipelines could be routed to avoid longleaf pine communities, which are associated with the red-cockaded woodpecker as well as the indigo snake and the gopher tortoise. Care would be taken to avoid endangered species during maintenance activities, and if herbicides were likely to harm such species, ROW clearings would be manually maintained.

Gulf Sturgeon

Construction of pipelines and raw water intakes are expected to degrade water quality in the Leaf and Chickasawhay Rivers temporarily. The Gulf sturgeon (which occurs mainly in the Gulf of Mexico and the Pascagoula River, generally downstream of the project area) may be affected by water quality degradation if the degradation and the sturgeon habitat overlap. Intake of water from the Leaf River, a tributary of the Pascagoula River, could alter water quality conditions in that river by changing the salinity and increasing concentrations of contaminants (e.g., dioxin). Construction of the Richton site and construction of the pipelines across small water bodies (when directional drilling will not be used) could result in increased siltation, increased concentrations of metals and other contaminants released from sediments, and decreased dissolved oxygen in these water bodies. Because the bulk of these environmental impacts should occur some distance upstream of known sturgeon habitat, the fish may not be affected. If poor water quality does extend downstream into sturgeon habitat, it is expected to be only for short time periods during construction.

Increasing oil inputs or the likelihood of a major spill or leak could increase the chances of direct and sub-lethal impacts on Gulf sturgeon due to oil pollution. Leaks or spills in either fresh, estuarine, or marine waters could affect this species. However, the increased chances of spills or leaks due to the SPR proposed project are thought to be minimal (see Chapter 6 of the DEIS).

Brine from a brine spill is not expected to affect adult Gulf sturgeon because they are mobile and can avoid the spill, and because they can tolerate at least marine salinities. If the proposed pipeline passes through spawning areas, and a leak were to occur in those areas, harmful effects on eggs or larvae are possible.

Specific upstream areas inhabited by the Gulf sturgeon could be identified. If further information indicates that water quality degradation in the Leaf and Chickasawhay River may affect Gulf sturgeon adversely, less harmful construction and operation methods could be determined and employed. DOE will comply with all relevant regulations and can use appropriate technology to prevent and clean up oil spills.

Red-cockaded Woodpecker

Pipeline construction may affect red-cockaded woodpeckers. None are reported to exist within at least a mile of the proposed pipeline ROWs, but surveys would need to be conducted to confirm that none are present. The pipeline could be surveyed simply for mature stands of longleaf and loblolly pines. If no stands were found or if pipeline ROWs were routed to avoid these stands, no impacts on future populations of the red-cockaded woodpecker would be expected.

Ringed Sawback Turtle

Construction of the Liberty pipeline may cause minor impacts (due to water quality degradation) on the ringed sawback turtle, which lives in the main channel of the Pearl and Bogue Chitto Rivers of Mississippi and Louisiana. Where the pipeline crosses tributaries and wetlands that discharge into the Pearl and Bogue Chitto Rivers, construction could cause water quality degradation. It is unknown whether the degradation would reach sawback turtle habitat. If further information indicates that water quality degradation due to the Liberty pipeline construction would affect the sawbacks, less harmful construction methods could be used to mitigate impacts.

Liberty pipeline oil leaks could also affect this species adversely if the oil reached sawback habitat. However, because the increased chances of oil spills due to the SPR proposed project are relatively small (see Chapter 6 of the DEIS), and the sawback turtles are not located in the immediate vicinity of the proposed project, the likelihood of impacts is small.

Brine from a brine spill may adversely affect the ringed sawback turtle, which normally is found in non-saline waters (i.e., riverine waters unaffected by coastal salt water).[201] However, these turtles are mobile and can avoid temporary spills which are flushed out by the influx of freshwater.

Areas inhabited by the sawback turtle could be identified, and the Liberty pipeline could be routed to avoid these areas. DOE will comply with all relevant regulations and can use appropriate technology to prevent and clean up oil spills.

Yellow-blotched Sawback Turtle

Impacts on the yellow-blotched sawback turtle may occur if construction of the Mobile/Pascagoula pipeline ROW degrades water quality and that poor water quality extends into map turtle habitat. During low flow periods, raw water intake from the Leaf River during site operations may reduce water flow enough to affect this species adversely. The yellow-blotched sawback turtle is known to occur near the confluence of the Leaf and Chickasawhay Rivers. Construction of the Mobile/Pascagoula pipeline ROW by means other than directional drilling across rivers or streams may degrade water that serves as habitat for the turtle or could directly impact the turtles. The yellow-blotched sawback turtle generally prefers rivers wide enough to receive several hours of sun, and pipelines will be directionally drilled under rivers greater than 500 feet wide, but indirect impacts may occur if silt and elevated contaminant levels from smaller upstream tributaries travel down to their habitat.

Inland oil spills or pipeline oil leaks could also could also affect this species adversely if the oil reached the yellow-blotched sawback turtle's habitat. However, the increased chances of spills due to the SPR proposed project are thought to be relatively small (see Chapter 6 of the DEIS).

Brine from a brine spill may adversely affect the yellow-blotched sawback turtle, which typically is found in non-saline waters (i.e., riverine waters unaffected by coastal salt water).[202] However, these turtles are mobile and could avoid a temporary spill which would be flushed out be the influx of freshwater.

To mitigate potential impacts, areas inhabited by the yellow-blotched sawback turtle could be identified, and pipelines could be routed to avoid these areas. Directional drilling could be used to lay pipelines under rivers inhabited by the yellow-blotched sawback turtle and under tributaries to those rivers. DOE will comply with relevant regulations and could use appropriate technology to prevent and clean up oil spills.

F.6 Cumulative Impacts

Cumulative impacts are difficult to address, because so many factors are involved that a high level of uncertainty is inherent. Cumulative impacts can harm a species when a number of separate conditions act additively or synergistically to stress a population beyond a tolerable threshold. Cumulative impacts related to SPR expansion potentially could affect threatened and endangered species in four ways:

- The incremental increase in the likelihood of an oil spill in the Gulf of Mexico could add to the oil pollution stress already experienced by pelicans, plovers, or Gulf sturgeon.

- Human activity and related disturbances (e.g., noise) could raise the current level human disturbance (possibly affecting bald eagles).

- Water quality degradation could worsen already degraded riverine and estuarine systems (possibly affecting sturgeon or aquatic turtles).

- Destruction of habitat could reduce or fragment already small areas of available habitat at a given locale below a required minimum of undisturbed acreage.

Little information is available on specific threshold levels for the above types of stresses for these threatened and endangered species, making it difficult to evaluate cumulative impacts effectively. Incremental increases in Gulf oil spills and human activity are not expected to harm any threatened or endangered species of concern. It is unlikely that, for example, a small amount of oil added to the Gulf due to an SPR related spill, would push the pelicans over their tolerance limit for oil pollution. Human activity should not affect bald eagles at all, if nesting, foraging, and roosting sites are avoided. Similarly, stream and river water quality degradation is expected to be temporary and concentrated in relatively small areas.

Water quality degradation due to the SPR project may harm aquatic turtles or sturgeon. The yellow-blotched sawback turtle is known to live near the proposed Pascagoula pipeline. Water quality degradation has been a factor in declining populations of this threatened species.

Site construction may prove harmful to black bear populations at Weeks Island. Development at Weeks Island already has diminished the black bear's habitat. Further extensive reduction of black bear habitat could result in extirpation of the black bear from the island.

F.7 Summary of Potential Impacts

The following tables summarize potential impacts of the Stratton Ridge, Weeks Island/Cote Blanche, and Richton alternatives of the SPR expansion on threatened and endangered species.

Table F.7-1

Potential Concerns and Possible Impacts on Threatened and Endangered Species: Stratton Ridge

Species	Potential Concerns	Likelihood of Impact	Rationale of Findings
Construction			
Bald Eagle	Disturbance of breeding habitat	No Impacts	No known eagle nests are located on or near proposed ROWs. The closest nest to the Stratton Ridge pipeline is at least 20 miles away
	Disturbance of roosting/foraging habitat	Possible Impacts	If eagles roost or feed in the area, the pipeline construction could disrupt this habitat.
Brown Pelican	Habitat destruction	No Impacts	Brown pelican populations do not live close enough to the proposed site or pipeline to be affected by construction.
Piping Plover	Habitat destruction	No Impacts	Interior piping plover populations do not live close enough to the proposed site or pipeline to be affected by construction.
Operation and Maintenance			
Bald Eagle	Disturbance of breeding habitat	No Impacts	No known eagle nests are located on or near proposed ROWs. The closest nest to the Stratton Ridge pipeline is at least 20 miles away
	Disturbance of roosting habitat	Possible Impacts	If eagles roost in the area, the pipeline maintenance or easy accessibility of ROWs to human activity could disrupt this habitat.
Brown Pelican	Loss of habitat	No Impacts	Brown pelican populations do not live close enough to the proposed site or pipeline for habitat to be lost due to operation and maintenance activities.
Piping Plover	Loss of habitat	No Impacts	No interior piping plover populations do not live close enough to the proposed site or pipeline for habitat to be lost due to operation and maintenance activities.
Spills			
Bald Eagle	Habitat destruction	No Impacts	Spills are not likely to affect eagle nesting or roosting sites, and would only affect a small portion of an eagles large foraging area. Brine spill would not be expected to affect this species.
Brown Pelican	Habitat destruction	Possible Impacts	There is a small increased chance of Gulf oil spills due to the SPR expansion, and such a spill could affect the pelican populations if it reached pelican habitat. Brine spill would not be expected to affect this species.
Piping Plover	Habitat destruction	Possible Impacts	There is a small increased chance of Gulf oil spills due to the SPR expansion, and such a spill could affect the plover populations if it washed up on plover habitat. Brine spill would not be expected to affect this species.

Table F.7-2
Potential Concerns and Possible Impacts on Threatened and Endangered Species: Cote Blanche/Weeks Island

Species	Site/Pipeline	Potential Concerns	Likelihood of Impact	Rationale of Findings
Construction				
Louisiana Black Bear	Pipeline	Fragmentation of habitat	Possible Impacts	Black bears inhabit Weeks Island. Pipeline construction could temporarily fragment what undeveloped habitat remains.
	Site	Destruction/loss of habitat	Likely Impacts	Black bears inhabit Weeks Island. Site construction could further diminish what undeveloped habitat area remains.
Operation and Maintenance				
Louisiana Black Bear	Pipeline	Fragmentation of habitat	Possible Impacts	Black bears inhabit Weeks Island. Pipeline ROWs could permanently fragment what undeveloped habitat remains. If mitigation measures are used, bears will be more likely to cross the pipeline ROW.
Spills				
Louisiana Black Bear	Pipeline	None	No Impacts	Spills are not likely to affect black bears adversely

Table F.7-3
Potential Concerns and Possible Impacts on Threatened and Endangered Species: Richton

Species	Site/Pipeline of Concern	Potential Concerns	Likelihood of Impact	Rationale of Findings
Construction				
Bald Eagle	Pascagoula pipeline	Disturbance of breeding habitat	No Impacts	No known eagle nests are located within a mile of proposed ROWs.
		Disturbance of roosting/foraging habitat	Possible Impacts	If eagles roost or feed in the area, the pipeline construction could disrupt this habitat.
Eastern Indigo Snake and Gopher Tortoise	Site/all pipelines	Destruction of habitat	Possible Impacts	No known populations of indigo snakes or gopher tortoises are recorded on or near proposed ROWs, but sections of the ROWs cross areas of suitable habitat. These areas would be surveyed to confirm and pinpoint the presence of these species.
	All pipelines	Pesticide use along pipeline ROW	Possible Impacts	ROWs may attract indigo snakes and gopher tortoises, and indiscriminant use of pesticides could be harmful to the species.
Gulf Sturgeon	All pipelines	Habitat destruction (water quality degradation)	Possible Impacts	Gulf sturgeon may be affected, although because they are located in the Pearl and Pascagoula Rivers, downstream of the RWI in the Leaf River.
Red-cockaded Woodpecker	Site/all pipelines	Habitat destruction	Possible Impacts	No known populations of indigo snakes or gopher tortoises are recorded on or near proposed ROWs, but sections of the ROWs may cross areas of suitable habitat. More information is needed to determine whether suitable habitat (mature pine stands) is crossed.
Ringed Sawback Turtle	Liberty pipeline	Food and habitat destruction (water quality degradation)	Possible Impacts	If water quality degradation travels far enough downstream, sawbacks may be affected because they are located in the Pearl and Bogue Chitto Rivers, both of which will be crossed by the Liberty pipeline.
Yellow Blotched Map Turtle	Pascagoula pipeline	Food and habitat destruction (water quality degradation)	Likely Impacts	Known populations exist in the Leaf River, west of the proposed Pascagoula pipeline, near the towns of Beaumont and McLain. Damage to Leaf River water quality (e.g., siltation due to dredging in tributary streams, etc.) could adversely affect this species.

(continued)

Table F.7-3 (continued)
Potential Concerns and Possible Impacts on Threatened and Endangered Species: Richton

Species	Site/Pipeline of Concern	Potential Concerns	Likelihood of Impacts	Rationale of Findings
Operation and Maintenance				
Bald Eagle	None	Habitat destruction	No Impacts	No known eagle nests are located on or near proposed ROWs. The closest nest to the Stratton Ridge pipeline is at least 20 miles away.
Eastern Indigo Snake and Gopher Tortoise	All pipelines	Pesticide use along ROW	Possible Impacts	Indigo snakes and gopher tortoises may be attracted to ROWs, and indiscriminant use of pesticides could be harmful.
Gulf Sturgeon	RWI	Reduced stream flow; water quality degradation	Possible Impacts	Reduced stream flow and water quality degradation due to RWI may affect the Gulf sturgeon adversely. Sturgeon are located in the Pearl and Pascagoula Rivers, generally downstream of the RWI in the Leaf River.
Red-cockaded Woodpecker	All pipelines	Habitat fragmentation	Possible Impacts	It is unknown whether populations or suitable habitat (i.e., stands of mature pines) exist in or adjacent to the proposed site or pipeline ROWs.
Ringed Sawback Turtle	None	None	No Impacts	Once pipelines are constructed, wetlands and aquatic areas will be permitted to revert to previous conditions, and no impacts on turtles are expected. RWI will not affect these turtles because they do not occur in the Pascagoula or Leaf Rivers.
Yellow Blotched Map Turtle	RWI	Reduced stream flow; water quality degradation	Possible Impacts	Known populations exist in the Leaf River, west of the proposed Pascagoula pipeline, near the towns of Beaumont and McLain. Reduced stream flow and water quality degradation due to RWI may adversely affect this species.

(continued)

Table F.7-3 (continued)
Potential Concerns and Possible Impacts on Threatened and Endangered Species: Richton

Species	Potential Concerns	Likelihood of Impact	Rationale of Findings
Spills			
Bald Eagle	Food	No Impacts	Eagle nesting and roosting sites should not be affected by spills. Eagles feed from a large area and should be able to avoid spill areas.
Eastern Indigo Snake and Gopher Tortoise	Habitat destruction	Possible Impacts	A spill may destroy habitat in the immediate area of the spill.
Gulf Sturgeon	Habitat destruction	Possible Impacts	Gulf sturgeon could be affected by freshwater, estuarine, or marine oil spills. A brine spills may affect sturgeon eggs or larvae if it occurs in a spawning or nursery area.
Red-cockaded Woodpecker	Habitat destruction	Possible Impacts	It is unknown whether populations or suitable habitat (i.e., stands of mature pines) exist in or adjacent to the proposed site or pipeline ROWs. If so, a terrestrial oil leak or long-term brine leak from a pipeline could adversely affect this species
Ringed Sawback Turtle	Habitat destruction	Possible Impacts	The turtle could be affected adversely by oil or brine spills in the Pearl or Bogue Chitto Rivers.
Yellow Blotched Map Turtle	Habitat destruction	Possible Impacts	Known populations exist in the Leaf River, west of the proposed Pascagoula pipeline, near the towns of Beaumont and McLain. An oil or brine spill could adversely affect this species.

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APPENDIX G

POTENTIAL ECONOMIC IMPACT OF BRINE PLUMES ON FISHERIES

This appendix addresses the potential for proposed SPR brine discharges to cause economic impacts to commercial fisheries off the Gulf Coast of Texas, Louisiana, and Mississippi. It is divided into two main sections. The first section identifies the commercially important shellfish and finfish species in the Gulf Coast and discusses the ecology of these species, detailing the various life stages, the normal salinity range for each life stage, and, when data are readily available, the effects of salinity on the animals' growth and survival. The second section of this appendix provides estimates of the value of the fishery resources found within the area of the potential plumes of elevated salinity associated with the brine diffuser portions of the proposed SPR expansion. Estimates of the values of the commercial catch within the predicted plumes of elevated salinity are made for each diffuser and are divided by species. These estimates are intended to identify the value of the commercial species within the plume that are expected to experience the increases in ambient salinity. The ecological and life history information provided in the first section of this appendix, combined with the observed environmental impacts of historical SPR brine discharges in the Gulf of Mexico (see Appendix I), provide convincing evidence that the potential economic impacts of the proposed expansion are small, if not negligible. The salinity increases predicted for most areas of the plume are well within the tolerance range of most commercially important species, and any commercially important species that are displaced by the plume are expected to be available to fishermen working in other areas of the Gulf.

G.1 Ecology of Potentially Affected, Commercially Important Species

Shellfish comprise the most economically important fishery in the Gulf Coast, with white shrimp and brown shrimp bringing in the highest revenues. Another valuable fishery, the Gulf Coast oyster fishery, is worth about $28 million annually and provides one-third of U.S. oyster landings. The saltwater finfishery has traditionally been dominated by menhaden, which bring in over $50 million annually. The importance of other finfisheries has increased in recent years; eight additional species currently have commercial values of over $1 million per year.

Section G.1.1 below describes the ecology of Gulf Coast shrimp, section G.1.2 characterizes the life history of the American oyster, and sections G.1.3 and G.1.4 address menhaden and other commercially important finfish, respectively.

G.1.1 Shrimp

The shrimp fishery is essentially based on two species: *Penaeus aztecus* (the brown shrimp) and *Penaeus setiferus* (the white shrimp).[1] NMFS tabulates fisheries landings from the Gulf Coast according to statistical reporting grids. Landings refer to the amount of shrimp (heads-off) in pounds that are unloaded on shore. In 1990, the Gulf shrimp landings totaled over 120 million pounds valued at about $385 million.[2]

Because the life cycle and environmental requirements for the brown shrimp and white shrimp are very similar, this ecological summary examines these species simultaneously. Both species undergo the same life stages and experience similar environmental effects. Temporal and spatial shifts represent the major differences between these shrimp species. For example, the brown shrimp harvest begins in May, peaks in June and July, and continues through November in offshore waters. White shrimp, in contrast, are harvested from late August to December. Fishing activities for brown shrimp are concentrated within the 180-foot (55-meter) depth contour, but extend to 300 feet (90 meters).

G.1.1.1 Life Cycle

The life stage and activity of an animal are important in evaluating its response to environmental stresses. Different life stages and activities occur at varying depths or locations, and an animal's exposure to environmental factors can vary tremendously based on the particular habitat that is being utilized. In addition, an organism's environmental requirements and sensitivities may change depending on its life stage or activity.

The life histories of shrimp are described in the following sections in chronological order: spawning, the shedding of eggs into the water column; larvae, the first stages after hatching, including five naupliar, three protozoal, and three mysis stages; postlarvae, the mastigopus stages; emigration, the migration of juvenile shrimp from their estuarine nursery grounds into the Gulf; and adults, the reproductive and final stage.

Spawning and Larvae

Brown shrimp spawn at night, primarily in offshore waters deeper than 60 feet (18 meters), and possibly as deep as 450 feet (137 meters) or more.[3] Renfro and Brusher (1965) found that brown shrimp spawn continuously at depths of 150 to 360 feet with two peaks in spawning activity.[4] The major spawning season extends from September through May, but may occur at other times during the year, particularly at depths greater than 150 feet (46 meters). Two spawning peaks for brown shrimp occur in the northern Gulf of Mexico, September through November and April to May. The eggs are externally fertilized and semi-buoyant. Within 24 hours, the eggs hatch and the shrimp begin the 10 to 25-day period as larvae, including five naupliar, three protozoeal, and three mysis stages. Brown shrimp eggs and larvae require the open ocean environment, which is more constant in salinity than estuaries.

White shrimp spawn at various locations and times: in 25- to 100-foot (8- to 31-meter) oceanic waters in the northern Gulf of Mexico, in similar water at depths of 30 to 180 feet (9.1 to 55 meters) from April to September in Louisiana, and from April to August near Galveston, Texas. Spawning for white shrimp usually peaks in June or July and occurs between one and four times during their life span. The eggs of the white shrimp hatch within 10 to 12 hours after fertilization, beginning the same life cycle as the brown shrimp.

Postlarvae

Brown shrimp postlarvae move into estuaries, a process termed "recruitment." Although estuarine recruitment of brown shrimp in the northern Gulf of Mexico apparently spans all months, the most commonly cited period is February through April. Postlarvae move into the estuaries primarily at night on incoming tides. Postlarvae become demersal (bottom-dwelling) and move to shallow, soft-bottom areas of the estuarine nursery grounds. These postlarvae metamorphose to the juvenile stage within four to six weeks after entering the estuary. Growth and survival during the postlarval and early juvenile stages are thought to be critical factors affecting the harvestable adult population size.[5] According to Muncy (1984), "the maintenance or loss of nursery habitat will ultimately determine the future of Gulf Coast shrimp resources."[6]

White shrimp enter estuaries 15 to 20 days after hatching. Recruitment occurs from May until November in the Gulf, peaking around June and again in September. Juvenile white shrimp are reported to move farther up the estuary than brown shrimp.[7]

Emigration

Young brown shrimp remain in shallow estuarine waters near marshes that provide predator protection and a source of food. As they reach 60 to 70 millimeters (approximately 2 to 3 inches) in size, the shrimp move into deeper, open waters or "staging areas." Reaching the size of 90 to 110 millimeters (3.5 to 4.3 inches), they begin their migration into the Gulf. This process, called emigration, occurs mainly during June and July, but may occur anytime from May through August. A major portion of the Louisiana shrimp harvest occurs during this period.[8]

Postlarval and juvenile white shrimp use the estuaries during summer and fall until they reach 120 to 160 millimeters (4.7 to 6.3 inches) in length. Open coastal lakes and bays serve as staging areas for juveniles before they move offshore. White shrimp become abundant on the inshore fishing grounds by mid-June in Louisiana and Mississippi and by mid-July in Texas. Offshore movements of shrimp seem to consist of random feeding movements of 100 miles (160 kilometers) or more, as well as some inshore movements in response to temperature changes. Cold fronts increase movement to offshore waters.[9]

Adults

Upon leaving the estuaries, brown shrimp move to depths of 60 feet (18 meters) and make their way to the spawning depths of 150 to 300 feet (46 to 91 meters). Offshore adult populations in the northern Gulf tend to move westward with prevailing currents. Adults usually spawn only once and die soon after spawning, ending an annual life cycle. Tagging studies indicate, however, that some brown shrimp may live two or three years.[10]

During fall and winter, white shrimp move into deeper water and toward the mouth of the Mississippi River. The river outflow may be a natural barrier to east-west movements of white shrimp. Because few white shrimp live longer than one year, the bulk of the shrimp in the commercial catch is less than one year old.[11]

G.1.1.2 Environmental Requirements

This section identifies the temperature and salinity requirements of brown and white shrimp. It also discusses how brown and white shrimp are affected by the interaction of temperature and salinity.

Temperature

The optimum temperature for larval development in brown shrimp is 28 to 30° C. Estuarine recruitment of postlarval shrimp was reported only at temperatures greater than 12° C. Rapid change in temperature causes postlarvae and juveniles to become inactive, often to convulse, and sometimes to become paralyzed.[12] The highest catches of brown shrimp occur above 20° C.[13] Temperatures of 4.4° C or less may cause mass narcosis and mortality, and a suggested maximum tolerable temperature for postlarvae is just over 35° C.[14] Brown shrimp postlarvae tolerate a larger temperature range than white shrimp postlarvae.

White shrimp are more tolerant of high temperatures and less tolerant of low temperatures than brown shrimp. Mortality in white shrimp occurs under 8° C and above 42° C, regardless of salinity.[15] Growth rates increase rapidly above 20° C and are inhibited below this temperature.[16]

Salinity

Brown shrimp have been caught in salinities from fresh to 69 ppt, but few have been taken in waters of less than 5 ppt. Studies have indicated that minimum salinities for brown shrimp survival range between 0.5 and 0.8 ppt. A salinity optimum of 19 ppt has been suggested.[17] Heavy freshwater introduction into marsh nursery areas may cause juveniles to migrate to deeper water or laterally towards offshore shallows for higher salinity habitats.[18] Because brown shrimp are adapted to areas with high salinities, they may not survive lower salinity conditions in estuaries during periods of high freshwater discharges.[19] Kaiser and Aldrich (1976) reported no evidence to suggest that postlarvae are adapted to specific salinities and conclude that temperature is apparently more important than salinity to postlarval shrimp growth and survival.[20]

Cook and Murphy (1969), as cited in Muncy (1984), report preferred salinities for white shrimp spawning of at least 25 ppt.[21] Juvenile white shrimp seem to prefer relatively low salinities, but they have been successfully reared at salinities of 18 to 34 ppt. Gunter (1967) reported that postlarvae were most abundant in salinities of 5 to 10 ppt, and small white shrimp did not fare well in 41 ppt salinity.[22] Perez-Fontaine (1969) reported that 0.42 ppt was the lowest salinity in which white shrimp were found in the Gulf. Christmas and Etzold (1977) suggested that increases in salinity caused shifts in dominance from white shrimp to brown shrimp along the central-northern Gulf.[23]

Temperature-Salinity Interaction

Brown shrimp seem to tolerate a wide range of temperature-salinity combinations. A wider range of salinities is tolerated at a relatively high temperature (26° C) compared to lower temperatures.[24] A similar increase in the range of temperature tolerance has also been observed at higher salinities. Several studies have shown that the combination of low salinity and low temperature are damaging to brown shrimp. A warm, relatively high salinity spring generally brings a good brown shrimp harvest.[25]

Peaks of white shrimp emigration out of estuarine waters in Texas correlates closely with decreases in estuarine water temperature of 3 to 6° C and decreases in estuarine salinity of 3 to

10 ppt. Sudden drops in salinity combined with low water temperatures are harmful to white shrimp. Zein-Eldin (1964) stated that temperature and food supply limited growth of postlarvae more than salinity.[26]

G.1.2 Oysters

The oyster fishery is based on *Crassostrea virginica*, commonly known as the American, eastern, or Virginia oyster. Combined landings for the Gulf states average about 8,000 metric tons (18 million pounds) per year with half of these landings taken in Louisiana.[27]

Oysters cluster in "beds" and typically live in shallow, well-mixed estuaries, bays, or lagoons where salinities fluctuate widely. They can be found in mudflats and offshore sandy bars and occur at depths ranging from 1 to 40 feet (0.3 to 12 meters).[28] The Gulf of Mexico has about 3,600 square kilometers (1,400 square miles) of suitable oyster habitat.[29]

Predators are the primary cause of juvenile and adult oyster mortality in the Gulf of Mexico. The southern oyster drill is the major oyster predator in Louisiana and Mississippi and can kill up to half of the oysters on a given oyster bar.[30] Oyster diseases, such as protozoan infections by *Perkinsus marinus* or *Labyrinthomyxa marina*, can also be lethal.[31] Oysters must compete for space with a variety of other animals, including the hooked mussel, barnacles, slipper shells, and jingle shells.[32]

On the east coast of North America, American oysters occur from the Gulf of St. Lawrence to the Gulf of Mexico. Environmental requirements vary somewhat from one population to another.

G.1.2.1 Life cycle

There are two major life stages for oysters: spawning and larvae, and spat and adults. These stages are discussed separately below.

Spawning and Larvae

In the Gulf of Mexico, oysters spawn between March and November.[33] A female oyster may release over 20 million eggs at one spawning, and may spawn more than once a year.[34] Fertilized eggs develop into ciliated veliger larvae. Larvae may swim upward at nearly 1 cm/sec, and are thought to swim upward or sink to take advantage of tidal transport. Generally, larvae are transported upstream in an estuary. In the Gulf of Mexico, they tend to drift westward and may be transported up to 10 kilometers by coastal currents. Larvae usually grow and swim for two to three weeks before settling.[35]

When ready to settle, a larva develops a foot, becoming a pediveliger larva. During this two- to three-day pediveliger stage the larva crawls around the substrate "searching" for suitable substrate, usually oyster shell or rock. The larva then settles, cements itself to the substrate, and metamorphoses into a juvenile oyster, called a spat.[36]

Spat and Adults

Once cemented, oysters remain attached. As sessile animals, they cannot avoid environmental conditions by moving away. Like many bivalves, however, they can survive extreme conditions for short periods of time by closing their shells.

The fastest growth occurs during the early months of an oysters life. Growth is affected by salinity, temperature, food availability, and parasitic infection.[37] The size of an adult oyster affects its reproductive potential, i.e., larger oysters produce more eggs or sperm.

G.1.2.2 Environmental Requirements

This section identifies the temperature and salinity requirements of American oysters and discusses the effects of temperature and salinity, including interactive effects, on these bivalves. Both temperature and salinity requirements vary according to life stage, activity, and location of origin.

Temperature

Temperature affects oyster growth. Oysters tolerate widely fluctuating salinities, but excessively high temperatures can be lethal. Suitable temperatures for Atlantic coast embryos range from 20 to 30° C, and larva develop best between 27.5 and 37.5° C.[38] Optimum temperatures for Gulf Coast embryos and larvae may be higher. In general, adults exist at temperatures from 2 to 36° C, with optimum temperatures for growth, reproduction, and survival between 20 and 30° C.[39] Gulf Coast populations are less tolerant of low temperatures.

Salinity

Oysters not only tolerate widely fluctuating salinities, they tend to grow better under these conditions than under constant salinities.[40] Oysters tolerate salinities from 2 to more than 40 ppt, but usually occur at salinities from 10 to 30 ppt.[41] However, excessively low salinities (6 ppt or less) over extended time periods (two weeks or more) can kill oysters.[42]

The greatest growth and reproduction of oysters in the Gulf area occurs between 12 and 30 ppt, and the abundance is greatest between 10 and 20 ppt.[43] Embryos from the Atlantic coast develop normally at 16-30 ppt.[44] Larvae tolerate salinities of 3-31 ppt, but growth of larvae, spat, and adults is inhibited below 12 ppt.[45,46] At salinities below 20 ppt, spat settlement generally declines with salinity.[47] On the other hand, low salinities can increase survival by providing spat and adults with a refuge from predation and disease. For example, the southern oyster drill cannot survive in salinities below 11 ppt.[48]

Temperature-Salinity Interaction

Reduced salinity can lower or narrow the temperature range at which oysters can develop and grow normally. For an Atlantic coast oyster population, larvae grow best at 30 to 32.5° C if salinities are between 10 and 27.5 ppt, but they grow best at 27.5° C if salinity is 7.5 ppt.[49] Oyster embryos and larvae tolerate a wider temperature range at medium to high salinities than at low salinities.[50]

G.1.3 Gulf Menhaden

The gulf menhaden, *Brevoortia patronus*, supports the largest single fishery (by weight) in the United States. In 1989, 1.3 billion pounds of this species were caught in the Gulf of Mexico, with a reported value of $53 million.[51] Fishery activities from eastern Texas to Florida are located from 1 to 3 miles (1.6 to 4.8 kilometers) offshore. As a result of this location, the menhaden fishery is subject to state rather than Federal regulations.[52] The fishing season runs from mid April to October, and the greatest concentrations of gulf menhaden are found in areas surrounding the Mississippi River Delta. This small, short-lived species congregates in large schools and is caught with purse-seine nets. The menhaden catch is used for fish meal and oil, and is comprised primarily of individuals from only two age classes (one- and two-year-old fish).[53] Catch levels can vary tremendously annually because of variations in recruitment (numbers of fish surviving to adulthood).[54] The recruitment level is thought to be closely associated with the availability and water quality of estuarine ecosystems.

Over their lifetime, gulf menhaden display two distinct feeding strategies. Fish in the larval and post larval stages are particulate feeding carnivores and selectively consume individual zooplankters. The juvenile and adult menhaden display gill rakers that form a basket-like sieve; these fish are omnivorous filter feeders that eat zooplankton, phytoplankton, and organic detritus (Reintjes and Pacheco 1966).[55] The menhaden are thought to be an important component in the estuarine ecosystem, as they are one of the few species of filter feeding omnivores.[56] Although menhaden do not directly utilize the substrate (ocean floor), they are most often caught above areas with soft bottom (muddy) substrates.[57]

Gulf menhaden are the prey of many commercially and recreationally important fish species, including mackerel, red drum, sea trout, bluefish, and sharks.[58] Many shorebirds also depend upon the menhaden supply, including the brown pelican,[59] a threatened species.

G.1.3.1 Life Cycle

The life cycle of gulf menhaden is similar to that of other commercially important species that are dependent on estuaries. The menhaden go through five developmental stages: egg, larval, post larval, juvenile, and adult. With the exception of the egg, each stage uses estuarine waters to some extent.

Spawning and Larvae

Menhaden have not actually been observed spawning, but information about this event has been derived from studies of larvae and sexually mature adults.[60] Evidence of spawning has been reported in waters of various depths, but spawning generally occurs in waters less than 60 feet (18 meters) deep (Christmas and Waller 1975).[61] Etzold and Christmas (1979) suggest that the spawning season lasts from September through May.[62] The peak for spawning activity appears to be in March, but an individual menhaden may spawn four or five times within a single season.[63] Eggs float near the surface of the water, and probably hatch after about two days. Newly hatched larvae move into estuaries after spending three to five weeks drifting in offshore waters. The peak for this activity extends from December through March.[64]

Postlarval and Juvenile Stages

Postlarval menhaden remain in the estuaries from November until June, concentrating in shallow, low salinity areas near shore. Transformation from postlarval to juvenile morphology also occurs within the estuary.[65] Soon after this transformation, the menhaden move into the upper reaches of the estuary. The juveniles congregate in dense schools, and over the summer gradually return toward the mouth of the estuary.[66] Juvenile menhaden may remain in the estuaries until the next year's spawning season. Some of the maturing juveniles are thought to emigrate with the adults in late summer/early fall to participate in the spawning season before they have reached one year of age.

Adults

By the time a menhaden reaches 50 millimeters (almost 2 inches) in length, it displays the adult form.[67] Following the spawning season, the surviving juveniles and adults in the open water return to the food-rich waters of the estuaries. To a large extent, the depth and water movements of menhaden follow this annual inshore-offshore migration pattern. In a study by Roithmayr and Waller (1963), menhaden were caught from surface to bottom in 6 to 50 feet (2 to 15 meters) of water from June through September; were found to depths of 90 feet (27 meters) in October and November; from 23 to 108 feet (7 to 33 meters), and occasionally 290 feet, from December through February; and came back up to 6 to 85 feet (2 to 26 meters), and occasionally 110 feet (34 meters), from March until May.[68]

G.1.3.2 Environmental Requirements

This section identifies the temperature and salinity requirements of gulf menhaden and discusses the effects of temperature and salinity, including interactive effects, on these fish.

Temperature

In a summary of temperature and salinity studies, Copeland and Bechtel (1974) found that harvests of juveniles in estuaries were distributed within a temperature range of 0 to 40° C, with an optimum catch (indicating highest abundance) at temperatures of 25 to 35° C. Definitive data on preferred temperatures, particularly on upper and lower lethal limits, are not currently available.[69]

Gunter and Christmas (1960) reported that fishing activities near the Mississippi Delta began in the spring as water temperatures rose to 23° C, and tapered off in the fall as the waters dropped toward this same temperature.[70]

Salinity

Gulf menhaden are considered euryhaline (able to tolerate a variety of salinities) in all stages of their life cycle, but various stages tend to be associated with slightly different salinity ranges. As described in the life cycle section (section 1.3.1), adults, eggs, and early larval stages are associated with the higher salinity gulf waters, while the post larval and juvenile stages are associated with the lower salinity estuaries. Developing adults are usually found in shallow, midsalinity waters.[71]

Copeland and Bechtel's (1974) summary concluded that the juveniles were found in a salinity range from 0 to 26 ppt, with an optimum catch from 0 to 12 ppt.[72] Simmons (1957) found juvenile gulf menhaden to be common in waters from 20 to 60 ppt, but also noted mass mortalities of these juveniles at salinities over 80 ppt.[73] In a study of menhaden catches in Louisiana, Mississippi, and Alabama, Christmas et al. (1960) found that all catches occurred in salinities between 6.2 to 31.6 ppt, with 88 percent between 15 and 29 ppt. The mean salinity at which menhaden were caught was 21.4 ppt.[74]

Salinity and Temperature Interactions

Copeland and Bechtel (1974) concluded that "there are clear temperature-salinity patterns, with juvenile menhaden found more often in low salinity waters when temperatures are high. Menhaden are abundant in a wider salinity range at higher temperatures and in a wider temperature range at lower salinities."[75]

With respect to all information regarding temperature and salinity observations, these ranges should be regarded as frequently observed associations rather than preferences shown by the menhaden, due to the lack of controlled experimental testing of this species.[76] It is quite possible that the juveniles' association with low salinity, high temperature estuarine waters is more related to food availability than to temperature or salinity requirements of the menhaden.

G.1.4. Commercially Important Finfish Other Than Menhaden

In addition to gulf menhaden, there are many other commercially important finfish in the Gulf of Mexico. Only eight species, however, were consistently valued at $1 million or more in terms of their annual landings. This ecological summary focuses on these eight species: red snapper (*Lutjanus campechanus*), vermillion snapper (*Rhomboplites aurorubens*), red drum or redfish (*Sciaenops ocellata*), black drum (*Pogonias cromis*), spotted sea trout (*Cynoscion nebulosus*), swordfish (*Xiphias gladius*), yellowfin tuna (*Thunnus albacares*), and bluefin tuna (*Thunnus thynnus*). Combined, these eight species form the third largest contribution to the Gulf Coast fishing industry, following shrimp and menhaden.

Ninety-eight percent of the commercially important species in the Gulf of Mexico, including these eight species, depend on the quality and availability of estuaries at some point in their life cycle.[77] Consequently, the continuing degradation of both riverine and Gulf water quality, along with the loss of coastal marsh and wetlands, threatens the future of the Gulf fisheries.[78] Also, many of these species have recently shown signs of population decline, possibly due to high rates of commercial and recreational fishing, high levels of incidental catch (fish caught accidentally by fishermen fishing for other species), or poor recruitment years. Although information regarding the life histories and ecological requirements of individual species is often not available, DOE has attempted to summarize what is known about the above eight species in the following sections.

G.1.4.1 Red Snapper and Vermillion Snapper

In the Gulf of Mexico, snapper species are native to coral reefs or rocky outcrops ("snapper banks") in offshore areas.[79] Individuals of these species are most commonly found near the ocean floor. Currently, little information is available on the life history and ecological requirements of the vermillion snapper; as a result, the following information directly describes only the red snapper species. It is likely that the vermillion snapper shares many of the ranges, food preferences, and tolerances described in the following summary.

Juveniles tend to inhabit shallow offshore areas (50 to 100 feet; 15 to 30 meters) in the summer and deeper areas in the winter (115 to 200 feet; 35 to 60 meters).[80] Adults are commonly found in depth ranges from 130 to 330 feet (40 to 100 meters).[81] In general, they stay near reefs and do not migrate far inshore or offshore. The red snapper spawns in the summer and fall, and may spawn several times during a single season. Spawning generally occurs away from the reefs, at depths ranging from 60 to 120 feet (18 to 37 meters).[82]

Adult red snapper eat shrimp, small reef fish, crabs, and gastropods, and the juveniles consume mostly shrimp, squid, and octopus.[83] This species is found in a temperature range of 13 to 32° C, and a salinity range of 33 to 37 ppt. Salinities of 60 ppt are lethal to adult red snapper, but concentrations of 45 ppt do not produce serious effects.[84]

Currently, the red snapper is a primary target of the commercial fishing industry, and is a very popular sport fish. It has been suggested that the population of this fish is in decline due to high incidental catches in shrimp trawl nets.[85]

G.1.4.2 Red Drum and Black Drum

Red drum and black drum spawn in shallow coastal waters, frequently near tidal passes.[86] The young migrate into estuaries, but when they are mature, they return to Gulf waters to spawn. Both species show a strong tendency to school.

Young red drum tend to spend their time in sheltered bays and lagoons, where they stay in the shallow waters along marsh edges.[87] The post larval red drum live among sea grasses in shallow water.[88] In the summer, adults and larger juveniles seem to concentrate farther offshore, near shell reefs, wrecks, and oil platforms.[89] During the winter, they move inshore and inhabit marsh lakes and bayous.[90] Red drum spawn in shallow offshore areas from mid-August to November, with a peak during September and October.[91] Commercial fishing for red drum is currently banned in Louisiana and Texas state waters in an effort to let this species recover from recent population declines.[92]

Black drum spawn most often in waters from 65 to 90 feet (20 to 27 meters) deep.[93] Following the spawning season, adults return from these shallow coastal waters to the estuaries, where they appear to spend most of their time. Juvenile black drum are commonly found in shallow tidal creeks and channels (within estuaries), and seem to prefer muddy waters.[94]

Adult black drum feed primarily on oysters, but their diet also includes crabs, shrimp, and fish. Juvenile black drum feed on small fish and invertebrates, and the larvae eat zooplankton.[95] The diet of the red drum is similar at each life stage, although this species does not prey on oysters.

Black drum are commonly found in waters with salinities ranging from 9 to 26 ppt, and in temperatures of 12 to 33° C.[96] Red drum are found in waters of similar temperatures and salinities, however they have been found in areas with salinities as high as 40 or 50 ppt. They are most often found in waters with salinities between 30 and 35 ppt.[97]

G.1.4.3 Spotted Sea Trout

The spotted sea trout spends most of its life in estuaries, but the adults are sometimes found in adjacent shallow coastal waters.[98] Adult spotted sea trout are demersal, i.e., they tend to stay near the bottom of their marine habitat. This species also shows a strong tendency to school. Spotted sea trout are carnivores, feeding on a variety of ocean animals, including crustaceans (such as shrimp) and fish.[99] Juvenile sea trout feed on zooplankton.[100]

Spotted sea trout generally spawn in estuaries near tidal passes, although some offshore spawning has been recorded.[101] Spawning occurs from April through September. Newly hatched spotted sea trout (larvae and early juveniles) tend to be found in the lower parts of estuaries. As these fish mature in the fall and early winter, they move farther into the upper reaches of the estuaries, and commonly concentrate in bayous, canals, and along lake shores.[102]

Spotted sea trout can be found in conditions ranging from freshwater to hypersaline, but are most common in waters ranging from 5 to 20 ppt salinity, and from 8 to 35 °C.[103]

G.1.4.4 Swordfish

As is true of many of the large ocean fish, little is known about the biology of the swordfish. This species is widely distributed both north and south of the Equator, and individuals have been recorded weighing up to 537 kilograms.[104] Swordfish spawning in the Gulf of Mexico is thought to occur from late spring through late summer.[105] It is likely that the larval and/or juvenile swordfish spend at least a part of their lives in estuaries.

G.1.4.5 Bluefin Tuna and Yellowfin Tuna

Currently, not much is known about the biology of tuna in the Gulf of Mexico. In general, tuna are fast-swimming oceanic species that travel in schools and feed on smaller fish or squid. Both the bluefin and yellowfin are found in wide ranges of the Atlantic Ocean, and are fairly rare in the Gulf.[106] The bluefin tuna enters gulf waters from the Atlantic in the winter, and spawns there between mid-April and mid-June.[107] This species has suffered stock declines in the Atlantic, and commercial fisheries for bluefin tuna are strictly managed on an international level.[108] As is true for most species, it is likely that larval and/or juvenile tuna spend part of their lives in the food-rich waters of an estuary.

G.2 Estimate of Economic Cost of Maximum Catch Displacement Due to Brine Discharge

This section provides estimates of the value of the fishery resource that is caught within the area encountered by the increased salinity plumes that may be associated with the proposed SPR expansion. Estimates are made for each fishery based on the plumes associated with the worst-case environmental conditions, and 55 open diffuser ports (these analyses are based on plumes of 1 ppt and 3 ppt above ambient salinity). The ecological and life-history information provided in the first section of this appendix, along with the observed environmental impacts of historical SPR brine discharge in the Gulf of Mexico (see Appendix I), provide convincing evidence that the economic impacts to commercial fisheries would be very low; the majority of the potential catch predicted to be in the area of the plumes is not expected to be negatively impacted, or to emigrate from the area, because the salinity increases in most areas of the brine plume fall well within the range of most species' salinity tolerance.

G.2.1 Overview

The essential elements in the methodology used to predict the value of the fishery resource in areas that may be encountered by brine plumes were:

- An estimate of the average market value (dollars) of commercially important shrimp, oysters, and finfish caught annually per unit area (acre) in the vicinity of the proposed diffuser sites;

- Estimates in Appendix Q of the size (in acres) of the area of increased salinity (calculated for both a 1 ppt and 3 ppt increase) associated with each diffuser (under maximum discharge conditions and most severe environmental conditions); and

- The assumption of total displacement of the catch within the zone of elevated salinity.

Using this approach, a maximum estimate (for each diffuser location) of the value of the commercial species that would potentially be caught in the areas for which salinity increases are predicted are presented in Tables G.2-1 and G.2-2 below.

Table G.2-1
Estimated Value of Commercial Species Found in the Predicted Brine Plume Contours of 1 ppt Elevated Salinity

Proposed Diffuser Site	Estimated Annual Fishery Value (dollars)			
	Shrimp	Finfish	Oysters	Total
Stratton Ridge	$213,440	$14,498	$0	$227,938
West Weeks Island/ Cote Blanche	$788,334	$473,190	$0	$1,261,524
Richton	$337,746	$6,216	$0	$343,962

Table G.2-2
Estimated Value of Commercial Species Found in the Predicted Brine Plume Contours of 3 ppt Elevated Salinity

Proposed Diffuser Site	Estimated Annual Fishery Value (dollars)			
	Shrimp	Finfish	Oysters	Total
Stratton Ridge	$62,965	$4,277	$0	$67,242
Weeks Island/ Cote Blanche	$234,584	$140,326	$0	$374,910
Richton	$98,898	$1,820	$0	$100,718

These estimated fishery values range from approximately 0.1 to 2.3 percent of the total annual value of the catch in the NMFS statistical grid (see section G.2.2) encompassing each proposed diffuser site; total revenue values associated with each diffuser represent a small fraction of the total annual value of the fishery catch in the northern Gulf of Mexico. Due to the far offshore location of the proposed diffusers and predicted brine plumes, oysters will not come into contact with the increased salinity contours.

G.2.2 Methodology

NMFS has determined the total amount (pounds) and the market value (dollars) of commercially important shrimp, oysters, and finfish caught annually within each of 21 grids established for the northern Gulf of Mexico (Figure G.2-1). These data are subdivided based on water depth (for shrimp) or distance from shore (for finfish and oysters). The depth sections for shrimp are in 5-fathom (30-foot) increments (i.e., 0-5 fathoms, 5-10 fathoms, 10-15 fathoms, etc.). The distance sections for finfish and oysters are 0-3 nautical miles from shore, 3-12 nautical miles from shore, and greater than 12 nautical miles from shore. Catch data for finfish and oysters landed in Louisiana and Mississippi are reported separately for all three distance sections; for finfish landed in Texas, the catch in distance sections 2 and 3 are combined (i.e., catch and market value data are reported only for 0-3 nautical miles from shore, and greater than 3 nautical miles from shore). The proposed diffuser sites are located in NMFS grids 11, 16, and 19 (Figure G.2-1).

Reported catch varied considerably among the various depth and distance sections within each grid. For example, bluefin tuna were caught only in the most distant sections (i.e., greater than 12 nautical miles from shore); oysters were caught only in inshore areas or offshore areas within 3 miles of shore. To calculate the average market value of the catch per unit area within the predicted zone of elevated salinity, a simple average of the catch per unit area within the depth or distance sections potentially affected by each plume was used (i.e., of each proposed diffuser. DOE determined the sections of each grid within which the zone of elevated salinity (under most severe conditions environmental conditions, 55 open ports) at each proposed diffuser site would fall (see Appendix Q for a discussion of the predicted areal extent of the largest plumes for each proposed diffuser site). For example, when the predicted largest brine plume from the Stratton Ridge diffuser site is shown on nautical maps, it is centered almost directly on a line three nautical miles from shore; the predicted largest plume also overlaps the 5-fathom contour line. Therefore, the relevant sections of grid 19 are depth 1 and 2 (i.e., 0-5 and 5-10 fathoms) and distance 1 and 2 (i.e., 0-3 nautical miles and 3-12 nautical miles). The grids and relevant sections for each proposed diffuser site are presented in Table G.2-3.

Patella (1975)[109] calculated the area of each depth section within each grid in hectares; for the relevant depth sections, these values were converted into acres. DOE calculated the approximate area of the relevant distance sections by tracing each section as delineated on NOAA nautical charts on mile-calibrated graph paper, counting the number of squares (i.e., square miles) covered, and converting these values into acres. The resulting values used in the analysis are presented in Table G.2-3.

All market value data are based on reported catch from each NMFS grid (regardless of where the catch was landed). For shrimp, the market value estimate is an average of the annual value of the catch from 1988 through 1990. For finfish and oysters, the market value estimate is an average of the annual value of the catch from 1987 through 1989 (complete data sets for 1990 were not available at the time of analysis). Because the proposed diffuser locations are in offshore waters, only catch data reported from offshore locations were included in the 0-5 fathom and 0-3 nautical mile sections; data from inshore locations (i.e., bays, estuaries, saltwater lakes) were not included. In calculating average market value of the catch per unit area, equal productivity over the entire relevant NMFS grid section was assumed.

To calculate the average market value of the catch per unit area within the predicted zone of elevated salinity, a simple average of the catch per unit area within the depth or distance sections potentially affected by each plume was used (i.e., no attempt was made to quantify the proportion of each plume that fell within each section). At the Stratton Ridge site, for example, shrimp catch per acre within the sections depth 1 and depth 2 were averaged, and finfish and oyster catch per acre within the sections distance 1 and distance 2 were averaged (Table G.2-3).

To estimate the value of catch found in the area that may be encountered by the plume of elevated salinity, the average annual catch value per unit area within the predicted zone of elevated salinity was multiplied by the predicted plume area for elevated salinities of 1 ppt and 3 ppt. This assumes that the salinity changes due to the plume encounter the fish species uniformly over depth. Data on the value of the affected catch are presented both in absolute (i.e., dollars) and relative (i.e., proportion of total value of catch within affected NMFS grid) terms. Species-specific data for each proposed diffuser site are presented in Tables G.2-4 through G.2-6.

The estimated annual value of the catch from areas potentially encountered by the 1 ppt salinity increase contours ranged from approximately $230,000 (Stratton Ridge) to $1,300,000 (Weeks Island/Cote Blanche). These values represent 0.4 to 2.3 percent of the total annual value of the catch within the appropriate NMFS fishery grid. The estimated value of the catch from areas potentially encountered by the 3 ppt salinity increase contours ranged from approximately $70,000 (Stratton Ridge) to $370,000 (Weeks Island/Cote Blanche). These values represent 0.1 to 0.7 percent of the total annual value of the catch within the appropriate NMFS fishery grid. The estimated value of the commercial species encountering increased salinity at any single diffuser site is a small percentage of the value of the total annual catch in the northern Gulf of Mexico, which exceeds $440 million.

Figure G.2-1
Location of Proposed Diffuser Sites Within NMFS Fishery Grids for the Northern Gulf of Mexico

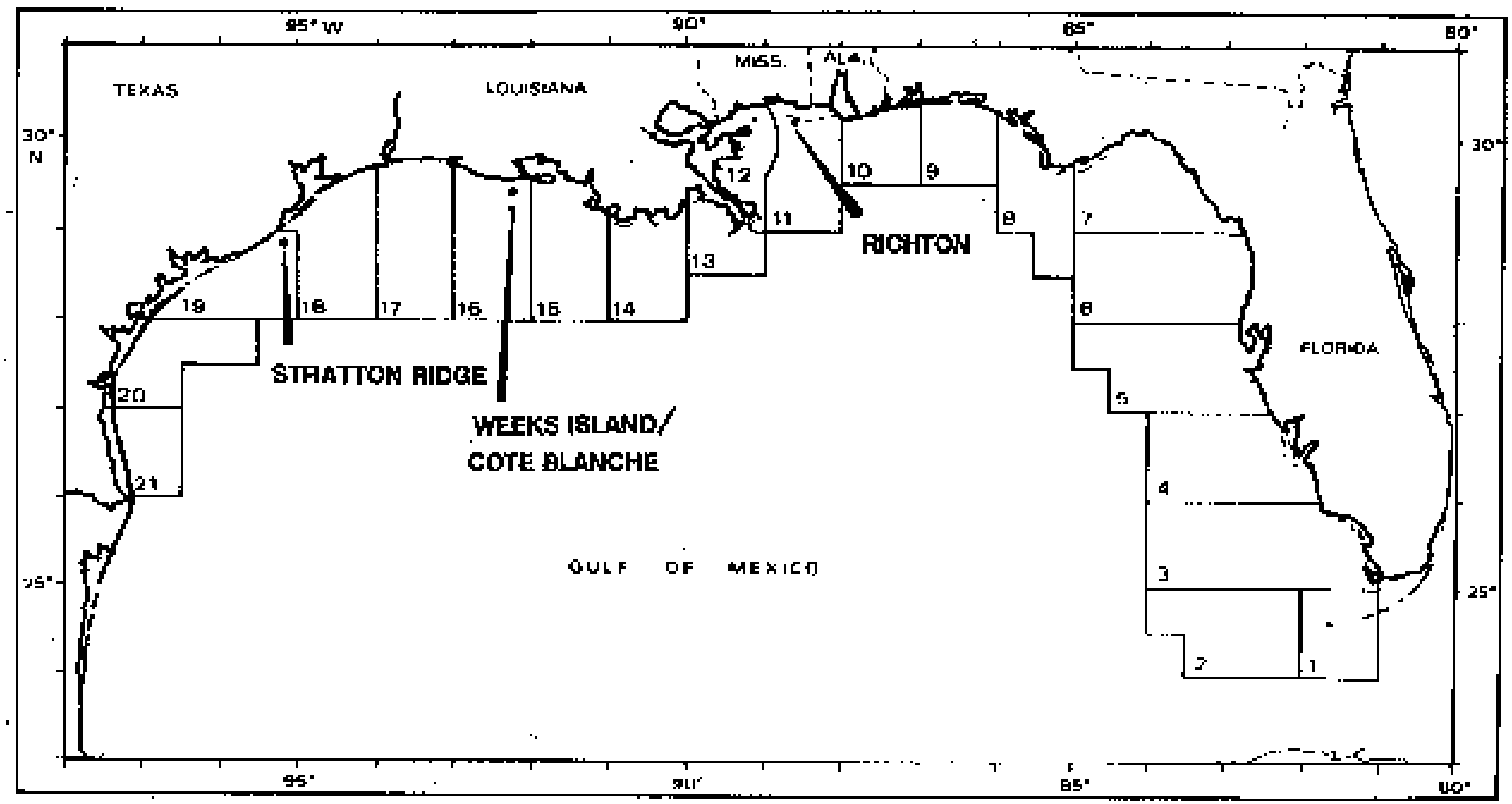

Table G.2-3
Size (Area) of NMFS Fishery Grids and Relevant Depth and Distance Sections Used in Analysis

Proposed Diffuser Site	NMFS Grid No.	Predicted plume area for 1 ppt contour[1] (acres)	Predicted plume area for 3 ppt contour[1] (acres)	Depth section(s) relevant to plume	Area of relevant depth sub-division(s)[2] (acres)	Distance section(s) relevant to plume	Approximate area of relevant sections[3] (acres)
Weeks Island/ Cote Blanche	16	24,900	7,400	depth 1 (0-5 fathoms)	547,139	dist 2 (3-12 n miles)	439,000
Stratton Ridge	19	20,000	5,900	depth 1, 2 (0-10 fathoms)	752,432	dist 1,2[4] (0-12 n miles)	580,000
Richton	11	18,100	5,300	depth 2 (5-10 fathoms)	579,459	dist 1,2 (0-12 n miles)	556,000

1 The size of the predicted brine plume (worst-case) is discussed in Appendix Q. For all sites the plume size reflects worst case environmental conditions and 55 open diffuser ports.

2 The areas of each depth section of the NMFS statistical grids were calculated by Patella (1975);[110] values for relevant depth subdivisions were converted to acres.

3 The area of each distance subdivision was approximated by tracing each distance section as delineated on NMFS nautical charts on mile-calibrated graph paper, counting the number of squares (i.e., square miles) covered, and converting these values to acres.

4 Catch data for fish caught in grid 19 and landed in Texas are reported for the 3-12 and > 12 nautical mile sections in a combined form (i.e., catch data for distance 2 and 3 were combined). As a consequence, the entire area of grid 19 (i.e., 2,983,627 acres)[111] was used as the "relevant distance section" for finfish species other than black drum because the diffuser was expected to affect distances 1 and 2.

Table G.2-4
Estimated Annual Value of the Commercial Fishery: Stratton Ridge Diffuser

Species	Section(s) of NMFS grid 19 where species is caught[1]	Value of catch per acre within relevant sections of NMFS grid 19	Total value of catch within NMFS grid 19	Value of catch within 1 ppt contour	Percent catch value within 1 ppt contour	Value of catch within 3 ppt contour	Percent catch value within 3 ppt contour
Brown Shrimp	in, depth 1, 2, 3	$5.03	$37,229,962	$100,660	0.3%	$29,695	0.1%
White Shrimp	in, depth 1, 2, 3	$5.64	$11,384,329.	$112,780	1.0%	$33,270	0.3%
Menhaden	not caught[2]	-	-	-	-	-	-
Red Drum	not caught[2]	-	-	-	-	-	-
Black Drum	in, dist 1	< $0.01	$22,117	$80	0.4%	$24	0.1%
Red Snapper	dist 2/3	$0.09	$263,568	$1,760	0.7%	$519	0.2%
V. Snapper	dist 2/3	$0.06	$17,733	$118	0.7%	$35	0.2%
S. Sea Trout	not caught[2]	-	-	-	-	-	-
Swordfish	dist 2/3	$0.07	$220,390	$1,480	0.7%	$437	0.2%
Yellowfin Tuna	dist 2/3	$0.45	$1,338,445	$8,940	0.7%	$2,637	0.2%
Bluefin Tuna	dist 2/3	$0.11	$317,021	$2,120	0.7%	$625	0.2%
Oyster	in	-	$2,243,337	-	-	-	-
TOTAL	-	$11.45	$53,036,902	$227,938	0.4%	$67,242	0.1%

1 Definition of category abbreviations: in = inshore (bays, estuaries, saltwater lakes within the grid); depth 1 = 0-5 fathoms, depth 2 = 5-10 fathoms, depth 3 = 10-15 fathoms; dist 1 = 0-3 nautical miles of distance from shore, dist 2/3 = greater than 3 nautical miles from shore (catch data for grid 19 are combined for the 3-12 and > 12 nautical miles from shore distance sections).

2 It is currently illegal to fish commercially for red drum and spotted sea trout in Texas; menhaden were not included because no catch of this species was reported between 1987 and 1989.

Table G.2-5
Estimated Annual Value of the Commercial Fishery: Weeks Island/Cote Blanche Diffuser

Species	Section(s) of NMFS grid 16 where species is caught[1]	Value of catch per acre within relevant sections of NMFS grid 16	Total value of catch within NMFS grid 16	Value of catch within 1 ppt contour	Percent catch value within 1 ppt contour	Value of catch within 3 ppt contour	Percent catch value within 3 ppt contour
Brown Shrimp	in, depth 1, 2, 3	$4.96	$15,079,310	$123,504	0.8%	$36,704	0.2%
White Shrimp	in, depth 1, 2, 3	$26.70	$19,431,607	$664,830	3.4%	$197,580	1.0%
Menhaden	dist 1, 2	$18.90	$18,044,384	$470,610	2.6%	$139,860	0.8%
Red Drum	not caught[2]	-	-	-	-	-	-
Black Drum	in, dist 1, 2, 3	$0.03	$60,811	$846	1.4%	$251	0.4%
Red Snapper	dist 2, 3	$0.07	$325,174	$1,619	0.5%	$481	0.2%
V. Snapper	dist 2, 3	< $0.01	$193,062	$115	0.1%	$34	< 0.1%
S. Sea Trout	in	-	$112,414	-	-	-	-
Swordfish	dist 3	-	$25,454	-	-	-	-
Yellowfin Tuna	dist 3	-	$152,194	-	-	-	-
Bluefin Tuna	dist 3	-	$9,141	-	-	-	-
Oyster	in, dist 1	-	$391,752	-	-	-	-
TOTAL	-	$50.66	$53,825,303	$1,261,524	2.3%	$374,910	0.7%

1 Definition of category abbreviations: in = inshore (bays, estuaries, saltwater lakes within the grid); depth 1 = 0-5 fathoms; depth 2 = 5-10 fathoms; depth 3 = 10-15 fathoms; dist 1 = 0-3 nautical miles from shore; dist 2 = 3-12 nautical miles from shore; dist 3 = > 12 nautical miles from shore.

2 It is currently illegal to fish commercially for red drum in Louisiana.

Table G.2-6
Estimated Annual Value of the Commercial Fishery: Richton Diffuser

Species	Section(s) of NMFS grid 11 where species is caught[1]	Value of catch per acre within relevant sections of NMFS grid 11	Total value of catch within NMFS grid 11	Value of catch within 1 ppt contour	Percent catch value within 1 ppt contour	Value of catch within 3 ppt contour	Percent catch value within 3 ppt contour
Brown Shrimp	in, depth 1, 2, 3	$14.00	$25,097,143	$253,400	1.0%	$74,200	0.3%
White Shrimp	in, depth 1, 2, 3	$4.66	$7,904,866	$84,346	1.1%	$24,698	0.3%
Menhaden	in, dist 1	$0.15	$4,829,320	$2,715	< 0.1%	$795	< 0.1%
Red Drum	in, dist 1, 2, 3	$0.01	$88,099	$181	0.2%	$53	< 0.1%
Black Drum	in, dist 1, 2, 3	$0.11	$81,120	$1,991	2.5%	$583	0.7%
Red Snapper	in, dist 1, 2, 3	$0.06	$148,757	$1,086	0.7%	$318	0.2%
V. Snapper	dist 1, 2, 3	< $0.01	$33,514	$81	0.2%	$24	< 0.1%
S. Sea Trout	in, dist 1, 2, 3	< $0.01	$67,263	$98	0.2%	$29	< 0.1%
Swordfish	dist 2, 3	< $0.01	$284,608	$4	< 0.1%	$1	< 0.1%
Yellowfin Tuna	dist 2, 3	< $0.01	$2,183,550	$60	0.3%	$17	< 0.1%
Bluefin Tuna	dist 3	-	$158,114	-	-	-	-
Oyster	in	-	$478,784	-	-	-	-
TOTAL	-	$18.99	$41,355,138	$343,962	0.8%	$100,718	0.2%

1 Definition of category abbreviations: in = inshore (bays, estuaries, saltwater lakes within the grid); depth 1 = 0-5 fathoms; depth 2 = 5-10 fathoms; depth 3 = 10-15 fathoms; dist 1 = 0-3 nautical miles from shore; dist 2 = 3-12 nautical miles from shore; dist 3 = > 12 nautical miles from shore.

G.3 Conclusions

The estimated value of the catch in areas of the predicted brine plumes is a reasonable maximum estimate based on the following conservative assumptions:

- Maximum (i.e., maximal discharge and most severe environmental conditions) discharge of brine from the diffusers;

- Salinity changes due to the plume affect the marine habitat uniformly over depth.

The impact of the brine plumes on fisheries is expected to be very small, if not negligible. Appendix I summarizes the results of post-discharge monitoring studies that have evaluated the mortality rate of exposed individuals at SPR sites that have discharged brine to the Gulf in the past. As shown in that Appendix, the mortality rate of exposed individuals has been very small. Most of the commercially important fish and shellfish species that contribute to the value estimates can tolerate a wide range of salinities (see section G.1 of this appendix), and would probably not be adversely impacted, or repelled by the increased salinity in most areas of the plume of elevated salinity (especially not in areas where the salinity has increased only 1 - 3 ppt above ambient). For example, brown shrimp have been caught in salinities ranging up to 69 ppt, and juvenile gulf menhaden are common in waters ranging up to 60 ppt. Other important species such as red snapper and red drum, typically can tolerate salinities as high as 45 or 50 ppt. These tolerances are considerably above peak salinities (40-42 ppt) recorded in the vicinity of the Bryan Mound diffuser (Hann et al. 1984).[112]

Peak salinities resulting from brine discharge may have some effects on fishery species. For example, peak salinities in the vicinity of the diffuser may reach 40-42 ppt, and small white shrimp may suffer some mortality at 41 ppt salinity. It is possible that this would result in a shift in dominance from white shrimp to the more salinity-tolerant brown shrimp within the highest salinity areas of the excess-salinity plume. Individuals swimming or drifting into the brine plume might suffer adverse effects due to rapid changes in salinity; no data on tolerance to rapid changes in salinity were found in the available literature. However, field studies have indicated that the existing brine diffuser at Bryan Mound has had little effect on the nekton (i.e., fish and shrimp) community inhabiting the diffuser area (see Appendix I). Benthic studies indicated that there was no significant difference in diversities observed within any distance "rings" around the diffuser (e.g., 200, 500, 1000, 2000, and 4000 meters or greater). Although variability among sampling stations and seasons was noted, there were no consistent differences in total shrimp abundance, total fish abundance, total nekton biomass, fish species diversity, and the size structure of fish populations within and outside the brine plume.[113] At West Hackberry, reductions in species abundance and total biomass could not be associated with the brine plume or diffuser. Benthic studies at West Hackberry did find a general decrease in abundance of dominant species around the diffuser, but this impact was not significant.[114] Future studies as outlined in Chapter 8 of this document will continue to monitor impacts of the SPR.

The maximum estimates of the value of commercial species caught within the areas of the predicted brine plumes show that the value of the total commercially important species population expected to encounter areas of increased salinity due to a single diffuser site is a small percentage of the value of the total annual catch in the northern Gulf of Mexico. It is expected that the value of any species displaced from the area encountered by the plume would be recovered in terms of increased catch in other areas of the Gulf. It follows from the ecological information provided in the first section of this appendix and the past experience at operating SPR diffusers that only a small percentage of this value may be lost due to the impacts of the very high salinity areas of the brine plume. DOE anticipates the value of any economic impacts to commercial fisheries to be very low. Further, the brine discharge will have limited duration (approximately three years) and species that tend to avoid the plume during discharge are expected to return shortly after discharge ceases. For example, in a study of brine disposal from the West Hackberry site, Matis and Grant found no important negative effects on brown and white shrimp catch associated with the spatial-temporal extent of the West Hackberry brine plume.[15] In fact, the Matis and Grant study suggested that brine disposal from West Hackberry resulted in an increase in catch for brown and white shrimp. Because no significant impacts are predicted, there also are no cumulative impacts of simultaneous operation of several diffusers.

ENDNOTES

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14. *Ibid.*, pp 8-9.

15. Muncy, R.J., *Species Profiles: Life Histories and Environmental Requirements of Coastal Fishes and Invertebrates (Gulf of Mexico) -- White Shrimp*, U.S. Department of the Interior, Fish and Wildlife Service, September 1984, FWS/OBS-82/11.20, p 11.

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APPENDIX H

NOISE ANALYSIS

This appendix explains the calculations and assumptions involved in assessing ambient noise levels and potential noise impacts at each of the proposed SPR sites. In addition to providing these basic assumptions and calculations, this appendix details the method for estimating sound attenuation over flat surfaces. This appendix does not address site-specific information nor does it assess noise impacts at any of the sites. As a result, this appendix should be used only as a supplement to the analyses provided in Chapters 4, 5, and 7 of the main document.

H.1 Estimating Noise

EPA developed the scale depicted in Figure H.1-1 as a guide to relative ambient sound levels. This figure presents day-night (L_{dn}) sound levels. The L_{dn} sound levels are the long term equivalent A-weighted (a single value measure that approximates sound as processed by the human ear) sound level that accounts for differences in response to day and nighttime noise. The formula for calculating L_{dn} shown below is essentially designed to add a 10 decibel (dBA) penalty to the daytime value for nighttime noise.

$$L_{dn} = 10 \log 1/24 \left[15 \left\{ 10^{(Ld/10)} \right\} + 9 \left\{ 10^{((Ln + 10)/10)} \right\} \right]$$

where,

$L_d = L_{eq}$ *for daytime (0700 hours to 2200 hours)*

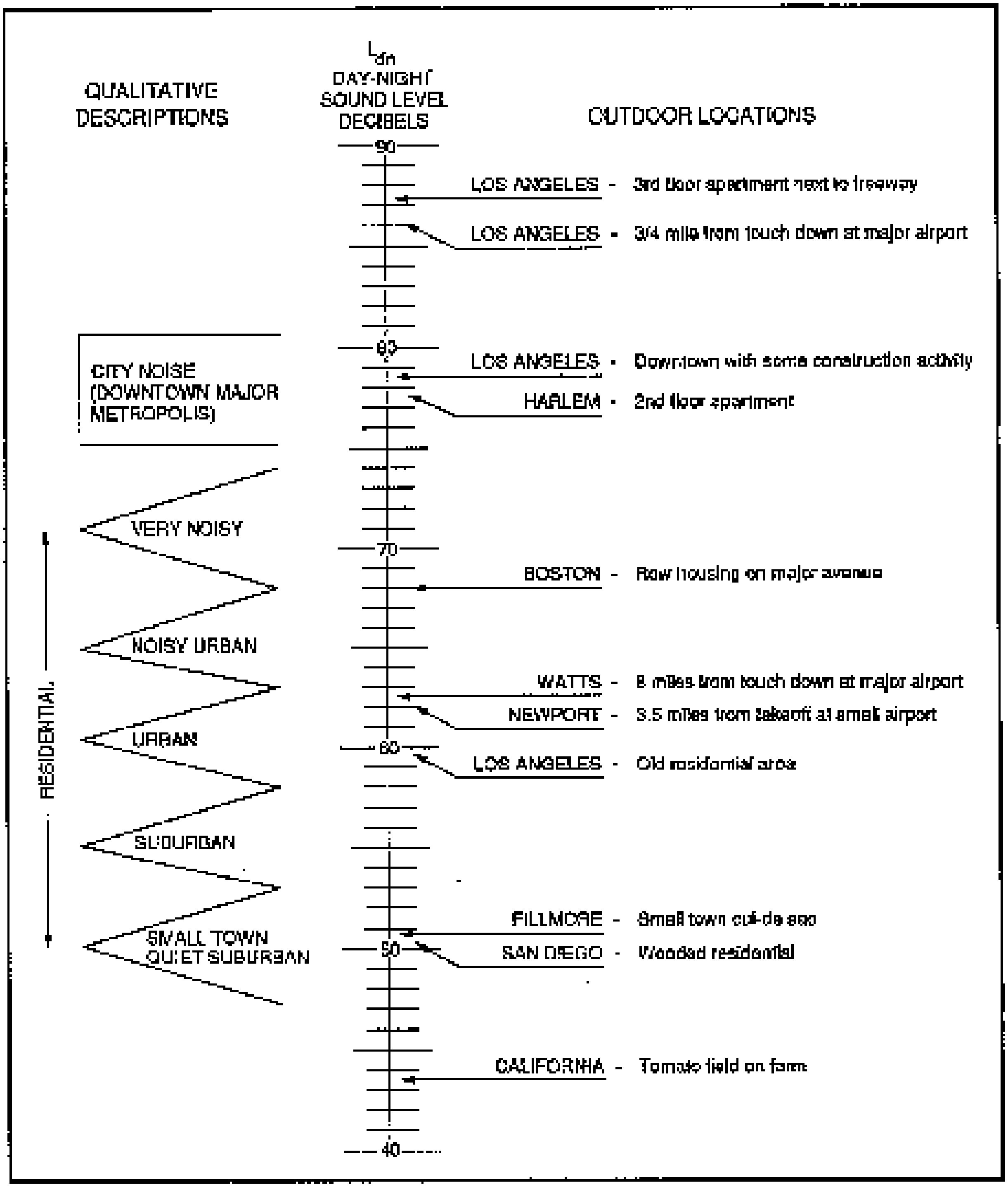
$L_n = L_{eq}$ *for nighttime (2200 hours to 0700 hours)*

The equivalent steady sound level (L_{eq}) measures sound over a discrete time period.

Noise naturally dissipates as it travels through the air in a process known as atmospheric attenuation. Additional attenuation occurs based on the ground surface, foliage, hills, and humidity of the area. For the purposes of this analysis, however, only atmospheric attenuation is considered. For this reason, all noise levels discussed in this section and in Chapters 5 and 7 represent worst-case scenarios that are unlikely to occur at the proposed sites.

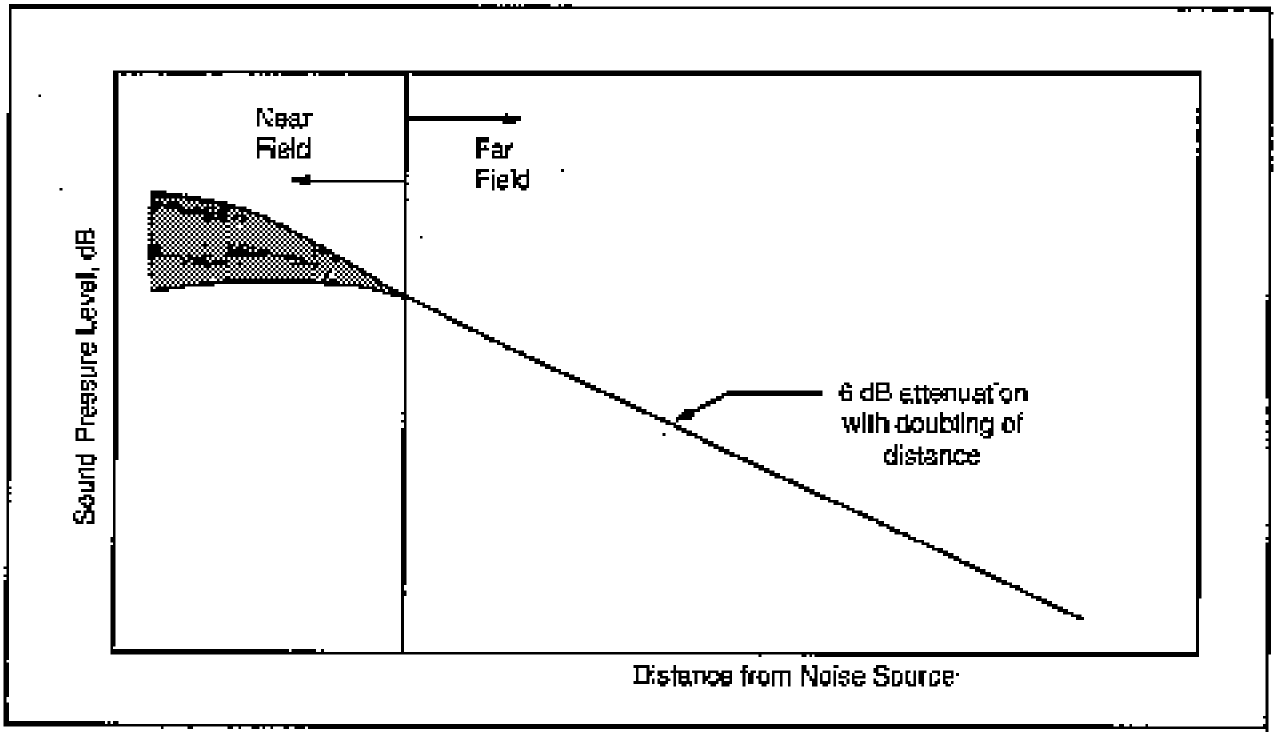
In the far field (i.e., beyond a distance of one wavelength from the noise source) sound pressure levels attenuate in a linear fashion according to the inverse square law. For each doubling of the distance from the source, the noise level can be expected to decrease by roughly six dBA. Although this is not the most accurate method for calculating noise attenuation (i.e., it tends to over estimate noise levels), it provides a conservative estimate suited to the purposes of an environmental impact analysis.[1] This method is used to measure noise attenuation in Chapters 5 and 7. Figure H.1-2 illustrates this approach.

Figure H.1-1
Examples of Outdoor Day-Night Sound Level in Decibels
Measured at Various Locations



Source: Information on Levels of Environmental Noise Requisite to Protect Public Health and Welfare with an Adequate Margin of Safety, U.S. EPA, 550/9-74-004, March 1974.

Figure H.1-2
Illustration of Atmospheric Attenuation



Source: Albert Thumann and Richard K. Miller. *Secrets of Noise Control*, 2nd ed. Williams, Kent C. Ed. *Fairmont Press*: Atlanta, Georgia, 1976.

H.2 Noise Impact Zones and Noise Sources

Impacts of construction were estimated considering the following construction activities:

- **Drilling New Cavity Entrances.** Conventional oil well drilling rigs are used to construct new cavern entry wells. During construction of existing sites, four large drills have operated simultaneously. The L_{eq} contribution of this construction activity is estimated to be 67 dBA at 500 feet. The L_{dn} value, assuming 24-hour drilling, is approximately 73 dBA. Development of each new cavern well would require 60 to 90 days of drilling.[2] The maximum number of days during which drilling might occur in the Seaway Complex is 225 days, based on the construction of ten 10-MMB caverns. In the Capline Complex, a maximum of 360 days of drilling could occur based on the construction of up to sixteen 10-MMB caverns.

- **Leaching of Caverns and Raw Water Intake.** Leaching of caverns is accomplished by pumping raw water into the drilled cavern well. The primary noise source of this activity is the raw water pump. Maximum sound levels near the pumphouse are in the 90 to 100 dBA range; average levels are considerably lower. The increase in sound over ambient levels is negligible at a distance of 500 feet because of the attenuation caused by the wall at the pumphouse.

- **Construction of Support Facilities.** For an existing site support facility construction would be relatively minor. For new sites, however, DOE will have to construct support facilities such as the main pump building, warehouses, laboratory, offices, surge ponds, and oil tanks. Access roads and on-site piping would also be constructed. The L_{eq} contribution of this activity at 500 feet is expected to be 68 dBA. See Table H.2-1, which lists noise levels for specific construction noise sources.

- **Pipeline Construction.** Three basic techniques are used for pipeline construction, including: 1) flotation canal; 2) push-ditch method; and 3) conventional dry method. The typical equipment and sound levels associated with each of these methods are summarized in Table H.2-2. The L_{eq} is conservatively estimated at 69 dBA at 500 feet for all pipeline construction activity.

- **Road Construction.** Road construction along the pipeline rights-of-way would include the use of two dump trucks and one bulldozer producing an L_{eq} of 68 dBA at 500 feet.[3] The specific sound levels and usage factors for the construction equipment is summarized in Table H.2-3.

Overall sound levels from the construction activities discussed above are presented in Table H.2-4.

Table H.2-1
Equipment Sound Levels Due to Construction of Support Facilities

Equipment	Sound Level (dBA†) at 50 feet	Usage Factor for Construction Phase*				
		Clearing	Excavation	Foundation	Erection	Finishing
Air Compressor	81	-	1.0	.04	0.4	0.4
Backhoe	85	0.04	0.16	0.4	--	0.04
Concrete Mixer	85	--	--	0.4	0.16	0.16
Concrete Pump	82	--	--	0.05	0.16	0.08
Concrete Vibrator	76	--	--	0.2	0.1	0.04
Crane, Derrick	88		--	--	0.01	0.02
Crane, Mobile	83	--	--	--	0.08	0.04
Dozer	87	0.2	0.4	--	--	0.04
Generator	78	0.4	0.4	--	--	--
Grader	85	.005	--	--	--	0.02
Paving Grader	88	-	0.1	0.04	0.04	0.04
Loader	84	0.16	0.4	--	--	0.04
Paver	89	--	--	--	--	0.12
Pile Driver	101	--	--	0.04	--	-
Pneumatic Tool	85	--	--	0.04	0.1	0.04
Pump	76	--	0.4	1.0	0.4	--
Rock Drill	98	--	0.02	--	--	0.003
Roller	80	--	--	--	--	0.1
Saw	78	--	--	0.04	0.1	--
Scraper	88	0.14	--	--	--	0.08
Shovel	82	--	0.4	--	--	0.06
Truck	88	0.16	0.26	--	-	0.16

* Fraction of time equipment is in its noisiest mode.
† A-weighted sound level; sound measurement that simulates noise as perceived by the human ear.
Source: *Background Document for Proposed Portable Air Compressor Noise Emission Regulations*, U.S. Environmental Protection Agency, EPA-550 90 9 74-016 (October 1974).

Table H.2-2
Noise Created by Pipeline Construction Equipment

Equipment	Number	dBA[1] at 50 Feet	dBA at 500 feet	Usage Factor[2]	L_{eq} at 500 feet
Dry Land Method					
Truck	2	85	65	0.16	
Backhoe	1	85	65	0.4	
Concrete Mixer	1	85	65	0.16	
Welding Machine	1	83*	63	0.15*	
Scraper	1	88	68	0.08	
Crane	3	83	63	1.0	
					68
Push-Ditch Method					
Backhoe	1	85	65	0.4	
Dragline	1	80	60	1.0	
Dozer	2	87	67	0.4	
Diesel Winch	1	85	65	0.4	
Marsh Buggy	1	78	58	0.5	
Welding Machine	1	83	63	0.5*	
					69
Flotation Canal Method					
Dredge	1	65	45	1.0	
Barge	5	63	45	1.0	
Boats	5	63	45	1.0	
Welding Machine	1	83*	63	0.5*	
					64

[1] A-weighted sound level; sound measurement that simulates noise as perceived by the human ear.
[2] Fraction of time equipment is in its noisiest mode.
* Estimated.
Source: U.S. Environmental Protection Agency, 1974.

Table II.2-3
Noise Created by Pipeline Access Road Construction

Equipment	Number	dBA† at 50 Feet	dBA at 500 Feet	Usage Factor*
Truck	2	88	68	0.4
Bulldozer	1	87	67	0.4

† A-weighted sound level; sound measurement that simulates noise as perceived by the human ear.
* Fraction of time equipment is in its noisiest mode.
Source: U.S. Environmental Protection Agency, 1974.

Table II.2-4
Summary of Construction Activity Noise Levels Contributions at 500 Feet

		Sound Level, dBA	
Activity	L_{eq} [1]	L_d [2]	L_n [3]
Drilling Shafts	67	67	67
Support Facilities Construction	65	66	–
Pipeline Construction	60	67	–
Access Roadway Construction	68	66	–

[1] Equivalent steady sound level that provides an equal amount of acoustic energy as the time-varying sound.
[2] Equivalent sound level, L_{eq}, for the daytime period (0700 to 2200) only.
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APPENDIX I

ENVIRONMENTAL IMPACTS OF HISTORICAL BRINE DISCHARGE IN THE GULF OF MEXICO

I.1 Introduction

Oil at all of the existing SPR sites is stored in underground salt domes. At some sites, DOE has used pre-developed salt caverns, and at others, DOE has developed new caverns by solution-mining subterranean salt deposits. During this solution-mining or "leaching" process, raw water is circulated through the salt formation to dissolve the salt and create a cavern. The creation of one barrel of storage space requires the introduction of seven barrels of raw water and the subsequent disposal of an equal volume of brine.

When leaching is complete, crude oil is pumped into the newly formed caverns, displacing the remaining brine to the surface. In the case of a national energy emergency, oil will be withdrawn from the caverns by displacement with raw water according to SPR program requirements. Once the national energy emergency has been solved, a second cycle of cavern fill would be initiated, again requiring disposal of cavern-sized volumes of brine.

After brine is displaced to the surface, it is routed to an anhydrite settling pond for the removal of suspended solids before it is disposed. Traditionally, DOE has used two methods to dispose of brine: discharge to the Gulf of Mexico and underground injection. The vast majority (94 percent) of the brine generated by the SPR in 1990 was discharged to the Gulf, while the remaining six percent was injected underground. To date, all of the brine that has been discharged to the Gulf originated from three sites, Bryan Mound and Big Hill in Texas, and West Hackberry in Louisiana. Table I.1-1 estimates the brine volumes generated by the creation of the caverns, initial fill, and one refill at these sites.

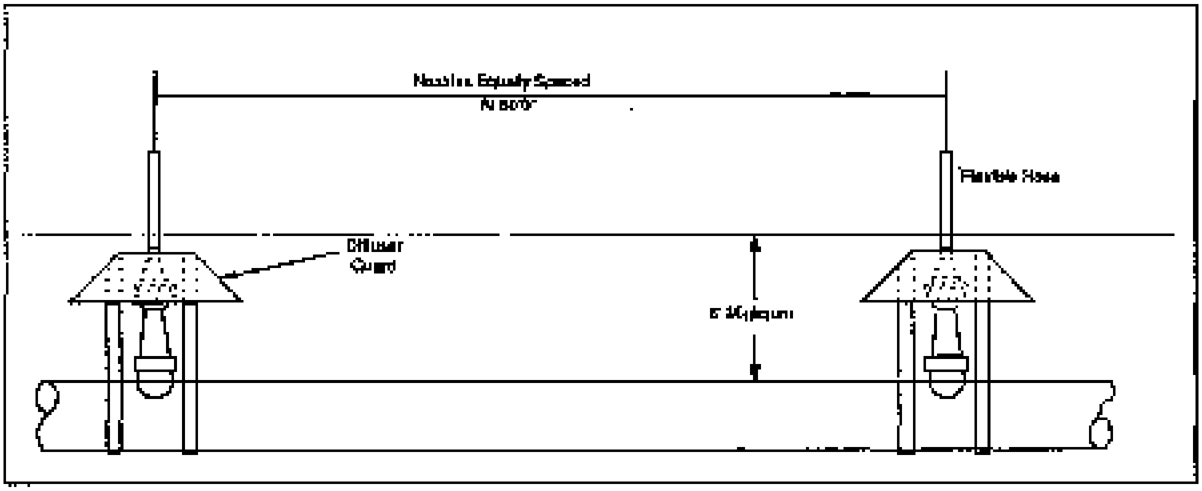
Table I.1-1
Brine Volume (MMB) At SPR Sites Historically Discharging to the Gulf

Site & Storage Capacity	Leach	Initial Fill	Refill	Total
Bryan Mound - 226	1,600	226	226	2,050
West Hackberry - 219	1,533	219	219	1,970
Big Hill - 60	1,120	160	160	1,440

When discharged to the Gulf, brine is transported through an underground pipeline to a "diffuser" located offshore. For Bryan Mound, West Hackberry, and Big Hill, the diffuser is located 20, 11.2, and 6.3 kilometers (12, 6.9, and 3.8 miles) offshore, respectively. As shown in Figure I.1-1, a diffuser is a continuation of the brine pipeline with a series of vertical ports spaced 18 meters apart. The vertical orientation and spacing of the ports are intended to promote brine diffusion. When brine is discharged through the ports, it is initially diluted by means of jet mixing.

Since the brine (about 250 ppt salinity) is more dense than the receiving waters (about 30 ppt salinity), it falls to the bottom and spreads over the sea floor. It is then further diluted and carried away by the natural ocean bottom currents and turbulent diffusion.

Figure I.1-1
Diffuser Head Showing Typical Nozzle and Diffuser Guard



Source: Phase III; Development EIS, U.S. DOE; October 1981

This appendix analyzes the environmental impacts of past brine disposal in the Gulf of Mexico from Bryan Mound, West Hackberry, and Big Hill. For each of these sites, the appendix describes the existing disposal system and discharge practices to date. Available monitoring data for each site are summarized and conclusions are drawn regarding environmental impacts.

I.2 Bryan Mound

I.2.1 Existing Discharge System

Brine from Bryan Mound is discharged through a 0.9-meter diameter pipeline to a point almost 20 kilometers off the Freeport, Texas coast (28° 44' N and 95° 14.5' W) in 22 meters of water. The last 933 meters of the pipeline is a diffuser consisting of 52 diffuser ports that extend vertically 1.2 meters above the bottom. These ports are 7.6 centimeters in diameter and placed in 18-meter intervals.

Discharge from the site is regulated under the jurisdiction of the U.S. Environmental Protection Agency's (EPA's) National Pollutant Discharge Elimination System (NPDES) and a Texas Water Commission (TWC) permit. While the TWC permit does not include every NPDES requirement, each of its requirements correspond to those of the NPDES permit. These permits specify several maximum constituent concentrations, three discharge limits (i.e., rate of discharge, nozzle exit velocity, and oxygen scavenger[a] concentration), and required frequencies of measurement for each limit. The concentration and discharge limits are listed below in Table I.2-1. When an oxygen scavenger is used, the concentration can be no greater than 10 ppm NH_4HSO_3/ppm dissolved oxygen (DO) or 18 ppm K_2SO_3/ppm DO. A detectable level of DO must remain in the pipeline at all times.

Table I.2-1
Bryan Mound NPDES Permit Requirements

Parameter	Compliance Range
Flow	≤ 1.1 million bbl/day
Velocity	> 6.1 m/s
Oil and Grease	≤ 15 mg/ℓ
TDS	report only
TSS	report only
pH	6.0 - 9.0

Source: 1990 Annual Site Environmental Report, U.S. Strategic Petroleum Reserve, Boeing Petroleum Service, Inc., June 1991.

The NPDES permit also specifies the minimum required daily discharge rates corresponding to given numbers of open diffuser nozzles to maintain at least a 6.1 m/s exit velocity. In addition, to assure brine pipeline integrity, the NPDES permit requires a plan for hydrostatically testing the pipeline to be submitted for approval 90 days after the permit's effective date. Finally, the NPDES permit calls for the installation of an approved leak detection system that monitors the flow of brine into the pipeline and out of the first operating diffuser nozzle.

I.2.2 Discharge Practices to Date

Brine discharge to the Gulf of Mexico from Bryan Mound began in March 1980 and was still continuing at the time of this writing. Since cavern leaching ceased in 1986, the rate of discharge has leveled off substantially. Table I.2-2 summarizes, for different time periods throughout this history of discharge, the number of ports that have been open, the daily brine discharge rate, and the brine salinity.

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[a] Brine additive used to regulate the level of oxygen in the brine before it is discharged from the brine pond to the pipeline. The level of oxygen is lowered to prevent oxidation or rusting of the pipeline.

Table I.2-2
Brine Discharge History at Bryan Mound

TIME PERIOD	# PORTS OPEN	DISCHARGE RATE (MMB/DAY)	BRINE SALINITY (PPT)
March-June 1980[1]	15	0.23	240
July-August 1980[1]	31	0.5	<160->200
Sept. 1980-July 1981[1]	31	0.6-0.68	240-250
August-December 1981[1]	34	0.75	240-250
January 1982-Nov. 1983[2]	55	1	240-250
Dec. 1983-Sept. 1984[3]	NA	0.65-1	230-263
Oct. 1984-Dec. 1987[3]	55	0.65-1	230-263
January 1988-March 1989[3]	55	<0.1->0.4	260-270
April 1989-December 1990[3]	55	<0.1	260-270

[1] Source: Hann, Giammona, and Randall, 1985.
[2] Source: SPR Program Management Office Estimates, 1991.
[3] Source: FEIS, Texoma Group Salt Domes, 1978.

During the first four months of operation, the brine was discharged continuously through 15 ports for approximately 10 to 16 hours per day. In mid-July 1980, 16 additional ports were opened, bringing the total of open diffuser ports to 31. New caverns were being leached at this time, causing the salinity to be less than 160 ppt, and continuous discharge was maintained for approximately 20 hours per day. In August 1981, discharge operations were shut down for pipeline maintenance and three additional ports were opened. Eventually, the daily discharge rate reached nearly 1 million barrels, which was maintained until December 1983 when the diffuser was shut down for two weeks. Discharge began again near the end of December.

When cavern development was completed in June 1987, the rate of brine discharge leveled off significantly and discharge occurred irregularly. After cavern development, cavern creep (i.e., a slow advancement of cavern walls resulting in a relatively slight reduction in cavern volume) is the only source of brine generation, resulting in the displacement of brine remaining in the cavern. From January 1988 to the start of 1989, low volumes of brine were discharged intermittently. The rate of discharge ranged from below 0.1 to more than 0.4 million barrels per day and was usually continuous 10 to 16 hours at a time, although sometimes lasting longer and shorter periods. From April 1989 and through 1990, brine discharge became less frequent -- sometimes occurring not more than once a month. The discharge rate was usually less than 0.1 million barrels per day and was maintained for less than 10 hours at a time.

From 1984 through 1990, brine discharge had six instances of noncompliance with the NPDES permit. Three of these instances were due to a failure to meet the required measurement frequency called for by the permit (i.e., a failure to take a sample). Two instances of noncompliance were due to an exceedance of the oil and grease limit and an exit velocity that was too low. The sixth noncompliance was not explained.

I.2.3 Observed Environmental Impacts

Texas A&M University conducted five studies that monitored environmental impacts associated with brine discharge at Bryan Mound (Hann & Randall, 1981,[1] 1982,[2] 1983;[3] Hann, Giammona, & Randall, 1984a,[4] and 1985).[5] Collectively, these studies account for the first 3.5 years of brine disposal from March 1980 to August 1984. Each study involved field investigation and measurement and estimated:

- The areal extent, vertical extent, and above ambient salinity of the brine plume using monthly measurements of the brine plume;
- The effect of brine discharge on water and sediment quality in the vicinity of the diffuser site, using the analyses of quarterly samples from 14 stations collected in conformance with the American Public Health Association's and EPA's sampling protocols; and
- The effect of brine discharge on the benthic and nekton communities in the diffuser site area based on quarterly sampling cruises at 17 stations.

Unless otherwise noted, the remainder of this section summarizes monitoring results from the two most recent Bryan Mound postdisposal studies.[6] These two studies together cover the two-year period from September 1982 through August 1984.

I.2.3.1 Extent of Brine Plume

From the initiation of brine discharge in March 1980 to August 1984, the maximum areal extent of the +1 ppt contour (i.e., the area with a salinity that is 1 ppt above the baseline) was 50.4 km^2. The longest distance to the +1 ppt contour line was 7.5 kilometers. The highest measured above ambient salinity contour (+6 ppt) was observed in April and November in 1981; its areal extent during these two months was 0.04 and 0.1 km^2, respectively. The highest measured salinity was 41.6 ppt, which was 6 ppt above the ambient salinity of 35.6 ppt located near the diffuser. The highest measured vertical extent of the brine plume was 4 meters. The largest areal extent within the +1, +2, +3, +4, +5, and +6 ppt above salinity contours was 50.4 km^2, 24.5 km^2, 9.3 km^2, 5.6 km^2, 1.2 km^2, and 0.1 km^2, respectively.

I.2.3.2 Water and Sediment Quality

Water quality and sediment samples were collected quarterly at 12 offshore stations (e.g., three control stations, five diffuser stations, and four stations located 0.8 km from the diffuser). Water samples were collected at three depths (surface, mid-depth, and bottom). The routine water and sediment quality parameters that were analyzed included salinity (or TDS for sediment pore water), temperature, pH, oil and grease, dissolved bulk ions (calcium (Ca^{++}), magnesium

(Mg^{++}), sodium (Na^{+}), potassium (K^{+}), chloride (Cl^{-}), and sulfate (SO_4^{--})), high molecular weight hydrocarbons, dissolved heavy metals (cadmium (Cd), chromium (Cr), copper (Cu), mercury (Hg), zinc (Zn), lead (Pb), iron (Fe), and nickel (Ni)), and ion ratios (Ca/Mg, Na/K, and SO_4/Cl). The sediment quality parameters also included the redox potential (E_h), a partial determinant of metal solubility in sediments, and major ions (Ca^{++}, Mg^{++}, Na^{+}, K^{+}, Cl^{-}, and SO_4^{--}) in sediment pore waters. Changes in the E_h of the sediments as a result of hypoxia or near hypoxia could lead to increased solubilization of metals in sediment pore waters during the year. In addition to the routine water and sediment sampling, samples for the determination of high molecular weight hydrocarbons were collected occasionally to determine the potential of petroleum contamination. At one diffuser station, samples were collected semi-annually from surface and bottom water and from sediment. Key findings of the monitoring studies are summarized below.

Water Sampling. The quarterly water quality data show insignificant increases in salinity (see above plume analysis), as well as insignificant increases in sodium and chloride concentrations in the bottom waters. These increases in ion levels had little if any effect on the ion ratios. The greatest observed differences between ion ratios of ambient seawater and seawater in the diffuser area were: Na/K, 8.6 percent; Ca/Mg, 10.1 percent; SO_4/Cl, 10.2 percent. During the first 3.5 years of brine disposal at Bryan Mound, metal levels at the diffuser area were essentially the same, if not lower than, the levels outside the diffuser area. As shown in Table I.2-3 below, the observed metal levels were also below the acute EPA ambient water quality criteria in every case, with the exception of mercury and copper.

Table I.2-3
Range of Seawater Metal Levels at Bryan Mound

Metals	Observed Concentration (µg/ℓ)		EPA Criteria (µg/ℓ) for Marine Aquatic Life[1]	
	Diffuser Area	Control Station	Acute	Chronic
Cd	<0.1 - 3.5	<1 - 8	43	9.3
Cr	<1 - 7	<1 - 8	1100	50
Cu	<0.5 - 12.3	<0.2 - 9.5	2.9	2.9
Fe	<1 - 58	1 - 21	–	–
Hg	<0.1 - 0.7(4)[2]	<0.1 - 0.4	2.1	0.025
Ni	<1 - 11	<1 - 11	75	8.3
Pb	<1 - 6	<1 - 11	140[3]	5.6[3]
Zn	<1 43(87)[2]	<1 - 73	96	86

[1] EPA ambient water quality criteria of 1980.
[2] Value in parenthesis represents a single value above listed range.
[3] No criteria listed at the time of the study. Values presented are the current EPA criteria for marine life.
Source: Carr, Chamberlain, and Randall; DOE, 1981.

The water in the Bryan Mound diffuser area does not appear to be petroleum contaminated. Surface seawater hydrocarbon concentrations ranged from 1.6 to 0.4 $\mu g/\ell$ and near-bottom seawater hydrocarbon concentrations ranged from 0.13 to 0.57 $\mu g/\ell$. The two unnatural (i.e., of petroleum origin) hydrocarbons detected, phenanthrene and methyl phenanthrene, appeared below trace levels (one nanogram/liter).

Sediment Sampling. The quarterly sediment quality data collected from the field studies showed significant increases in sodium and chloride concentrations were observed in sediment pore waters near the diffuser (six to nine percent). However, overall, these increases did not produce significant changes in the ion ratios in sediment pore waters. The greatest observed differences between ion ratios in sediment at control stations and in sediment at the diffuser were: Na/K, 17.1 percent; Ca/Mg, 12.3 percent; SO_4/Cl, 21.1 percent.

There was no clear relationship between brine discharge and elevated metal levels present near the diffuser because the ambient metal levels observed at control stations were similar to those observed at the diffuser (see Table I.2-4). When monitoring results suggested that metal accumulation was occurring near the diffuser as a result of brine discharge, they also suggested that the levels would return to normal once the source was removed. For instance, during the first year of brine discharge (1980 to 1981) the greatest elevation of nickel in the brine was observed. When the discharge levels diminished, nickel concentrations in the diffuser area sediments also decreased. During other single year periods, lead and cadmium levels near the diffuser increased above the ambient levels of these metals (although mean lead levels for the diffuser exceeded control values only twice in this year). It was suspected that this increase was related to brine discharge since lead and cadmium concentrations were higher in the brine than in the Gulf waters. During subsequent years, however, no differences were observed between the rate of increase of lead and cadmium levels in the diffuser area and the rate at control stations.

Table I.2-4
Mean Sediment Metal Levels at Bryan Mound

Metals	Observed Concentrations ($\mu g/g$)	
	Diffuser Area	Control Stations
Cd	0.02	0.02
Cr	2.5	2.9
Cu	1.9	2.3
Fe	3,511	3,959
Hg	0.05	0.06
Ni	2.1	2.6
Pb	7.7	8.5
Zn	18.8	20.0

Source: Hann, Giammona, and Randall; 1984 and 1985.

In the most recent monitoring study completed in 1985, analysis of soluble metals in the sediment pore waters indicated that nickel, copper, and lead exceeded EPA's chronic ambient water quality criteria for aquatic organisms. Of 20 samples, nickel exceeded EPA's chronic ambient water quality criteria eight times. These exceedances occurred in samples collected at four (of five) sampling stations on the two most recent sampling dates (November 7, 1983; February 16, 1984). The average concentration for these eight samples is 21.4 µg/ℓ. Copper concentrations exceeded the chronic ambient water quality criteria twice; both exceedances occurring in samples collected at two different sampling stations on the same date. The levels in samples collected at these stations were below the chronic ambient water quality criteria on the two subsequent sampling dates. Exceedances for lead occurred in one sample, as shown in Table I.2-5. Overall, the levels of soluble heavy metals in the vicinity of the diffuser were similar to those at control stations.

Table I.2-5
Ranges of Metal Levels in Sediment Pore Water at Bryan Mound

Metals	Observed Concentrations (µg/ℓ)		EPA Criteria (µg/ℓ) for Marine Aquatic Life[1]	
	Diffuser Area	Control Station	Acute	Chronic
Cd	<0.1 - 0.2	<0.1 - 0.6	43	9.3
Cr	<1 - 32	<1 - 62	1100	50
Cu	0.9 - 3.4(4.3)[2]	0.4 - 2.3	2.9	2.9
Fe	7 - 8300	11 - 8000	–	–
Ni	1.8 - 26	0.5 - 26	75	8.3
Pb	<0.5 - 2(16)[2]	<0.5 - 0.6	140[3]	5.6[3]
Zn	<0.5 - 14	1.7 - 11.2	96	86

[1] EPA criteria as of 1987.
[2] Value in parenthesis represents a single value above listed range.
[3] No criteria listed at the time of study. Values presented are the current EPA criteria for marine life.
Source: Hann, Giammona, and Randall, 1985.

From February 1983 to August 1984 (1.5 years), hydrocarbon concentrations in brine ranged from 8.0 to 10.6 µg/ℓ, most of which was determined to be of petroleum origin. The highest hydrocarbon content was detected in August 1983. The hydrocarbon concentration of sediment in February 1983, August 1983, February 1984, and August 1984 (all of the times sediment samples were analyzed for hydrocarbons) were 0.48, 13.0, 3.0, and 6.0 µg/g dry weight, respectively. With the exception of August 1983, no hydrocarbons of petroleum origin were detected. The concentration in sediment in August 1983 was unusually high as the level of hydrocarbons at this station was usually less than 1.0 µg/g dry weight. It appeared that this oil originated from the Bryan Mound brine pit since testing showed that these hydrocarbons were of petroleum origin. By February 1984, 90 percent of the petroleum contamination from six months before had degraded. Although hydrocarbon levels at this station continued to be higher than normal in August 1984, analyses suggest that the hydrocarbon contaminants were not of petroleum origin and, therefore, were not petroleum contaminated.

I.2.3.3 Impacts on the Biological Community

Benthos. Benthic studies consisted of two years of quarterly samples collected from 26 stations, including 11 samples collected after the diffuser flow rate was increased to one million barrels per day. Analyses indicated that there was no significant difference in diversities observed within any distance "rings" around the diffuser (e.g., 200, 500, 1000, 2000, and 4000 meters or greater). Also, species composition at the diffuser and control stations were similar. A total of 104 different species were found at diffuser stations and 115 species were found at control stations. When the ten dominant species of each station group were compared, six species were common to both diffuser and control stations.

However, the overall data show that the total abundances were depressed 200 meters around the diffuser and that an enhancement ring (i.e., an area with increased abundances that gradually decrease to ambient conditions) of 500 to 1000 meters surrounds the diffuser. Species distribution results showed that two species played a major role in providing differences in abundance levels between diffuser and control stations. Both *K. aequalis* and *Paraprionospio pinnata* showed levels of highest abundance around, but not at, the diffuser site.

Nekton. The nekton investigations show that brine disposal at Bryan Mound has resulted in no profound disruption to the overall nekton community of the diffuser area. The studies concluded that since the inception of brine disposal in 1980:

- No dramatic lethal effects on nekton have been observed during the studies;
- No sharp reductions in total biomass or species abundance occurred in relation to the brine plume;
- No clear or consistent relationship between brine plumes and nekton abundance, biomass, and diversity could be established; and
- Brine effects are a minor source of observed variations.

This low impact is attributed to several factors: the intrinsic dynamism of shrimp and fish populations; the negligible area covered by the brine plume in relation to areas occupied by nekton; and the fact that maximum observed brine salinities are below levels known to cause mortality or evoke avoidance responses in laboratory tests.

Although field data and analysis do not indicate a direct or consistent influence of brine disposal on shrimp and fish, it is conceivable that brine may indirectly impact some nekton species through its effects on the abundance or diversity of benthic organisms. Few dietary analyses have been conducted on nekton common to this diffuser site, but the morphology and epibenthic/demersal habits of some species suggest that they utilize benthos as a primary food source during part or all of their lives.

I.3 West Hackberry

I.3.1 Existing Discharge System

Brine from West Hackberry is discharged through a 91-centimeter diameter pipeline to a point approximately 11.2 kilometers offshore (29°39'52" N and 93°28'35" W) in 10 meters of water. The last 987.5 meters of the pipeline is a diffuser with 55 7.6-centimeter diameter ports. The ports are spaced 18.2 meters apart. The diffuser was designed to disperse 1.1 million barrels of brine per day at an exit velocity of 7.6 m/s.

Discharge from the site is controlled by an EPA NPDES permit (brine discharge from West Hackberry is not regulated by a Louisiana State permit). This permit specifies several maximum constituent concentrations, three discharge limits (i.e., rate of discharge, nozzle exit velocity, and oxygen scavenger concentration), and measurement frequency requirements. The concentration and discharge limits are listed in Table I.3-1 below. When an oxygen scavenger is used, the concentration can be no greater than 10 ppm NH_4HSO_3/ppm DO or 18 ppm K_2SO_3/ppm DO. A detectable level of DO must remain in the pipeline at all times.

Table I.3-1
West Hackberry Permit Requirements

Parameter	Compliance Range
Flow	≤ 1.07 million bbl/day
Velocity	> 7.6 m/s
Oil and Grease	≤ 15 mg/ℓ
TDS	report only
TSS	report only
pH	6.0 - 9.0
Dissolved Oxygen	detectable

Source: 1990 Annual Site Environmental Report, U.S. Strategic Petroleum Reserve, Boeing Petroleum Services, Inc., June 1991.

Just like the permit for brine discharge for Bryan Mound, the NPDES permit for West Hackberry also: specifies the minimum allowable daily discharge rates corresponding to given numbers of open diffuser nozzles based on the minimum 6.1 m/s exit velocity; requires a plan for hydrostatically testing the pipeline to be submitted for approval 90 days after the permit's effective date; and calls for the installation of an approved leak detection system that monitors the flow of brine into the pipeline and out of the first operating diffuser nozzle.

I.3.2 Discharge Practices to Date

The table below summarizes the West Hackberry discharge practices to date (Table I.3-2). Intermittent brine discharge began in May 1981 at approximately 50,000 barrels per day. During the first year of operation, the discharge rate and brine salinity varied significantly while the daily discharge duration was frequently less than 24 hours. The average daily discharge rate was 529,000 barrels and the average brine salinity was 216 ppt. From late August to mid-September 1981, no discharge occurred. Intermittent pumping, resulting in low discharge volumes, occurred during mid-September to mid-October 1981, and again during January 1982.

Table I.3-2
Brine Discharge History at West Hackberry

TIME PERIOD	# PORTS OPEN	DISCHARGE RATE (MMB/day)	BRINE SALINITY (ppt)
May 1981 - Feb. 1982	32	0.05-0.75	30-260
May 1982	32	0.75	240-263
March 1982	50	0.75	240-263
April 1982 - Oct. 1982	42	0.75	240-263
mid-Nov. 1982 - Nov. 1983	47	0.8-1.0	240-270
Dec. 1983 - Dec. 1987	55	0.8-1.0	240-270
January 1988 - July 1988	55	0.2-0.4	240
July 1988 - December 1988	55	0.2-0.3	260
January 1989 - Dec. 1990	55	>0.1	260

Source: Hann, Giammona, and Randall, 1984b.

During the first five months of the second year of operation, the brine discharge was more continuous and the brine salinities were consistently higher. In July 1982, the discharge rate of 750,000 barrels per day was maintained; however, the brine salinity was below 240 ppt and was as low as 181 ppt on July 30. From August to November 1982, the discharge rate remained near 750,000 barrels per day and the brine salinity increased to more than 240 ppt in October. The maximum discharge rate and maximum salinity occurred in May 1983 when brine was discharged at 1,013,500 barrels per day and the salinity increased to 270 ppt.

During the first nine months of 1988, the rate of discharge decreased to a rate of 200,000 to 400,000 barrels per day as cavern development was completed. Discharge was maintained for 24 hours per day and the brine salinity averaged 240 ppt. In October 1988, brine discharge became more intermittent. For example, in December, brine discharge only occurred on 9 days. The salinity remained close to 260 ppt and the rate of discharge averaged little more than 100,000 barrels a day. In 1990, this rate was maintained; however, discharge became less frequent and occurred less than 24 hours at a time.

From 1983 through 1990, brine discharge at West Hackberry had 24 incidents of permit noncompliance. Thirteen of these incidents were due to a failure to meet the required measurement frequency called for by the permit; five were attributed to a nondetectable or low dissolved oxygen content in brine (0.0, 0.1 mg/ℓ); two were caused by low pHs (5.8, 5.98); two were caused by low exit velocities (7.3, 7.5 m/s); and two were caused by excessive oil and grease contents (24, 150 mg/ℓ).

I.3.3 Observed Environmental Impacts

From the initiation of brine discharge in May 1981 to November 1983, two post-discharge studies were conducted for West Hackberry. The first study (DeRouen, 1982)[7] examined the environmental impact during the first 12 months of brine discharge from May 1981 through April 1982. The second study (Hann, Giammona, & Randall, 1984),[8] conducted by Texas A&M University, observed the results of brine discharge over the next 18-month period from May 1982 through November 1983. The purpose of these studies was:

- To determine and describe the areal extent, vertical extent, and above ambient salinity of the brine plume by conducting tracking surveys six times a year;

- To determine the effect of the brine discharge on the quality of the water and sediment in the vicinity of the diffuser by analyzing monthly and quarterly water samples collected at 14 offshore stations using methods and quality assurance procedures conforming to EPA standards;

- To determine what pollutants, if any, were being transferred to the offshore area from the Intracoastal Waterway (ICW) or from the salt cavern leaching process by analyzing eleven samples collected from four stations (at the raw water intake structure, brine pond, diffuser site, and control site); and

- To characterize the effect of the brine discharge on the biological (benthic, nekton, zooplankton, and phytoplankton) communities in the vicinity of the diffuser.

Unless otherwise noted, the following discussion summarizes monitoring results for the period May 1982 to November 1983 as reported in the most recent West Hackberry postdisposal study (Hann, Giammona, & Randall 1984b).[9]

I.3.3.1 Extent of Brine Plume

During the 30-month period from initial brine discharge in May 1981 until November 1983, the maximum areal extent of the +1 ppt contour was 40 km^2. The highest measured above ambient salinity contour was 11 ppt, which covered an area of 0.1 km^2. This maximum salinity increase occurred when discharge was below the minimum permitted exit velocity. The longest distance to the +1 ppt contour was 7.6 km from the diffuser, and the highest measured vertical extent of the brine plume was 2.7 meters. The mean predicted areal extent of the +1, +2, +3, and +4 ppt contours was 17.5, 8.6, 4.4, and 1.8 km^2, respectively.

I.3.3.2 Water and Sediment Quality

From May 1982 until October 1982, water and sediment samples were collected monthly from 14 sample stations and analyzed for temperature, salinity, dissolved oxygen, pH, oil and grease, silicate, turbidity, and nutrients (total phosphorus, phosphate, nitrate, nitrite, and ammonia). In addition to these monthly measurements, water and sediment samples were collected quarterly at each of the 14 stations for measurement of major ions (Ca^{++}, Mg^{++}, Na^{+}, K^{+}, Cl^{-}, and SO_4^{--}). Sediment analyses also included measurement of the redox potential (E_h) and measurement of major ions in sediment pore waters. After October 1982, only eight offshore stations were sampled and monthly turbidity and water nutrient analyses were discontinued.

Based on results obtained from May 1982 to November 1983, brine discharge had no adverse effects on these observed parameters. Monitoring indicated that slight increases in concentrations of some constituents were observable in areas near the diffuser, but as predicted in the site-specific EIS, levels of contamination were low and not likely to cause significant impacts. Key findings of the field studies are summarized below.

Water Sampling. Slight increases in salinity and ion concentrations (Na^{+}, Cl^{-}, K^{+}, Ca^{++}, SO_4^{--}) were observed in water near the diffuser. With the exception of December 1982, when diffuser stations had salinities three ppt over ambient, there was no significant difference between ambient surface water salinity and surface water salinity at the diffuser. Sampling at the diffuser showed that water salinity in the bottom waters reached as much as four ppt above ambient salinity. Insignificant patterns also were observed in major ion ratios (Na/K, Ca/Mg, and Cl/SO_4) in surface and bottom waters. Although the Na/K ratio at the diffuser was higher than the Na/K ratio at control stations 50 percent of the time, the change in ion ratios that appeared to be caused by brine discharge was within the natural range of variability. Dissolved oxygen values ranged from 0 to 11.6 mg/ℓ with the lowest values occurring in June 1982 when hypoxic conditions were observed. This hypoxic condition was sufficiently widespread to indicate that it was not a result of brine discharge. Furthermore, the dissolved oxygen values generally followed the natural seasonal trend.

Sediment Sampling. The highest above ambient salinities measured in pore water at the diffuser were two to three ppt. No buildup of salt in the upper three inches of surface sediments had been observed during the monitoring period. There were insignificant elevations in the Na/K and Ca/Mg ratios at the diffuser stations relative to control stations. Also, the natural variability of the Cl/SO_4 ratio was greater than the variability in the Cl/SO_4 apparently caused by brine discharge.

I.3.3.3 Water Pollutant Survey

In July and November of 1982, and April and October of 1983, sampling was conducted to determine if pollutants were being transferred offshore from cavern leaching or the raw water intake via the brine diffuser. Water and sediment samples were collected at the raw water intake structure, the diffuser site, and one control site; biota samples were collected at the diffuser site and control site; and water samples were collected at the brine pond. The water and sediment samples were analyzed for E_h, pH, major ions (Ca^{++}, Mg^{++}, Na^{+}, K^{+}, Cl^{-}, and SO_4^{--}), total metals (Cd, Cu, Cr, Fe, Hg, Mg, Pb, and Zn) and organics (silvex, parathion, hexachlorobenzene, PCBs, and high molecular weight hydrocarbons). The biota were analyzed only for the total metals and organics.

Water Sampling. A comparison of major ions at the diffuser and control station indicated no difference in the ion content of the water at the two stations. Table I.3-3 shows that there were also no essential differences between the metal content of water at the diffuser and that of water at the control station.

Table I.3-3
Seawater Metal Levels at West Hackberry

Metals	Observed Concentrations (µg/ℓ)[1]	
	Diffuser Site	Control Station
Cd	<0.2	<0.2
Cr	<0.5	<0.5
Cu	0.8	0.7
Fe	18	47
Hg	<0.2	<0.2
Mg	1,030,000	1,020,000
Pb	<1	<1
Zn	4.2	3.7

[1] Observations are based on sampling done in October 1983.
Source: Hann, Giammona, and Randall, 1984b.

The concentrations of total phthalic acid esters (0.008 - 0.019 µg/ℓ), PCBs (< 1.0 µg/ℓ), and hexachlorobenzene (0.2 µg/ℓ) detected in water near the diffuser fall within ranges reported at various other sites along the Gulf Coast. An insignificant level of petroleum contamination in water near the diffuser could be related to brine discharge. The water at the diffuser station contained a total of 1.90 µg/ℓ hydrocarbons of which low levels of phenanthrene (0.005 µg/ℓ) and methyl-phenanthrene (0.0065 µg/ℓ) were attributed to brine discharge. Although EPA has not established ambient water quality criteria for these two constituents, toxicity data reported in the literature for other polycyclic aromatic hydrocarbons (PAHs) indicate that the observed concentrations of phenanthrene and methyl-phenanthrene are well below the thresholds that may be harmful to saltwater organisms.[b]

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[b] Based on limited toxicological data, it appears that a PAH concentration of 15 µg/l may be acutely toxic to saltwater organisms (this value is based on the lowest reported acute LC_{50} multiplied by an assessment factor to account for interspecies variability and divided by 2 to reduce the effect level from 50 percent to few percent mortality). It appears that chronic exposures to PAH concentrations above 0.05 µg/l may cause deleterious sublethal responses.

Sediment Sampling. An approximate 10 percent elevation in Na^+, Cl^-, and Ca^{++} levels in sediment pore waters was observed. The table below (Table I.3-4) shows no essential difference between the metal content in sediment at the diffuser and control stations. Although lead was higher in the brine than in the raw leach water, the increased lead observed in the diffuser sediments at Bryan Mound were not discovered at West Hackberry in this study.

Table I.3-4
Sediment Metal Levels at West Hackberry

Metals	Observed Concentrations[c] (mg/kg)	
	Diffuser	Control Stations
Cd	0.21	0.47
Cr	17.1	27.8
Cu	11.7	16.5
Fe	9,964	17,000
Hg	0.066	0.058
Mg	5,820	9,120
Pb	16.3	19.5
Zn	59	88

[c] Observations are based on sampling done in October 1983.
Source: Hann, Giammona, and Randall, 1984b.

The concentrations of total phthalic acid esters (0.077 - 1.20 μg/kg), PCBs (3.0 μg/kg), and hexachlorobenzene (0.04 μg/kg) found in sediment at the diffuser fall within the range reported at various other sites along the Gulf Coast. The sediment at the diffuser showed no evidence of oil contamination.

Biota Sampling. Table I.3-5 compares the metal content of white shrimp (*Penaeus setiferus*) found at the diffuser site with that of white shrimp found at a control station. Cadmium, copper, lead, and mercury were present in organisms at higher levels (as much as 2.5 times higher) at the diffuser site than at control stations.

Table I.3-5
White Shrimp Metal Levels at West Hackberry

Metals	Observed Concentrations[a] (mg/kg)	
	Diffuser	Control Stations
Cd	0.005	0.002
Cr	0.05	0.06
Cu	4.6	3.4
Fe	19.4	19.8
Hg	0.03	<0.02
Mg	495	545
Pb	0.005	0.002
Zn	12.4	12.6

[a] Observations based on sampling done in October 1983.
Source: Hann, Giammona, and Randall, 1984b.

The concentrations of total phthalic acid esters in biota (0.019 - 0.92 μg/kg) fall within the range reported at various other sites along the Gulf Coast. The level of PCBs (<0.02 μg/kg) and hexachlorobenzene (<0.02 μg/kg) found in biota at the diffuser were below detection levels. The heavy hydrocarbons found in the biota appeared to be of natural origin since the mass spectra of the unsaturated fraction showed no aromatic hydrocarbons to be present in sampled organisms, and the distribution of saturated hydrocarbons were not typical of petroleum contamination.

I.3.3.4 Impacts on Biological Community

This section summarizes the findings of the most recent study of potential impacts to the benthic, nektonic, and planktonic communities by brine discharge at West Hackberry.

Benthos. A research group from McNeese State University conducted two initial benthic studies between May 1981 and May 1983. A Texas A&M University group assumed the benthic studies in May 1983 and continued them until November 1983. This section summarizes the results of the Texas A&M investigation using data gathered by both McNeese State University and Texas A&M from May 1982 to November 1983. According to this monitoring study, the unstable and highly variable environment of the benthos made the detection of brine effects on the benthic community very difficult. Essentially, no catastrophic brine-related effects were identified in the study. The primary adverse effect that could be correlated with brine discharge was a general decrease in abundance of dominant species around the diffuser. While this impact was not significant, the maximum impacted area for benthos was estimated to be 10 to 15 km^2.

The higher abundances at outer control stations was attributed to the presence of a few species (e.g., *Owenia fusiformis, Cirratulus hedgpethi*) in very large numbers. On the other hand, diversity was significantly higher at diffuser stations. The brine area had a greater abundance of rare species but in low numbers. The control stations, in contrast, had fewer numbers of rare species and few species in large numbers. The higher diversity in the diffuser area may be attributed to a noted increase in concentrations of bottom-feeding nekton near the diffuser.

Abundance and diversity data were compared to the salinity data at each station to determine the relationship between biological variations and the brine plume. The stations with salinities ranging between +4 to +6 ppt above ambient salinity had an insignificantly greater abundance than stations with other above ambient salinity ranges (+0-+2, +2-+4, and +6-+8 ppt). The stations with above ambient salinities in the +6-+8 ppt range had significantly greater diversity.

These effects could have implications for commercial fishing. The presence of nekton in the brine plume during feeding could depress the benthos community beyond "normal" constraints and recovery. In addition, the alteration of the benthic community could result in nekton species selecting other areas for feeding and reproductive activities.

Nekton. Nekton was assessed to determine the abundance, species composition, diversity, and distribution. An emphasis was placed on commercially and/or recreationally important nekters. Nekton was sampled in the diffuser area from May 1982 through September 1983. Eleven stations were sampled monthly from May 1982 through October 1982. Afterwards, seven stations were sampled in December 1982, March 1983, and monthly thereafter from June through September 1983. No dramatic lethal effects were identified during any of the sample cruises. Reductions in species abundance and total biomass could not be associated with the brine plume or diffuser.

Zooplankton. Investigations were conducted to determine if brine discharges could be associated with changes in the mortalities of these organisms. In the most recent study at West Hackberry, zooplankton data were collected at the diffuser site from May 1982 through September 1983. In this time period, nine stations were sampled monthly from May 1982 through October 1982, December 1982, February 1983, and monthly thereafter from June 1983 through September 1983. No dramatic lethal effects were identified during any of the sample cruises. However, further observations could not be made because of high data variability and a small sample size.

Phytoplankton. Studies were conducted to determine if there were brine-associated changes in phytoplankton biomass. Two phytoplankton studies have been conducted at the West Hackberry diffuser site; information presented here concerns data collected from May 1982 through April 1983. Phytoplankton was sampled from surface and bottom waters at seven locations in June, July, August, September, and November of 1983. The study notes that the high degree of spatial and temporal variation of the phytoplankton population makes the study and impact assessment of phytoplankton difficult. This natural variation almost precludes the correlation of phytoplankton variables to a point source discharge unless the impacts are very great. The study concludes that no effect to phytoplankton biomass could be attributed to the diffuser or brine.

I.4 Big Hill

I.4.1 Existing Discharge System

The brine from Big Hill is discharged through a diffuser located in 10 meters of water approximately 6.3 kilometers offshore. A 120-centimeter diameter pipeline carries the brine to a 1,335-meter diffuser comprised of 74 ports, each of which have a 25-centimeter diameter. The ports are spaced 18.2 meters apart.

Discharge from the site is controlled by an EPA NPDES permit and a Texas Water Commission (TWC) permit. While the TWC permit does not include every NPDES requirement, only the total suspended solids limit of the state permit differs from that of the NPDES permit. These permits specify several maximum constituent concentrations, three discharge limits, and the required measurement frequencies. The concentration and discharge limits are listed in Table I.4-1. When an oxygen scavenger is used, the concentration can be no greater than 10 ppm NH_4HSO_3/ppm DO or 18 ppm K_2SO_3/ppm DO. A detectable level of DO must remain in the pipeline at all times.

Table I.4-1
Big Hill Permit Requirements

Parameter	Compliance Range
Flow	$\leq$ 1.7 million bbl/day
Velocity	> 6.1 m/s
Oil and Grease	$\leq$ 15 mg/l
TDS	report only
TSS	< 40 mg/l (TWC only)
pH	6.0 - 9.0
Dissolved Oxygen	detectable

Source: *1990 Annual Site Environmental Report*, U.S. Strategic Petroleum Reserve, Boeing Petroleum Services, Inc., June 1991.

The NPDES permit also specifies the minimum allowable daily discharge rates corresponding to given numbers of open diffuser nozzles based on the minimum 6.1 m/s exit velocity. In addition, the NPDES permit addresses the assurance of brine pipeline integrity by requiring a plan for hydrostatically testing the pipeline to be submitted for approval within 90 days after the permit's effective date.

I.4.2 Discharge Practices To Date

The table below summarizes brine discharge at Big Hill from 1988 through 1990 (Table I.4-2). Generally, from 1988 to the end of 1990, brine discharge took place 24 hours per day. In January 1990, the rate of discharge averaged 570,000 barrels per day; the brine salinity averaged 190 ppt. The average discharge rate gradually increased to over 800,000 barrels per day and the brine salinity gradually increased to 200 ppt by March 1988. This rate was maintained until June when the average rate increased to nearly 1.3 million barrels per day and the brine salinity reached a salinity of 240 ppt. With occasional exceptions, this brine discharge was characteristic of the discharges through the rest of 1988, through 1989, and until the end of 1990. The diffuser was inactive for nine days in October 1989. In mid-May 1990, brine discharge decreased to 400,000 barrels per day for a period of 11 days, and at the end of May it decreased to 300,000. By mid-June, the discharge rate returned to 1.3 million barrels per day. In October 1990, the brine discharge rate decreased to 700,000 barrels per day which was maintained through the end of 1990. Cavern development at Big Hill was completed in August 1991.

Table I.4-2
Brine Discharge History at Big Hill

TIME PERIOD	# PORTS OPEN	DISCHARGE RATE (MMB/day)	BRINE SALINITY (ppt)
January 1988 - Feb. 1988	55	0.57	190
March 1988 - May 1988	55	0.8	200
June 1988 - Sept. 1990	55	1.3	240
October 1990 - Dec. 1990	55	0.7	250

Source: Offshore Brine Disposal Data, 1988, 1989, and 1990, Boeing Petroleum Services, Inc.

From 1987 through 1990, there were five permit violations at Big Hill. Three of these violations were due to lack of dissolved oxygen content in the brine; the remaining two were caused by a failure to meet the required measurement frequency called for by the permit.

I.4.3 Observed Environmental Impacts

Post-discharge data for Big Hill consists of two plume tracking studies conducted by Texas A&M University; water and sediment quality impacts and ecological impacts were not monitored. The first study was conducted over three days in August 1990, while the second was completed on two separate days in June and July 1991. In both studies, plume tracking was conducted in the bottom water of the Big Hill brine disposal area to measure the areal extent, depth, and relative temperature change of the +1 ppt above ambient salinity contour. The observed +1, +2, +3, and +4 above ambient salinity contours were plotted. Results from the first study were inconclusive since the diffuser was not operating during the first day of the survey. On the second day, the plume had detached itself from the diffuser and advected downcurrent to the southeast. On the third day, brine discharge was intermittent while the brine plume was much smaller in area. The highest bottom salinity observed during the study was 6 ppt above ambient salinity.

During the second study, the brine discharge rate was relatively steady at 500,000 barrels per day. This study consisted of two surveys, one in June and the other in July. In the June and July surveys, the highest salinities observed at the diffuser were 11 ppt and 5 ppt above ambient salinity (32 ppt), respectively. In the former case, ambient salinity levels were observed less than one mile away from the diffuser. In the latter case, ambient salinity levels were observed less than one-half mile from the diffuser.

Because above ambient salinity levels remain within one mile of the diffuser site, impacts associated with brine discharge should be limited to the immediate vicinity of the diffuser. While water quality and biological impacts of brine discharge were not monitored at Big Hill, brine discharge monitoring studies at Bryan Mound and West Hackberry (discussed above) suggest that brine discharge impacts at Big Hill are also isolated to the diffuser area.

1.5 Conclusions

Post-disposal studies at the Bryan Mound, West Hackberry, and Big Hill diffuser sites have generally shown that brine diffusion can produce relatively large above ambient brine salinity contours, but at relatively insignificant salinity levels. At Bryan Mound, the highest above ambient salinity contour of $^{+}6$ ppt was measured twice with areal extents of 0.04 and 0.1 km^2. The longest distance to the $^{+}1$ ppt contour line was 7.5 kilometers from the diffuser; the largest areal extent of the $^{+}1$ and $^{+}5$ ppt contours were 50.4 and 5.6 km^2, respectively. At West Hackberry, the brine plume salinity once reached a maximum $^{+}11$ ppt above ambient salinity which covered an area of 0.1 km^2. The longest distance to West Hackberry's $^{+}1$ ppt contour was 7.6 kilometers from the diffuser; the largest areal extent of the $^{+}1$ and $^{+}4$ ppt contours were 17.5 and 1.8 km^2, respectively.

Although the size of the above ambient salinity contours were relatively large, environmental monitoring at Bryan Mound and West Hackberry suggest that brine impacts to water and sediment are confined to the diffuser area and are not catastrophic. In fact, some impacts are likely to be restored soon after brine diffusion ceases.

<u>Bryan Mound.</u> Levels of metals and ion ratios detected in water and sediment near the diffuser were not noticeably different than those measured at control stations. In addition, the monitoring study did not find that brine disposal resulted in petroleum contamination. Although, overall levels of metals in sediment pore waters at the diffuser were similar to those at control stations, levels of nickel, copper, and lead did exceed EPA's chronic water quality criteria.

<u>West Hackberry</u>. Slight increases in salinity and ion concentrations were observed in water and sediment near the diffuser. No buildup of salt was observed in the upper 3 inches of surface sediments near the diffuser. Furthermore, the change in the water and sediment ion ratios that appeared to be caused by the brine were within their natural ranges of variability. There were also no significant differences between the metal content of water and sediment at the diffuser and of those at the control station. Petroleum contamination levels detected in water and sediment near the diffuser are within ranges reported at various other sites in the Gulf of Mexico. Bioassay results of white shrimp showed higher levels of copper, cadmium, lead, and mercury (of eight metals analyzed) in organisms at the diffuser than in those at control stations.

These water and sediment quality impacts translate to slight impacts to the biological community. Since brine tends to migrate to the sea floor, bottom dwelling organisms are likely to experience the greatest exposure to the brine. These studies, therefore, studied impacts to the benthic community. At both Bryan Mound and West Hackberry, a depression in the abundance of benthic creatures occurred within a range of 200 to 2100 meters from the diffuser area. However, this effect was accompanied by an increase in benthic diversity near the diffuser. Although the studies could not identify adverse impacts to the nekton and plankton communities, it is suspected that the decrease in benthic abundance could cause demersal nekton species to migrate to other feeding areas. This may or may not have implications for commercial fishing.

ENDNOTES

1. Hann, R.W., Jr. and R.E. Randall, eds, *Evaluation of Brine Disposal from the Bryan Mound Site of the Strategic Petroleum Reserve Program: Final Report of Twelve-Month Postdisposal Intensive Studies,* U.S. Department of Energy, 1981.

2. Hann, R.W., Jr. and R.E. Randall, eds. *Evaluation of Brine Disposal from the Bryan Mound Site of the Strategic Petroleum Reserve Program: Final Report of Eighteen-Month Postdisposal Intensive Studies,* U.S. Department of Energy, TX, 1982.

3. Hann, R.W., Jr. and R.E. Randall, eds, *Evaluation of Brine Disposal from the Bryan Mound Site of the Strategic Petroleum Reserve Program: Annual Report for September 1981 through August 1982,* U.S. Department of Energy, TX, 1983.

4. Hann, R.W., Jr., and C.P. Giammona and R.E. Randall, eds., *Offshore Oceanographic and Environmental Monitoring Services for the Strategic Petroleum Reserve: Annual Report for the Bryan Mound Site from September 1982 through August 1983,* U.S. Department of Energy, TX, December 1984.

5. Hann, R.W., Jr., and C.P. Giammona and R.E. Randall, eds., *Offshore Oceanographic and Environmental Monitoring Services for the Strategic Petroleum Reserve: Annual Report for the Bryan Mound Site from September 1983 through August 1984,* U.S. Department of Energy, TX, December 1985.

6. *Ibid.*

7. DeRouen, L.R., R.W. Hann, Jr., D.M. Casserly and C.P. Giammona, eds., *West Hackberry Brine Disposal Project Pre-Discharge Characterization: Final Report,* U.S. Department of Energy, 1982.

8. Hann, R.W., Jr., C.P. Giammona and R.E. Randall, eds., *Offshore Oceanographic and Environmental Monitoring Services for the Strategic Petroleum Reserve: Eighteen-month report for the West Hackberry Site from May 1982 through November 1983.* Texas A&M University and Research Foundation for U.S. Department of Energy, Strategic Petroleum Reserve Project Management Office, April 1984.

9. *Ibid.*

APPENDIX J

BASELINE CONDITIONS OF THE GULF OF MEXICO IN THE AREA OF THE PROPOSED STRATTON RIDGE BRINE DISPOSAL PIPELINE AND DIFFUSER

This appendix describes the baseline environmental conditions of the Gulf of Mexico brine disposal site. The information in this appendix was derived from existing data sources that cover the northern Gulf of Mexico in general. No new field investigations were conducted to collect detailed site-specific data for the proposed pipeline and diffuser locations, although the following description draws heavily on site-specific investigations for the Bryan Mound diffuser system.

J.1 Meteorology

Although brine diffusion is affected primarily by oceanographic bottom layer conditions (e.g., currents), wind stress at the ocean surface produces currents that could affect bottom layer conditions at the diffuser site. Data obtained at an offshore monitoring site located 28 miles southeast of Freeport (28°30'N and 95°01'W) from 1952 until 1971 show that the prevailing wind direction from January through June is southeast. The mean annual wind speed was 11 knots (12.7 mph). The highest average wind speed of 12.9 knots (14.8 mph) occurred in December when winds prevailed from the north; the lowest average wind speeds of 8.5 to 9.8 knots (9.8 to 11.3 mph) occurred from June through August. During July and August, the wind shifts to a more southerly direction and then easterly in September until late November.

The speed and direction of winds in the Texas coastal region vary more in December than in other months. The most persistent winds occurred between March and September. A 15-year record (1948-1963) of hourly wind data observed at Galveston, Texas shows that the frequency of occurrence of slack winds of less than or equal to five knots is not likely to last longer than twelve hours. More than half of the slack wind observations had a duration of less than five hours, indicating that these periods can often occur but in most cases they prevail for only a short time.

The fastest sustained (one-minute average) winds for each month over a 100-year period (1872-1971) ranged from 50 knots (58 mph) in December 1954 to an estimated 120 knots (138 mph) in September 1900. Between 1899 and 1971, there were 35 tropical storms in the Stratton Ridge area with winds exceeding 34 knots (39 mph) with 2.1 years between occurrences. Twenty-three of these storms were of hurricane intensity, with winds greater than 64 knots (74 mph) and with 3.2 years between occurrences. During Hurricane Camille, the most severe hurricane in recent history, winds reached an estimated 180 knots (202 mph).[1]

J.2 Physical Conditions

The following section summarizes the physical conditions of the Stratton Ridge coastal area, including nearshore features, sediments, water temperature and salinity, tides, waves, and currents.

J.2.1 Nearshore Features

The continental shelf along the Texas coast is a smooth, featureless, gently sloping plain. The width of the shelf off Texas varies from about 54 miles just north of the Rio Grande River and 86 miles off the Brazos River, to a maximum of 130 miles at the Texas-Louisiana border. The inner shelf has a very gentle gradient with the "shelf break" (i.e., the line with the greatest change in gradient) occurring at approximately 65 fathoms.[2]

Bathymetry at the proposed diffuser area shows that the region consists of a relatively smooth bottom and that bottom contours off Surfside Beach generally parallel the shore. The Gulf floor in the diffuser area is generally a hard sandy bottom surface. The proposed 3,300-foot diffuser would be located in depths ranging from 36 to 42 feet. Distances between bottom contours increase offshore. Typical distances from shore for the 20-foot, 30-foot, and 40-foot isobaths are 0.8, 2.3, and 3.8 miles, respectively. The bottom depths, two and five miles from the proposed diffuser site, are approximately 37 and 63 feet, respectively.

The most prominent nearshore features of the Stratton Ridge area include shallow bays, barrier islands, sand dunes, and relatively flat marshland that is dissected by man-made flood control structures. Texas bays are generally shallow and have relatively smooth shorelines. The width of the barrier islands are several hundred feet.

Oyster Creek and Drum Bay are environmentally sensitive areas lying near the diffuser area (see Figure 5-7). Drum Bay, 3.8 miles long and 1.1 miles wide, adjoins the lower portion of Christmas Bay and enters the Gulf of Mexico 3.8 miles north of the proposed diffuser location. Oyster Creek flows into the Freeport Harbor shipping channel and the ICW. Both Oyster Creek and Drum Bay lie onshore, more than 3.5 miles from the proposed diffuser location. In addition, the Freeport Harbor shipping channel lies approximately 4.5 miles southwest of the proposed diffuser site.

J.2.2 Sediments

Sediment character in the Gulf of Mexico is influenced by discharges from rivers in the area, particularly by the Mississippi and Brazos rivers. Sediments in the area are primarily sand to clayey sand with patches of sandy clay or silty sand. The banks in the western area of the Gulf of Mexico are more turbid and contain more sediments than the banks in the central area of the Gulf.[3]

Surficial sediments in the offshore area vary from loose, fine sand and silt nearshore to soft mud further offshore. The thickness of these sediments varies, ranging from 25 to 30 feet nearshore to less than two feet farther offshore where the water depth reaches 100 feet. There are areas where reworked glacial shorelines have resulted in shelly sand and silt as well as areas where nearshore sediments consist of barrier island sands overlying interbedded sand and silt-clay layers. Certain areas consist of sediments composed of firm clays underneath a thin layer of very soft silt, which can be shifted during a storm.[4]

Various sediment masses were deposited on the shelf during the alternating periods of post glacial activity, creating about half of the current bottom sediments as polymodal mixtures. Burrowing organisms and waves from storms have reworked and mixed these bottom sediments.

Shallow and deep shelf fauna frequently burrow in the sediment layers. Sand-sized forminara and echninoid fragments are contained in the outer shelf silty clays, and glauconite is frequently found in the relict basal sands in the outer shelf.[5]

During a 1983 study, it was noted that after a two-year decline, the redox potential increased at all the sampling stations, indicating that the sediments were being oxygenated. Hypoxic conditions returned in August of that year following the passage of Hurricane Alicia.

J.2.3 Water Temperature and Salinity

Surface water temperature and salinity are more sensitive to seasonal variations than bottom waters. A mass of dense water of higher salinity and temperature than coastal waters originating deep in the offshore Gulf, as well as freshwater inflows from river deltas, influence the local water temperature and salinity.[6] In the spring, continental runoff from rivers influences the surface salinity concentrations of estuarine and inner shelf waters. Dissolved oxygen values are high in November and low in March, ranging from four to nine mg/l. The effects of high temperature and salinity keep the oxygen levels low during the summer.[7]

Overall, water temperature and salinity follow an annual cycle. In late August or early September, throughout the upper 230 feet, temperatures are at a maximum of 82-90°F and at a minimum of 54-55°F in the late winter months. In January, February, and November, the top 65 feet undergo temperature inversions; bottom temperatures exhibit transient upwelling during the summer.[8]

Freshwater outflow from river runoff, such as runoff from the Mississippi River and the nearby Brazos River, reduce salinity levels in the late spring, decreasing the values to as low as 18 ppt over the inner shelf. The western Gulf is influenced by the runoff from the Mississippi River several months after its peak outflow. Freshwater flow in the western inner shelf follows a north-south trend characteristic of the entire Gulf of Mexico coastline. High levels of freshwater runoffs may cause vertical stratification in the fall and late spring.[9] Weak water density gradients occur except in December, when unseasonably strong stratification has been observed.[10]

J.2.4 Tides

The controlling dynamics of the tide in the western Gulf are not well understood. The predominant diurnal tide is thought to be caused by co-oscillation with the Atlantic.[11]

Tides at Freeport Harbor have a predicted range of 1.8 feet.[12] Near the diffuser site, tides have a vertical range of about three feet. Tidal velocity over the shelf (including the diffuser site) is approximately 0.5 knots, but increases several times near some bay entrances.[13]

J.2.5 Waves

The distribution of wave heights during the year closely follows wind velocity. Minimum wave heights occur during July and August, while maximum wave heights occur from December through February. Generally, wave heights increased from north to south along the coast and in a seaward direction for all months.[14]

Observational data from the National Climatic Data Center between 1884 and 1973 indicate that a median wave height average of 3.4 to 5.0 feet can be expected from November through May, and 1.5 to 3.4 feet from June through October.[15] These median heights, however, are biased because reporting ships tend to avoid areas with severe weather or high waves.[16]

J.2.6 Currents

The current characteristics described below are based on several studies performed in the late 1970's. These observations on currents are believed to be representative of the condition of shelf circulation today.

Current patterns are the most significant factor in determining disposal of brine. Wind stress, local runoff, and density stratification combine to shape the behavior of nearshore water. Wind-driven currents predominate in controlling nearshore circulation and beach drift, while density gradients and vertical mixing of brackish and fresh waters have a major effect on tidal passes and estuaries. Additionally, the Loop Current, a large clockwise current in the eastern Gulf, may occasionally extend into the coastal region of Louisiana and disrupt the normal local current pattern.

Current data were obtained and analyzed at sites southwest of the proposed diffuser location for Stratton Ridge. They were collected periodically during 1977 and 1978. These data indicate that the prevailing set of nearshore coastal currents vary seasonally. Bottom currents were predominantly westerly from February through May, and also during October. During July, August, November, and December the predominant bottom current direction was east. Approximately 15 percent of the time, the currents were northeast. The strongest currents were recorded in July (1.7 feet per second). Bottom current speeds measured in September through December were lowest in November (0.1 to 0.8 feet per second) and highest in September (0.3 to 1.4 feet per second).[17]

Results of a study conducted between October 1977 and October 1978 and performed northeast of the site also indicate that local currents were dominantly longshore to the west. Wind-forcing was often a dominant factor in driving local circulation.[18]

In the same study, over-the-side current measurements indicated that mean current speeds decreased with depth as expected, during October, November, and December. Measurements made in September showed that the mean bottom currents were faster than surface currents, although this was probably due to a recent storm.[19]

J.3 Chemical Conditions

The Texas-Louisiana shelf is one of the most heavily developed areas of offshore oil and gas drilling and production in the world. As a result, the chemical environment has undergone some important alterations that have been widely studied.[20]

The characteristics of the chemical factors in the nearshore Gulf of Mexico waters have been found to be highly dependent on the seasonal discharges of the Mississippi and Atchafalaya Rivers and the intrusion of deep marine waters. The upper water layers are generally highly influenced by the less saline, less dense riverine waters, while the bottom water layers are affected by the more saline, denser Gulf water. The seasonal changes in climatological conditions markedly affect the mixing and diffusion characteristics of these two water layers.[21]

Due to a lack of site-specific data, this summary of the chemical conditions at the proposed Stratton Ridge diffuser site focuses mainly on general chemical characteristics of the Texas-Louisiana coastal area. It includes sections on nutrients, trace metals, hydrocarbons, synthetic organics, and radionuclides.

J.3.1 Nutrients

The Mississippi and Atchafalaya Rivers have a tremendous influence on the amount of nutrient input to Texas and Louisiana coastal waters. A main characteristic of Gulf surface water is low inorganic nutrient levels.[22] Near-surface nutrient concentrations are low in open Gulf waters and generally increase toward shore, especially in the regions of river runoff. Phosphate and nitrate levels near the mouth of the Mississippi River are at least 8 and 30 times greater, respectively, than levels found in open-Gulf of Mexico waters. Near-surface nutrient concentrations are negatively correlated with salinity. Because salinity near the coast generally increase from east to west, the general trend for nutrient concentrations is to decrease from east to west.[23] In addition to river discharge, factors influencing nutrient concentrations include coastal currents and winds, intrusions of open-Gulf waters, upwelling, biological activity, rainfall, and proximity to coastal marshes.[24]

Nutrient concentrations are usually the limiting factor for growth of primary producers. Fluctuations in nutrient levels can affect the entire food chain of a marine system. In one study, nutrient samples taken at the Weeks Island area were found to be typical of the nearshore environment. High ammonia, phosphate, and silicate concentrations, particularly in near bottom samples, correlated with low oxygen concentrations. Nitrate concentrations were very low or undetectable in many of the samples containing low oxygen and high ammonia, as would be expected in a reducing environment. Nitrate showed a negative correlation with salinity, suggesting fresh water inputs as a source of this nutrient.[25]

J.3.2 Trace Metals

Trace metals enter northern Gulf waters from river outflow, the atmosphere, and local human activities. For most of the nearshore environments, most trace metals will come from the nearby land through river runoff. Once in the area, they may be dissolved or suspended in the water column, reside in the sediments, or concentrate in biological tissues.

Trace metal concentrations tend to be high off the Texas and Louisiana coast, especially around oil rigs and platforms. While the major source of trace metals is the sediment brought in by the Mississippi River, this is supplemented by outflow from several highly polluted estuaries and by drilling mud and other waste associated with oil exploration and production activities. Barium, although it is of little concern as a contaminant, is an important tracer. Its distribution clearly indicates that surface sediments of the inner half of the Louisiana and upper Texas shelf are subject to suspension and redistribution by active bottom currents. These sediments and trace metals then become resettled on the outer shelf and upper slope where bottom currents appear to be less active. Sediments around many drilling rigs may have elevated concentrations of trace metals, but concentrations decrease rapidly with distance from the source.

Offshore oil and gas drilling operations are a major source of barium. The barium contained in the drilling mud that is dumped from the drilling of new wells is slightly greater than the annual barium input from the Mississippi River. Other trace metals are present in much lower concentrations in drilling mud, but may in some cases be significant additives to local areas of the Texas-Louisiana shelf.[26]

One study[27] off the Louisiana shore found higher levels of trace metals in the open Gulf at surface and intermediate depths and consistently low values in deep waters. These heavy metal concentrations are especially influenced by sediment input from the Atchafalaya River. The study found that the particulate phase, onto which metals adhere in the water column, generally had a higher trace metal content than the dissolved phases, as would be expected in an area with high amounts of suspended matter.[28]

This study in Louisiana also showed that concentrations of dissolved heavy metals were higher in the sediment pore-water than in the overlying water column. This difference suggests that the metals may be diffusing from the sediments into the interstitial water. Generally, metals such as manganese and cadmium (with a high percent leachable fraction) and iron and zinc (associated with the minerals in the sediment) were found in high levels in the pore-water. The dissolved heavy metal levels observed in the water column during the study were well within the range expected for coastal environments.[29]

Another study performed at the Weeks Island site found that surficial sediments do not show any significant trace metal variation between the summer and winter seasons. The study did find, however, that there is less sediment homogeneity for Ba, Cd, Mn, and Sr in the summer season.[30]

J.3.3 Hydrocarbons

Hydrocarbons enter northern Gulf waters from river outflow, the atmosphere, natural seepage, oil and gas production, local transportation, and ship traffic. The most important sources are the Mississippi River outflow, local oil and gas production activities, and ship traffic. Hydrocarbon concentrations are high around the Mississippi River Delta, along the coast, and in the vicinity of some platforms and rigs. Texas and Louisiana shelf hydrocarbons include both natural petroleum compounds and anthropogenic hydrocarbons.

Hydrocarbons found in Gulf waters are mainly saturated hydrocarbons. Nonvolatile hydrocarbons were found to range from one to twelve ppb and aromatics from one to three ppb, with many samples containing undetectable amounts. Levels of paraffin compounds are high, with single-ring naphthenes being the most abundant type. Surface waters generally have a higher hydrocarbon content than deeper waters. A 1975 study found that hydrocarbon levels ranged from 17 to 64 ppb and made up 80 to 90 percent of the surface water organic matter in coastal Louisiana.[31]

High molecular weight hydrocarbon concentrations are very high in sediments off Louisiana and upper Texas, both in the nearshore and outer continental shelf areas. Many of these are unresolved complex mixtures including both weathered petroleum and anthropogenic fractions.[32]

Volatile hydrocarbons, which are mostly low molecular weight, water soluble compounds, are present in high levels in the sediments and water column of Louisiana and upper Texas. Large quantities are released in oil and gas produced water discharges and in the underwater venting of waste gases, and some derived from anthropogenic sources are brought in by river flow.[33]

Penaeid shrimp have been found to be sporadically contaminated with petroleum hydrocarbons off Calcasieu Pass in nearshore waters of central Louisiana. Off Timbalier Bay, in Louisiana, aromatic compounds have been found to be present in tissues of some fish species.[34]

J.3.4 Synthetic Organics

Synthetic organic chemicals are brought to coastal waters by rivers and streams. High levels of chemicals such as pesticides, polychlorinated biphenyls, and related organochlorines have been observed off the Mississippi River and in coastal bays and estuaries. In a comprehensive study of organochlorine residues in Gulf Coast estuarine fish conducted from 1972 to 1976, the three most common residues were DDT, PCB, and dieldrin, which occurred in 39, 22, and five percent of the samples, respectively.[35]

J.3.5 Radionuclides

Radionuclides in the Gulf of Mexico are both natural and anthropogenic in origin. Dissolved uranium concentrations measured in open Gulf waters are about the same as those seen in the rest of the world's oceans. Uranium concentrations in nearshore Gulf waters are variable because rivers and other land runoff sources vary in uranium concentration. The only radionuclide added to Gulf waters in measurable amounts as a direct result of offshore oil and gas operations is radium. Radium concentrations are sometimes higher in subsurface brines (produced waters), such as those from oil wells, than in other natural waters.[36]

J.4 Oil and Gas Activities

Since 1954, over 25,000 oil wells have been drilled in the northern Gulf of Mexico, mostly off the Louisiana coast.[37] At the same time, an extensive pipeline network has been installed offshore to transport oil and gas. As of October 1990, 4,457 kilometers of pipeline existed off the Texas coast on the Outer Continental Shelf.[38]

Currently, there is no readily available information that completely charts oil and gas activities in the Gulf of Mexico. The National Oceanographic and Atmospheric Administration's (NOAA) nautical charts provide a selection of submerged pipelines and oil platforms. According to NOAA nautical chart 11321, two offshore oil platforms exist within a 6-mile radius of the proposed Stratton Ridge diffuser site -- approximately 1.2 miles southeast and 5.9 miles southwest. The next closest platform is located 6.6 miles south of the diffuser. In addition, a large submerged pipeline lies 1.9 miles north of the proposed diffuser site. The pipeline enters the Gulf of Mexico from the Swan Lake area, apparently close to the proposed brine pipeline route.

Because the proposed diffuser location lies in State waters (i.e., generally three miles seaward of the boundary of any coastal State), the proposed diffuser site area is not subject to Federal jurisdiction under the Outer Continental Shelf Lands Act. Consequently, submerged lands underlying the brine pipeline and diffuser would not be federally leased areas.

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APPENDIX K

BASELINE CONDITIONS OF THE GULF OF MEXICO IN THE AREA OF THE PROPOSED WEEKS ISLAND AND COTE BLANCHE BRINE DISPOSAL PIPELINE AND DIFFUSER

The information presented in this appendix was derived from existing data sources that cover the northern Louisiana Gulf. No new field investigations were conducted to collect detailed site-specific data for the proposed pipeline and diffuser locations, but the following discussion draws heavily on previous DOE field investigations in the area, including one study[1] that conducted eight major cruises to collect data in the general vicinity of the diffuser location in 1977 and 1978.

K.1 Meteorology

Surface wind is an important factor in the mixing and diffusion characteristics of the water column at the diffuser site. Joint wind frequency distribution data obtained at the U.S Coast Guard Marine Station at Grand Isle from January to June 1978 and at a Chevron platform (28° 51' 29"N and 91° 06' 58"W) from June 1 to August 14, 1978 show that the majority of wind speeds in the proposed diffuser area are within the four- to ten-knot (4.5- to 11.5-mph) range. The prevailing wind direction is from the north, especially during January and February, though winds from the northeast, west, and south are common in the late spring and summer.

A 15-year record (1948-1963) of hourly wind data collected at Burrwood, LA, the closest primary coastal meteorological station, shows that the period of slack wind of less than or equal to five knots is not likely to last longer than twelve hours. More than half the observations have a slack wind of less than five hours, indicating that these periods can occur often but in most cases they prevail for only a short time.

The fastest sustained winds observed in New Orleans, LA during a twelve-year period (1960-1971) range from 26 knots (30 mph) observed in November 1969 to 60 knots (69 mph) observed in September 1965. Between 1899 and 1971, 45 tropical storms penetrated the Weeks Island area, with winds greater than 34 knots (39 mph) and about 1.6 years between occurrences. Eighteen of these storms were of hurricane intensity, with winds greater than 64 knots (74 mph) and slightly more than four years between occurrences. Offshore winds in excess of 175 knots (201 mph) are estimated to have occurred during hurricanes.

K.2 Physical Conditions

K.2.1 Nearshore Features

Vermilion Bay and Marsh Island are the dominant nearshore features in the vicinity of the Cote Blanche and Weeks Island proposed pipeline and diffuser site. Vermilion Bay is approximately 13 miles wide in an east-west direction (from Cypremort Point to Redfish Point) and slightly more than twelve miles wide in a north-south direction (from Champlain Point to its southern edge defined by Marsh Island). The bay is generally between seven and nine feet deep.

Two shoals lie offshore in the vicinity of the proposed diffuser site. The proposed diffuser would be located on the seaward side of these shoals.

- Tiger Shoal is located immediately south of Marsh Island. It is bisected by the ship safety fairway of Southwest Pass. Water depths on Tiger Shoal are generally less than twelve feet.

- Beyond Tiger Shoal is the smaller Trinity Shoal, situated about 20 miles south of the west end of Marsh Island. Trinity Shoal is about twelve miles south-southeast of the proposed diffuser location. Its major axis is about 20 miles long and is oriented in a west-southwest and east-northeast direction. The water depth of the shoal ranges from eleven to 18 feet. The shoal is fairly steep on its south side where the 30- and 60-foot contours are only about five miles apart. In calm weather, Trinity Shoal is discernible by high turbidity in the area; in stormy weather, the shoal is discernible by breaking seas.

K.2.2 Sediments

The floor of the northwestern Gulf has been heavily influenced by deltaic sedimentation from the adjacent river systems. The Mississippi River, because of its great drainage area, has been the major contributor of deltaic sediments. The sediment discharge of the Mississippi River consists primarily of clay, silt, and fine sand, with clay amounting to about 70 percent of the total sediment load.[2] The continental shelf west of the Mississippi Delta, in the vicinity of Cote Blanche and Weeks Island, grades from sand inshore, to silt and clay nearshore and offshore.[3]

Analyses of bottom sediments taken from the general area of the proposed diffuser site in 1978, showed variable mixtures of sand, silt, and clay. Closer to shore, in the vicinity of the proposed diffuser site, the bottom had a high proportion of silt and clay — silt and clay frequently made up more than 75 percent of the sediment composition.

K.2.3 Water Temperature and Salinity

Water temperature and salinity distributions off coastal Louisiana are influenced by freshwater inflow from the Mississippi and Atchafalaya Rivers, localized heavy precipitation, thermal heating and cooling due to weather changes, and energetic mixing by wind stress on the sea surface. Salinity within five to six miles of the Louisiana coast ranges from 15 to 35 ppt as a result of seasonal variations in riverine discharges.[4]

Farther offshore, typical salinities during the summer months increase from a surface value of 23 ppt to slightly over 36 ppt in the upper 50 feet, with a strong halocline at 23 to 26 feet. Temperatures are nearly isothermal, ranging from 77° to 79°F. The typical winter profile shows cooler temperatures (61° to 66°F) that again do not vary significantly with depth, and nearly isohaline conditions. Summer and winter vertical cross sections of coastal Louisiana show that during both seasons, fresher, less dense water appears at the surface, probably from the Mississippi River System. The strong vertical density gradient that exists during the summer would tend to inhibit vertical brine diffusion, while the strong horizontal stratification would lead to a strong westerly current that would enhance advection. The reduction of horizontal and vertical density gradients that occurs during the winter would tend to enhance vertical diffusion and inhibit advection. Bottom salinity levels do not fluctuate as much as surface levels do because of river runoff, unless storms have caused complete mixing.[5]

K.2.4 Tides

Although the tides in the Gulf have a small range, they are integral in the modification of currents and the acceleration of water movement through narrow passages. The tides in the Gulf are primarily diurnal in character. They are weakly developed with a usual range of less than 2.5 feet.[6] Tidal forces are dominant during the summer, when westerly winds are generally weak. During spring, discharge from the Mississippi and Atchafalaya river contribute to the westward motion, reducing the influence of the tides.[7]

The diurnal tide enters through the Florida Straits, progresses counterclockwise around the basin, is refracted by the northwestern and southern Gulf Coasts, and egresses through the Yucatan Channel. Maximum tidal ranges recur about every two weeks. Lowest and highest mean water levels occur from December through March and from September through October, respectively. Tidal currents are strongest in the deeper water areas off the Louisiana coast. The change in current speed and depth is related to the local water density gradients. The tidal currents have a tendency to rotate clockwise. They are weak near the Atchafalaya Bay. Tidal current speed slackens inshore of the 30-foot isobath, and the currents are oriented in the direction of the coastline. Bottom tidal currents are weaker than those at mid-depth or at the surface, but this aspect can be modified by the complex local density gradients. On the inner continental shelf, west of the Mississippi delta, tidal currents are a significant dynamic process and can markedly influence the motion of water in the area.[8]

K.2.5 Waves

Waves in the local area are a combination of local wind-generated waves and swells entering from open water. Wave direction generally corresponds to wind direction and changes according to the season of the year. Between March and August, waves travel in a northwesterly direction, while in the fall and winter they shift to a more westerly direction.[9]

K.2.6 Currents

Current patterns are the most significant factor in determining dispersal of brine. Current data were obtained and analyzed intermittently at sites in the general vicinity of the diffuser location.[10] Data were collected periodically between October 1977 to July 1978. Water current velocities on the inner continental shelf of southwestern Louisiana have shown that a prevailing northwesterly drift occurred throughout most of the year. Maximum current speeds of 2.6 to 4.6 ft/sec were measured during the winter storms. Minimum current speeds of 0.0 to 1.0 ft/sec were measured during June and early July. Current speeds during most other times of the year ranged from 0.3 to 1.3 ft/sec.

During the months of October, February, and March the circulation was tidally dominated, which may be due to the decreased effects of the Loop Current, lower precipitation and runoff, and lower wind speeds. There were brief periods of stagnation caused by low current speeds and little or no net drift during the months of May, June, and July. Detached eddies from the Loop

Current probably cause this stagnation. Stagnant-type conditions also occurred following the passage of a storm front in January.

Local winds have a major influence on the nearshore circulation pattern. For example, easterly to southeasterly winds during most of the year cause a westerly to northwesterly drift current. Strong southerly winds along the Texas Coast during the summer are believed to initiate a reversal in the net drift direction from the west to the east. However, it is not known if the net southeasterly drift during the early part of July marked the beginning of this transition. Other factors that could affect the circulation pattern are the Loop Current, barotropic slope currents, and the tide.

Current speeds generally decrease with depth due to shear stresses and may vary slightly in direction. Some instances of a two-layered flow regime were recorded in the area, but were of short duration and may have been induced by local wind effects.

K.2.7 Chemical Conditions

Appendix J on the surface water environment around Stratton Ridge provides a detailed discussion of the chemical conditions in the northern Gulf. Those conditions also reflect the general chemical conditions of the Gulf waters around the proposed Weeks Island diffuser site.

K.3 Oil and Gas Activities

As discussed in Appendix C, there are extensive and expanding oil and gas exploration/production activities in the northern Gulf of Mexico. There are more than 25,000 oil and gas wells and more than 27,000 km of existing pipelines in the northern and central Gulf.

Information that completely charts oil and gas activities in the Gulf of Mexico is not readily available. The National Oceanographic and Atmospheric Administration's (NOAA) nautical charts provide a selection of submerged pipelines and oil platforms. According to NOAA nautical chart 11349, a very active oil and gas area lies close to the proposed Weeks Island/Cote Blanche diffuser site. Over 30 oil platforms within a one-mile radius area are located approximately 5.5 miles northeast of the proposed diffuser site. In addition, a submerged pipeline traverses this platform area in a southeasterly direction. The closest platform is situated 2.8 miles west of the proposed site while two other platforms lie 4.5 miles southwest and 5.5 miles southeast of the proposed site.

Because the Minerals Management Service (MMS) is responsible for regulating and monitoring oil and gas operations in a lease block on the Federal Outer Continental Shelf (OCS), it is necessary to notify and consult with the MMS of any planned activities being conducted on the OCS.

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APPENDIX L

BASELINE CONDITIONS OF THE GULF OF MEXICO IN THE AREA OF THE PROPOSED RICHTON BRINE DISPOSAL PIPELINE AND DIFFUSER

L.1 Introduction

This appendix describes the baseline environmental conditions of the proposed Richton Dome brine disposal site. The proposed disposal area lies at approximately 30° 10.40' north latitude, 88° 37.35' west longitude. This site is in the Mississippi Sound offshore area, southwest of Horn Island Pass (the break between Horn Island and Petit Bois Island). The physical conditions at this site are affected by its proximity to this pass, which joins Mississippi Sound to the Gulf of Mexico.

The information presented here was gathered from existing sources containing data on the Mississippi Sound and adjacent offshore area of the northern Gulf of Mexico. Most of this information was compiled by or for the U.S. Army Corps of Engineers (COE) or the U.S. Department of the Interior Minerals Management Service (MMS). Because the proposed diffuser site lies within a recently designated COE dredged material disposal area, several COE reports on this area provide essential physiographic information. These reports include an investigation of oceanographic conditions in the Mississippi Sound offshore region (for COE by Kjerfve and Sneed) which includes a sample site within 3 miles of the proposed diffuser site.[1] Additionally, the MMS is performing a multi-year ecosystem study of the Gulf of Mexico off the coast of Mississippi and Alabama. This study is collecting biological, chemical, and physical characterization data from periodic cruises in the east Mississippi Bight, including a site within 10 miles of the proposed diffuser.[2] These sampling sites are referred to in this appendix as the COE sampling site and the MMS sampling site, respectively.

L.2 Meteorology

Meteorological conditions help create the oceanographic conditions that affect brine diffusion. Weather in the northern Gulf of Mexico varies strongly with season. The winter climate is temperate with frequent frontal events (every 3 to 5 days) and strong northerly winds. The sub-tropical summer climate is strongly influenced by the Azores-Bermuda high pressure cell, with less frequent frontal events (every 2 to 3 weeks) and light south or southeasterly winds.[3] These weather patterns affect the stratification of the water column, which in turn affects brine diffusion. Average monthly pressure over the northern Gulf reaches a minimum of 760-762 mm of mercury in the summer, and attains a maximum of 766 mm of mercury in the winter.[4] Air temperatures in the Pascagoula area range from 27 to 37°C in summer, and from 10 to 20°C in winter.[5] Wind speeds average seven to ten knots.[6]

O'Neil and Mettee calculated the probability that a tropical storm or hurricane might hit a 50-mile area from Biloxi, Mississippi to Mobile Bay, Alabama at 13, 6, and 1 percent, respectively, for a tropical storm, hurricane, or severe hurricane.[7] Others have estimated that the extreme weather of a tropical storm significantly affects this region approximately twice in three years.[8] Hurricane Camille brought winds of 200 miles per hour to this area in 1969.[9]

L.3 Physical Conditions

This section summarizes the physical environment of the Mississippi Sound offshore area, including nearshore features, sediments, water temperature and salinity, tides, waves, and currents.

L.3.1 Nearshore Features

The coast of Mississippi is indented by a series of bays, formed primarily at the mouths of rivers, and protected by a barrier island system located approximately seven to thirteen miles offshore. The Mississippi-Alabama shelf is a triangular area extending seaward from this barrier island system. The shelf width decreases west to east from about 80 miles near the Mississippi River Delta to 35 miles near DeSoto Canyon.[10] The shelf is generally smooth from the barrier islands to a depth of approximately 200 feet. Past the 200-foot contour line, the floor is punctuated by topographic features (primarily reefs and ridges) of limited areal extent.[11]

The proposed pipeline route runs south and slightly west through Mississippi Sound to a diffuser location approximately three nautical miles past the barrier island system that separates Mississippi Sound from the Gulf of Mexico. The proposed diffuser site is southwest of Horn Island Pass, the break between the Horn and Petit Bois Islands. Both islands are part of the Gulf Islands National Seashore. Additional barrier islands extend east and west from Horn and Petit Bois, and the Chandeleur Islands form a north-south chain approximately 20 miles southwest of the proposed diffuser site.

Depths in the immediate area of the proposed diffuser range from 45-50 feet. After dropping off sharply from the barrier islands to a depth of approximately 20 feet, the continental shelf slopes gently through the proposed diffuser area to a depth of about 300 feet, after which the floor deepens rapidly to the south and southeast.[12]

Four major man-made features are in close proximity to the proposed diffuser site. First, the proposed diffuser lies within a COE dredged material disposal area, which occupies 18 square miles of shelf south of Horn Island. Second, approximately 3 miles northeast of the proposed site in Horn Island Pass, there is a man-made island that serves as an important nesting site for least terns and other shorebirds. Third, the proposed diffuser site is approximately 3.5 miles west of Horn Island Pass Channel, a 350-foot wide, 40-foot deep ship channel providing access to Mississippi Sound. Finally, two high pressure natural gas pipelines are buried approximately 2 miles east of the proposed diffuser site.[13] The diffuser pipeline would cross the channel and the natural gas pipelines en route to the disposal site.

L.3.2 Sediments

An extensive sand sheet underlies the eastern Mississippi Sound offshore area, extending from the Chandeleur Islands east to the Alabama/Florida border and south to the 660-foot contour line. Further west and in deeper water, sand is replaced by clay and silt.[14]

At the MMS sampling site, considerable variation in sediment size was recorded in samples taken during different cruises: gravel was always a minimal component (ranging from 0 to 8 percent of sediment samples); sand ranged from 19 to 80 percent; silt from 2 to 73 percent; and clay from 6 to 43 percent. This variation was attributed to the presence of relict deposits of various sediment types, such as those associated with barrier islands, bars, coastal dunes, lagoons, and deltaic deposits.[15]

L.3.3 Water Temperature and Salinity

Temperature and salinity in this area are affected by atmospheric conditions, river inflows, and water circulation. Freshwater sources create tidal inlet plumes and variation in salinity. As mentioned above, seasonal variation in meteorologic conditions strongly influences stratification of the water column. In winter, frequent storms and low river inflows create a well-mixed water column. Fewer storms and increased river inflows in spring produce a partially-stratified water column.[16] As a result, disposed brine may disperse better in winter.

Surface water temperatures approximate air temperature, ranging from 12°C in winter to 27°C in summer. Winter and summer bottom temperatures range from 13 to 22°C, respectively.[17] Average near-bottom temperatures at the COE site were 17.7 and 19.4°C respectively in late fall/early winter and spring.[18] Near-bottom temperatures at the MMS site have been measured at 17, 18, and 29°C, respectively, in February, March, and August. Near-bottom temperatures in October are close to 27°C in this area.[19]

Salinities in this area vary with freshwater inputs and periodic intrusions of the Gulf Loop Current, and can range from 11 to 36 parts per thousand (ppt).[20] Near bottom salinities in the vicinity of the proposed diffuser site range from 30 to 36 ppt.[21] Bottom salinities averaged 31.0 and 30.9 ppt at the COE site in late fall/early winter and spring, respectively.[22] The MMS has measured bottom salinities in this area to be 34, 36, and 34 ppt respectively in February, March, and August. Likewise, near-bottom salinities in October are close to 34 ppt.[23] These values are similar to those found by other researchers; EPA studies, for example, have measured bottom salinities in this area at 31 to 37.8 ppt.[24]

The geology of this area affects water circulation, and thus temperature and salinity. Gulf water flows into Mississippi Sound through Horn Island Pass. The increased depth of Horn Island Pass Channel allows colder, high-salinity, de-oxygenated waters from the Gulf to intrude upon the sound.[25]

L.3.4 Tides

The diurnal tide is the most significant hydrographic driving force in the Mississippi Sound region. Tidal forces mix vertical water layers and prevent vertical stratification, which would concentrate highly saline brine in the bottom layer. The tide is modified by wind, the bathymetry and geometry of the basin, and river inflows.

The average tidal range in this area is 1.4 to 1.5 feet, with a maximum normal range of 1.9 ft. A fortnightly equatorial tide cycle results in the elimination of the diurnal tide for a few days out of each fourteen day cycle. At this time, a semi-diurnal tide occurs which is so small (0.2 ft) that the region is essentially non-tidal during this period.[26]

The barrier island system divides the Mississippi Sound region into two distinct tidal regions on either side of Horn Island Pass (see Figure L.3-1). West of the pass, tides advance north-northwest, or counter-clockwise, while east of the pass, waves turn eastward or clockwise.[27]

L.3.5 Waves

Waves on the Mississippi-Alabama shelf are of low to moderate intensity. Wave heights rarely exceed 7 feet and wave periods range from 3 to 8 seconds. Hurricanes and other storms, however, produce larger waves. Wave conditions vary with wind speed, wind direction, fetch, and water depth.[28]

L.3.6 Currents

Currents are primarily wind-driven and thus vary seasonally (see section L.2 above). Current meters deployed in the Mississippi Sound offshore area record that surface circulation is dominated by longshore currents flowing west in winter; surface circulation reverses and flows east in spring. However, recorded bottom currents were independent of surface currents, and were more likely to flow in the same general direction over time. In the area of the proposed diffuser, bottom currents flowed primarily northeast in late fall/early winter and in spring.[29] Figures L.3-2 and L.3-3 show resultant current vectors for several sampling stations in the Mississippi Sound offshore area in late fall/early winter and spring, respectively. Station No. 3 is the COE sampling site, located within 3 miles of the proposed Richton diffuser.

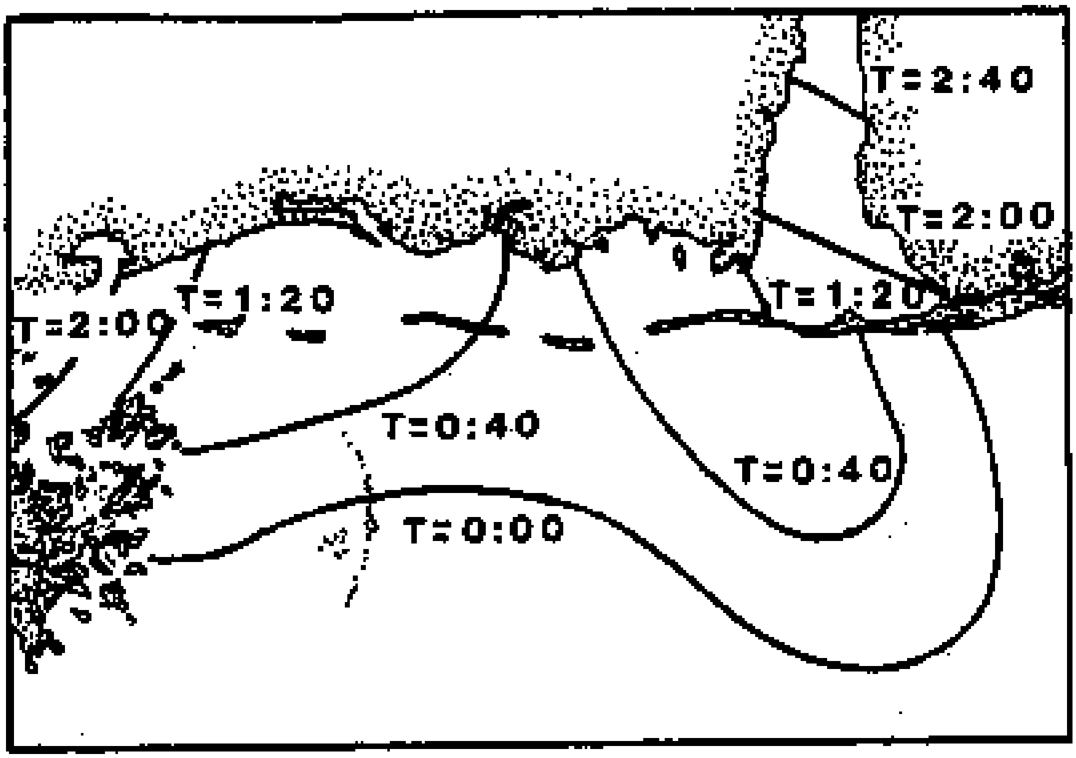
Winter and spring current roses from the COE sampling site are shown in Figure L.3-4. All of these figures indicate that the prevailing direction for bottom currents in the vicinity of the proposed diffuser is toward the northeast, and that these currents rarely exceed 0.7 feet per second. Bottom currents flow more consistently to the northeast in winter (26 percent of the time) than in spring (18 percent). The current flows in each of the other seven directions only a small fraction of the time (three to nine percent on average). The current is often calm (34 percent of the time on average) and is calmer in the winter (38 percent of the time) than in spring (23.5 percent of the time). The current speed most often ranges from 0.1 to 0.3 feet per second (45 percent of the time, on average, and more often in spring). This current speed increases to between 0.3 and 0.7 feet per second about 15 percent of the time (again, more often in winter) and increases to between 0.7 and 1 foot per second only about 2 percent of the time.

Water velocities directly in the barrier island passes, however, have a wider range and can be substantially greater. Water velocities in the barrier island passes range from 0 to 3 feet per second.[30]

L.4 Chemical Conditions

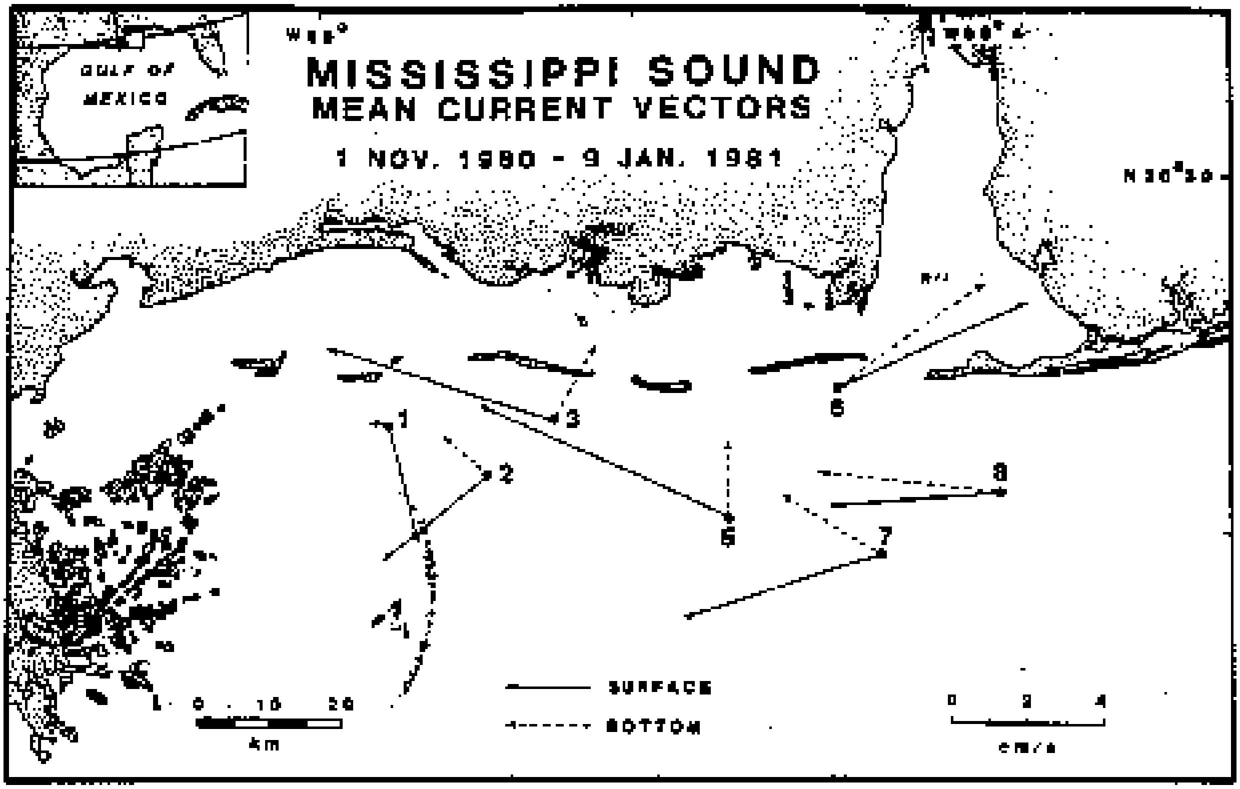
Mississippi Sound and the Mississippi Sound offshore area are used extensively for marine transportation, dredge dumping, and offshore oil and gas drilling, resulting in a complex chemical environment. Water column and sediment chemistry is highly dependent on seasonal riverine discharge because rivers are a major source of nutrients, trace metals, hydrocarbons, synthetic organics, and radionuclides.

Figure L.3-1
Progression of the Diurnal Tidal Wave
Through the Mississippi Sound Area



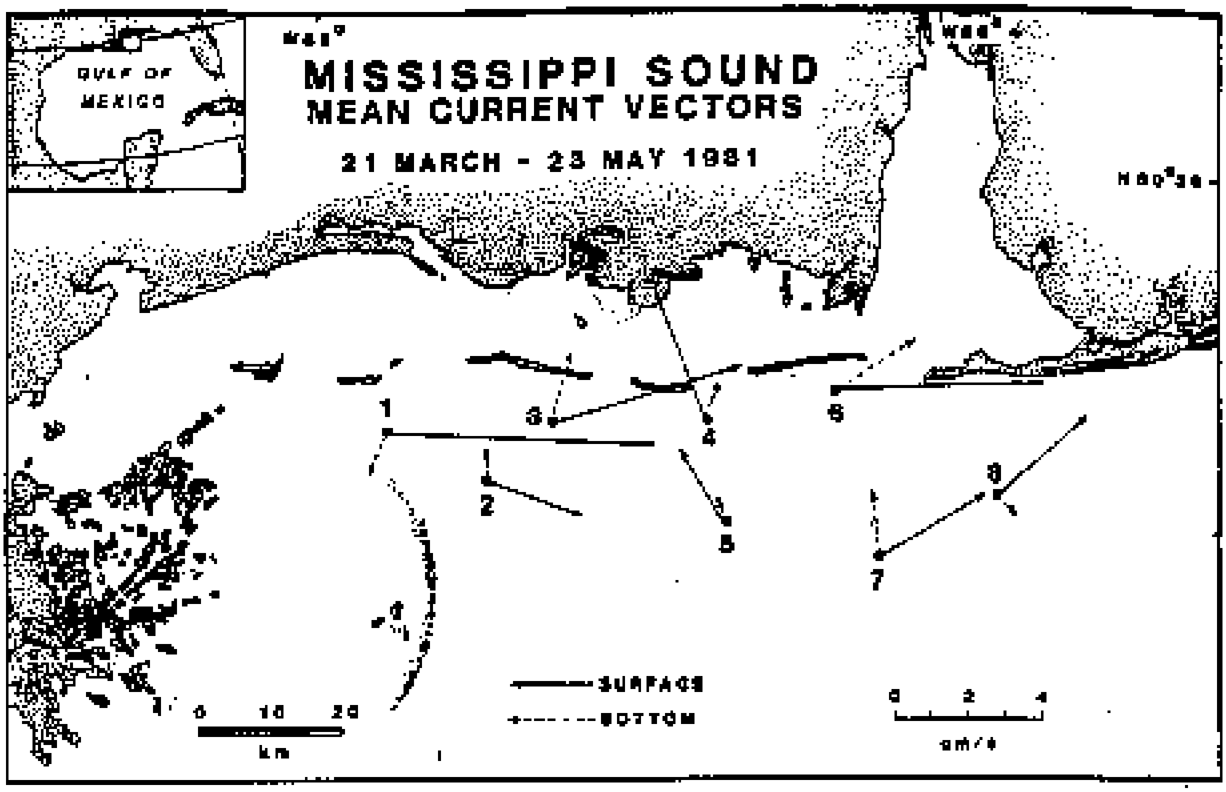
Note: Lines indicate the position of the tidal wave crest at successive times.
Source: Kjerve and Sneed 1984, p.11.

Figure L.3-2
Surface (Solid) and Bottom (Dashed) Current Vectors
for the Period November 1, 1980 - January 9, 1981



Note: Station No. 3 is the COE sampling site, located within 3 miles of the proposed Richton diffuser.
Source: Kjerve and Sneed 1984, p. 27.

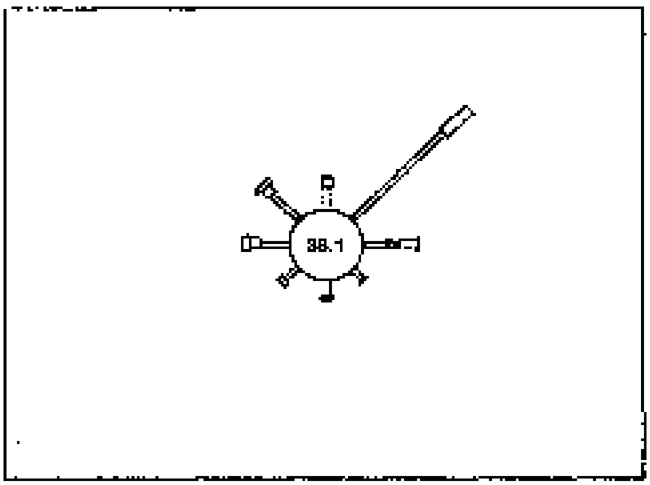
Figure L.3-3
Surface (Solid) and Bottom (Dashed) Current Vectors
for the Period March 21 - May 23, 1981



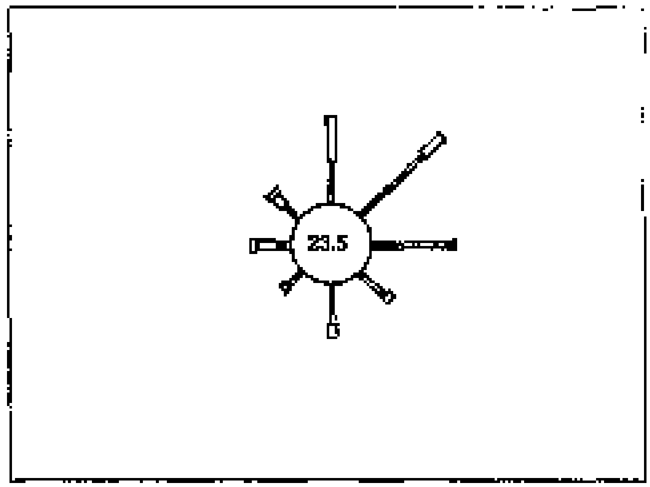
Note: Station No. 3 is the COE sampling site, located within 9 miles of the proposed Richton diffuser.
Source: Kjerve and Sneed 1984, p. 18.

Figure L.3-4
Speed and Direction Current Roses of Bottom Currents
for the COE Sampling Site

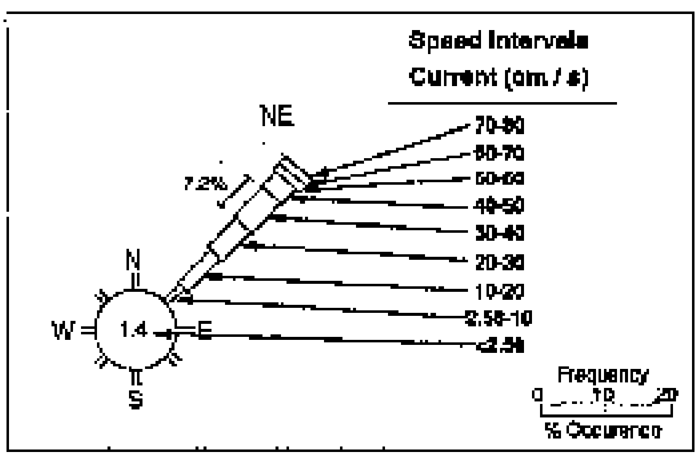
Nov. 1, 1980 - Jan. 9, 1981



March 21 - May 23, 1981



Interpretation of Current Roses



Direction is synthesized into 8 sectors, indicating flow towards that direction. The example details current towards the northeast (NE). The length of the area is proportional to the frequency of occurrence of all NE vectors. The speed intervals are differentiated by arm thickness. The length of each Interval represents the frequency of occurrence of NE vectors in that speed interval. The interval is n x 10 cm/s for currents. The value within the circle gives the percentage of currents below the instrument threshold.

Sources: U.S. EPA 1990, p. F-69; and U.S. EPA 1991, p. 7-25.

L.4.1 Nutrients

Silicate tends to be more abundant in shelf waters than in open Gulf waters, where it ranges from 0.048 to 1.9 ppm. Measured phosphate levels in shelf waters have been similar to levels in open Gulf waters, ranging from 0 to 0.25 parts per million (ppm). Nitrate levels are lower in shelf waters than in open Gulf waters, where levels range from 0.0031 to 0.14 ppm.[31]

L.4.2 Trace Metals

Petroleum exploration and production in this area have increased the amounts of trace metals released into the environment. Rivers are the main pathway of trace metals into nearshore environments, though atmospheric inputs, ocean dumping, industrial outfalls, and offshore drilling are contributing factors. Once in the Gulf, the metals may reside in the water column, sediments, or biological tissues.

In the water column, mercury has been measured from 0.0002 to 0.0009 milligrams per liter (mg/l), cadmium from 0.003 to 0.0018 mg/l, lead from 0.0045 to 0.016 mg/l, and copper from 0.003 to 0.028 mg/l.[32]

Iron and trace metal content of sediment varies considerably in this area, due to natural variability in grain size and mineralogy. In general, shallow-water sediment is less contaminated with iron and trace metals than deep-water sediment. Areas closer to the Mississippi delta are higher in barium by a factor of two. Sediment manganese concentrations are about half the value usually associated with the sediment iron concentrations found here, indicating the manganese may be solubilizing from biochemically active sediments in this area.[33]

L.4.3 Hydrocarbons

Hydrocarbons are ubiquitous in Mississippi offshore sediments. The primary source of hydrocarbon loading is the riverine transport of fine sediment loaded with unrefined petroleum hydrocarbons, though sediments in the Gulf of Mexico contain a mixture of both biological and petroleum-based hydrocarbons. A weak association has been found between finer grained, organic rich sediments and hydrocarbons.[34]

Large seasonal variation occurs in sediment hydrocarbon content at a particular site. This variation could result from the dilution of hydrocarbon-loaded riverine inputs by biological mixing (i.e., the disturbance of sediments by benthic organisms), or from transport of hydrocarbon-loaded sediment by water currents to the shelf break.[35]

MMS measured increasing levels of hydrocarbons in sediments along transects in the seaward direction, and measured higher levels near the Mississippi Delta. The amount and type of polynuclear aromatic hydrocarbons (PAHs) in shelf sediment differed from PAHs in bay sediment; shelf sediment PAHs were derived from unprocessed petroleum (rather than from combustion as in bays), and levels in shelf sediment were six times lower than in bays.[36]

L.4.4 Synthetic Organics

Synthetic organics enter coastal waters from river outflows. High levels of pesticides, polychlorinated biphenyls, and related organochlorines have been measured in the Mississippi River deltaic area, and in coastal bays and estuaries of the Gulf. Residues of DDT, PCB, and dieldrin have been found in 39, 22, and 5 percent, respectively, of Gulf coast estuarine fish sampled.[37]

L.4.5 Radionuclides

Both natural and anthropogenic processes contribute radionuclides into the Gulf of Mexico. Rivers and other land runoff carry uranium into nearshore waters. In the open Gulf, dissolved uranium concentrations are similar to those found in world oceans. Offshore oil and gas operations add radium to Gulf waters, and radium concentrations are sometimes higher in subsurface brines (i.e., brine produced from oil wells) than in the open Gulf.[38]

L.5 Oil and Gas Activities

There is presently no active oil or gas activity in the immediate vicinity of the proposed diffuser site, but there may be in the future. The MMS has considered leasing parts of the Mississippi Sound offshore area to petroleum exploration.[39] As mentioned previously, two high pressure natural gas pipelines are buried approximately two miles east of the proposed diffuser site.[40]

ENDNOTES

1. Kjerfve, B. and J. Sneed, *Analysis and Synthesis of Oceanographic Conditions in the Mississippi Sound Offshore Region Final Report*, Volumes 1 and 2, U.S. Army, Corps of Engineers, Mobile, AL, March 1984.

2. U.S. Department of Interior, *Mississippi-Alabama Marine Ecosystem Annual Report: Year 2, Volume 1: Technical Narrative*, Minerals Management Service, January 1990, Document Number MMS 89-0095.

   U.S. Department of Interior, *Mississippi-Alabama Marine Ecosystem Annual Report: Year 2, Volume 2: Appendices*, Mineral Management Service, January 1990, Document Number MMS 89-0096.

3. Kjerfve, B. and J. Sneed, *Analysis and Synthesis of Oceanographic Conditions in the Mississippi Sound Offshore Region Final Report*, Volumes 1 and 2, U.S. Army, Corps of Engineers, Mobile, AL, March 1984.

4. U.S. Department of Interior, *Final Environmental Impact Statement for Gulf of Mexico Sales 131, 135, and 137: Central, Western, and Eastern Planning Areas, Volume I*, Minerals Management Service, August 1990, Document Number MMS 90-0042, pp. III-3.

5. U.S. Environmental Protection Agency Region IV, *Final Environmental Impact Statement for the Designation of an Ocean Dredged Material Disposal Site Located Offshore Pascagoula, Mississippi*, June 1991, pp 4-1.

6. *Ibid.*

7. U.S. Environmental Protection Agency Region IV, *Final Environmental Impact Statement for the Designation of an Ocean Dredged Material Disposal Site Located Offshore Pascagoula, Mississippi*, June 1991, p 4-1.

8. Kjerfve, B. and J. Sneed, *Analysis and Synthesis of Oceanographic Conditions in the Mississippi Sound Offshore Region Final Report*, Volumes 1 and 2, U.S. Army, Corps of Engineers, Mobile, AL, March 1984.

9. *Ibid.*

10. *Ibid.*

11. U.S. Department of Interior, *Mississippi-Alabama Marine Ecosystem Annual Report: Year 2, Volume 1: Technical Narrative*, Minerals Management Service, January 1990, Document Number MMS 89-0095, and Mississippi-Alabama Marine Ecosystem Study Annual Report: Year 2, Volume I: Technical Narrative. U.S. Department of the Interior, Minerals Management Service, January 1990. Doc. No. MMS 89-0095, p 12-10.

12. *Ibid.*

13. U.S. Environmental Protection Agency Region IV, *Final Environmental Impact Statement for the Designation of an Ocean Dredged Material Disposal Site Located Offshore Pascagoula, Mississippi*, June 1991, pp 1-4 and 4-16.

14. U.S. Department of Interior, *Mississippi-Alabama Marine Ecosystem Annual Report: Year 2, Volume 1, Technical Narrative*, Minerals Management Service, January 1990, Document Number MMS 89-0095, Mississippi-Alabama Marine Ecosystem Study Annual Report: Year 2, Volume 1: Technical Narrative, U.S. Department of the Interior, Minerals Management Service, January 1990, Doc. No. MMS 89-0095, pp 2-5, 2-6.

15. U.S. Department of Interior, *Mississippi-Alabama Marine Ecosystem Annual Report: Year 2, Volume 1, Technical Narrative*, Minerals Management Service, January 1990, Document Number MMS 89-0095, Mississippi-Alabama Marine Ecosystem Study Annual Report: Year 2, Volume 2: Appendices, U.S. Department of the Interior, Minerals Management Service, January 1990, Doc. No. MMS 89-0096, pp A-29.

16. U.S. Environmental Protection Agency Region IV, *Final Environmental Impact Statement for the Designation of an Ocean Dredged Material Disposal Site Located Offshore Pascagoula, Mississippi*, June 1991, pp 4-5.

17. *Ibid.*

Kjerfve, B. and J. Sneed, *Analysis and Synthesis of Oceanographic Conditions in the Mississippi Sound Offshore Region Final Report*, Volumes 1 and 2, U.S. Army, Corps of Engineers, Mobile, AL, March 1984.

18. Kjerfve, B. and J. Sneed, *Analysis and Synthesis of Oceanographic Conditions in the Mississippi Sound Offshore Region Final Report*, Volumes 1 and 2, U.S. Army, Corps of Engineers, Mobile, AL, March 1984.

19. U.S. Department of Interior, *Mississippi-Alabama Marine Ecosystem Annual Report: Year 2, Volume 1, Technical Narrative*, Minerals Management Service, January 1990, Document Number MMS 89-0095.

U.S. Department of Interior, *Mississippi-Alabama Marine Ecosystem Annual Report: Year 2, Volume 2: Appendices*, Mineral Management Service, January 1990, Document Number MMS 89-0096.

20. U.S. Environmental Protection Agency Region IV, *Final Environmental Impact Statement for the Designation of an Ocean Dredged Material Disposal Site Located Offshore Pascagoula, Mississippi*, June 1991, pp 4-5.

21. U.S. Department of Interior, *Mississippi-Alabama Marine Ecosystem Annual Report, Year 2, Volume 1: Technical Narrative*, Minerals Management Service, January 1990, Document Number MMS 89-0095.

Kjerfve, B. and J. Sneed, *Analysis and Synthesis of Oceanographic Conditions in the*

Mississippi Sound Offshore Region Final Report, Volumes 1 and 2, U.S. Army, Corps of Engineers, Mobile, AL, March 1984.

22. Kjerfve, B. and J. Sneed, *Analysis and Synthesis of Oceanographic Conditions in the Mississippi Sound Offshore Region Final Report*, Volumes 1 and 2, U.S. Army, Corps of Engineers, Mobile, AL, March 1984.

23. U.S. Department of Interior, *Mississippi Alabama Marine Ecosystem Annual Report: Year 2, Volume 1: Technical Narrative*, Minerals Management Service, January 1990, Document Number MMS 89-0095.

    U.S. Department of Interior, *Mississippi-Alabama Marine Ecosystem Annual Report: Year 2, Volume 2: Appendices*, Mineral Management Service, January 1990, Document Number MMS 89-0096.

24. U.S. Environmental Protection Agency Region IV, *Final Environmental Impact Statement for the Designation of an Ocean Dredged Material Disposal Site Located Offshore Pascagoula, Mississippi*, June 1991, pp 4-5 to 4-6.

25. Eleuterius, C.K. *Mississippi Sound: Salinity Distribution and Indicated Flow Patterns*, Mississippi-Alabama Sea Grant Consortium, Document Number MASGP-76-023, pp. 19 to 20.

26. Kjerfve, B. and J. Sneed, *Analysis and Synthesis of Oceanographic Conditions in the Mississippi Sound Offshore Region Final Report*, Volumes 1 and 2, U.S. Army, Corps of Engineers, Mobile, AL, March 1984.

27. U.S. Environmental Protection Agency Region IV, *Final Environmental Impact Statement for the Designation of an Ocean Dredged Material Disposal Site Located Offshore Pascagoula, Mississippi*, June 1991, pp 4-2.

28. U.S. Army Corps of Engineers, *Mississippi Sound and Adjacent Areas Dredged Material Disposal Study Feasibility Report*, Volume 1, September 1984, p 16.

29. Kjerfve, B. and J. Sneed, *Analysis and Synthesis of Oceanographic Conditions in the Mississippi Sound Offshore Region Final Report*, Volumes 1 and 2, U.S. Army, Corps of Engineers, Mobile, AL, March 1984.

30. U.S. Environmental Protection Agency Region IV, *Final Environmental Impact Statement for the Designation of an Ocean Dredged Material Disposal Site Located Offshore Pascagoula, Mississippi*, June 1991, pp 4-2.

31. U.S. Department of Interior, *Final Environmental Impact Statement for Gulf of Mexico Sales 131, 135, and 137: Central, Western, and Eastern Planning Areas, Volume 1*, Minerals Management Service, August 1990, Document Number MMS 90-0042, pp. III-3.

32. U.S. Environmental Protection Agency Region IV, *Final Environmental Impact Statement for the Designation of an Ocean Dredged Material Disposal Site Located Offshore Pascagoula, Mississippi*, June 1991, pp 4-6.

33. U.S. Department of Interior, *Mississippi-Alabama Marine Ecosystem Annual Report: Year 2, Volume 1: Technical Narrative*, Minerals Management Service, January 1990, Document Number MMS 89-0095, and pp 1-3 to 1-4.

34. *Ibid.*, pp 1-2 to 1-3.

35. *Ibid.*

36. *Ibid.*

37. U.S. Department of the Interior, *Physical Oceanography of the Louisiana-Texas Continental Shelf: Proceedings of a Symposium Held in Galveston, Texas, May 24, 1988*, Minerals Management Service, New Orleans, LA, October, 1988, Document Number MMS88-0065.

38. *Ibid.*

39. U.S. Department of Interior, *Final Environmental Impact Statement for Gulf of Mexico Sales 131, 135, and 137: Central, Western, and Eastern Planning Areas, Volume I*, Minerals Management Service, August 1990, Document Number MMS 90-0042, pp. II-3.

U.S. Department of Interior, Draft Environmental Impact Statement for Gulf of Mexico Sales 139 and 141: Central, and Western Planning Areas, Minerals Management Service, Gulf of Mexico OCS Region, New Orleans, LA, April 1991, Document Number MMS 91-0018.

40. U.S. Environmental Protection Agency Region IV, *Final Environmental Impact Statement for the Designation of an Ocean Dredged Material Disposal Site Located Offshore Pascagoula, Mississippi*, June 1991, pp 4-16.

APPENDIX M

ANALYSIS OF METALS AND OTHER INORGANIC CONSTITUENTS IN SPR BRINE

Two other appendices of this DEIS evaluate the impacts of proposed brine discharges from the candidate expansion sites to the Gulf of Mexico:

- Appendix I evaluates potential future impacts by analyzing the environmental impacts that have been observed as a result of past SPR brine discharges, including past discharges of brine from Big Hill. It addresses historical impacts associated with excess salinity and a number of other individual contaminants, including ions (e.g., calcium, sodium, chloride, and sulfate) and metals (e.g., cadmium, chromium, copper, mercury, lead, and zinc).

- Appendix Q predicts the areal extent and height of brine plumes that may be caused by the discharge of brine to the Gulf of Mexico from the other candidate expansion sites, i.e., Stratton Ridge, Weeks Island, Cote Blanche, and Richton. It is limited to an evaluation of excess salinity contours.

This appendix evaluates the potential for metals and other inorganic constituents in SPR brine to cause adverse environmental impacts when discharged to the Gulf of Mexico. It supplements the analysis of metals and other constituents provided in Appendix I, and supplements Appendix Q by evaluating the potential effects of other constituents not considered in that appendix's brine plume predictions.

This appendix analyzes the hazard of SPR brine in terms of its metal and other inorganic chemical content. Because no data are available on the composition of brine from Stratton Ridge, Weeks Island, Cote Blanche, and Richton (brine has not been generated at these sites previously), brine from the candidate expansion sites could not be analyzed on a site-specific basis. Instead, the appendix evaluates the hazard of a "model" SPR brine that is based on brine composition data that are available for other SPR sites. Section M.1 presents available data on the brine composition at existing SPR sites. In section M.2, these data are analyzed statistically to determine the degree to which the brine composition varies from site to site and from cavern to cavern. Based on this statistical analysis, a model brine composition that is designed to reasonably represent the brine expected from the candidate expansion sites is developed. Section M.3 then evaluates the hazard of this model brine by analyzing its potential to result in harmful levels of metals in the Gulf of Mexico. This hazard analysis includes an examination of the potential for the brine's metals to exceed ecological protection thresholds and to bioconcentrate in aquatic organisms in the Gulf. Finally, section M.3 summarizes conclusions from the analysis.

M.1 Summary of Available Brine Composition Data

Table M.1-1 summarizes all available data on the level of metals and other inorganic constituents present in SPR brine. As shown, data are available for five separate SPR sites: Bryan Mound, Bayou Choctaw, West Hackberry, Sulfur Mines, and Big Hill. In addition, data are available for an unidentified salt dome and for the Starks (non-SPR) dome along the Gulf of Mexico coast. A total of 23 different inorganic constituents are represented by the data.

Table M.1-1
Brine Composition Data

CONSTITUENTS	Concentrations of Brine from Various Salt Domes[3]							West Hackberry Monitoring Report[4]	Projected Big Hill Concentrations[5]		Big Hill Brine[5]
MAJOR (mg/l)	BC-6	BC-17	BM-19	BM-5	SS-14	SU-2	WH-11	1983			
Sodium	102,500	121,200	120,400	117,000	120,800	121,600	120,000	117,060	128,339	125,015	130,209
Potassium	7,420	194	19	206	3	3	5	50	50	7,959	21
Chloride	200,500	200,000	196,000	194,000	198,000	196,000	200,000	176,050	186,057	194,376	202,609
Sulfate	1,480	1,540	690	1,060	800	2,200	1,440	2,490	750	5,130	6,996
Calcium	5,300	120	591	720	572	910	420	1,070	242	635	912
Magnesium	6,550	10	9	9	3	4	9	30	11.91	76	605
MINOR (ug/l)											
Aluminum											
Antimony	<2	<2	<2	<2	<2	<2	<2				
Arsenic	<2	10	6	3	<3	<2	4				
Barium	<400	<400	<400	<400	<400	<400	<400		ND	3,000	
Cadmium	100	2	2	<3	6	8	<2	0.2	ND	8	
Chromium	6	<2	<2	<2	<3	<3	<2	<0.5	ND		
Cobalt											
Copper	14	20	16	2	<3	<3	<2	2	ND	400	
Iron								735	60	30,000	
Lead	34	26	26	2	13	<2	3	8	ND	30	
Mercury	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	0.4	<1	ND		
Nickel	<2	2	2	2	<3	<2	<2		ND	300	
Manganese	40,850	420	320	100	140	280	160		ND	1,300	
Silver	<10	<10	<10	<10	<10	<10	<20				
Strontium										7,000	
Titanium											
Zinc	26,400	50	400	80	4	73	<2	9.1	ND	90	

[3] Weisberg, George H. et al., Candidate Brine Disposal Site Study: Baseline Conditions and Environmental Assessment Technical Report, U.S. DOE, Washington, D.C., December 12, 1980. Sample code (owner number follows the same code): BC = Bayou Choctaw, BM = Bryan Mound, SS = Sabine, SU = Sulfur Mines, WH = West Hackberry. Document does not specify whether data represent total or dissolved metals.

[4] Hann, Roy W., Jr. et al., eds. Offshore Oceanographic and Environmental Monitoring Services for the SPR, Eighteen Month Report for the West Hackberry Site from May 1982 to November 1983, Texas A&M University and Research Foundation, Volume I, April 1984. Data represent total metals.

[5] Strategic Petroleum Reserve, Final Supplement to Final Environmental Impact Statement, Phase III Development Texoma and Seaway Group Salt Domes, U.S. DOE, October 1981, DOE/EIS-0075. Document does not specify salt dome or whether the data represent dissolved or total metals.

Table M.1-1 (cont'd)
Brine Composition Data

CONSTITUENT	Compilation of Brine Analyses from Salt Caverns at Bryan Mound[1]							Brine Diffuser Data, Bryan Mound Site[2]												
MAJOR (mg/l)	C-5/9	C-5	C-1	C-2	C-3	C-4	C-4	3/80	10/80	4/81	8/81	3/82	11/82	2/83	5/83	8/83	11/83	2/84	5/84	8/84
Sodium	117,400	123,383	124,623	124,067	124,037	125,277	124,384						108,700	109,000	119,000	102,000	109,000	111,000	103,000	104,000
Potassium	725						184						660	610	310	400	416	780	700	480
Chloride	194,100	190,151	191,315	190,174	191,191	190,571	190,674						175,000	163,399	169,100	170,000	175,000	175,000	161,000	169,000
Sulfate	3,500	3,600	3,919	3,700	3,700	3,350	3,220						1,800	1,424	1,100	2,400	2,100	2,800	2,700	3,100
Calcium	720	115	580	706	310	280	240						930	850	810	910	730	639	720	800
Magnesium	9.2	14	31	31	32	26	ND						230	300	189	310	410	364	491	600
MINOR (µg/l)																				
Aluminum								<50	<50	<50	<10	<10	<5	8						
Antimony	<3																			
Arsenic	2																			
Barium	<100	600	510	900	791	ND	<1													
Cadmium	<2	9	8	9	7	ND	ND	11	1.5	1.2	1.5	1.1	6.8	<0.5	1.1	0.9	1.3	1.8	1.1	1
Chromium	<2	ND	ND	ND	ND	ND	ND	3.8	7.6	3.8	5	<0.2	5	3	5	4	0.5	1	3.8	0.6
Cobalt								<0.5	<0.5	<0.5	<0.5	<0.5								
Copper	2	ND	3,920	ND	ND	110	ND	7	5.5	2.8	9	4.5	3	1	<0.5	0.5	3	5	3	3
Iron		1,230	9,700	891	1,240	1,060	10	400	400	125	380	380	215	30	3,200	399	1,300	3,070	6,710	1,840
Lead	2	ND	ND	ND	ND	ND	ND	43	18	20	21	<2	27	4	21	36	19	124	69	51
Mercury	<0.2	ND	ND	ND	ND	ND	ND	4.3	2.9	4.2	0.16	4.9	<0.1	<0.2	<0.2	<0.2	<0.2	<0.2	0.8	4.2
Nickel	5	ND	ND	ND	ND	ND	ND	26	22	13	2	3	21	21	<1	<1	6	<1	6	<3
Manganese	100	60	130	48	10	10	ND	180	161	115	315	167								
Silver	<10																			
Selenium																				
Thallium								<100	<100	<100	<100	<100								
Zinc	80	ND	90	ND	30	30	ND	42	30	35	28	25	55	64	59	65	60	68	73	97

[1] Strategic Petroleum Reserve, Final Environmental Impact Statement, Seaway Group Salt Domes, Brazoria County, Texas, U.S. Department of Energy, June 1978, Volume 3 of 3. DOE/EIS-0021. Document does not specify whether data represent total or dissolved metals. C-4 corresponds to the cavern that was sampled.

[2] Data compiled from the following three sources:

Hann, Roy W., Jr., et al., eds., Evaluation of Brine Disposal from the Bryan Mound Site of the Strategic Petroleum Reserve Program, Final Report of Eighteen-Month Postdisposal Studies, Texas A&M University and Research Foundation, Volume 1, March 1982.
Hann, Roy W., Jr., et al., eds., Offshore Oceanographic and Environmental Monitoring Services for the SPR, Annual Report for the Bryan Mound Site from September 1982 to August 1983, Texas A&M University and Research Foundation, Volume 1, December 1983.
Hann, Roy W., Jr., et al., eds., Offshore Oceanographic and Environmental Monitoring Services for the SPR, Annual Report for the Bryan Mound Site from September 1983 to August 1984, Texas A&M University and Research Foundation, Volume 1, December 1984.
These data represent dissolved metals.

Table M.1-2 presents a break down of the brine composition data in terms of the number of sample sets available for each site. For the purpose of this summary, a sample set refers to a single column of data in Table M.1-1, regardless of how many constituents have reported concentrations in that column. As indicated by Table M.1-2, the vast majority of available brine composition data are from Bryan Mound.

Table M.1-2
Sites Covered by Available Brine Composition Data

Site	Sample Sets
Bryan Mound	21
Bayou Choctaw	3
West Hackberry	2
Sulfur Mines	1
Big Hill	1
Starks	1
Unspecified	2

Although the data as a whole are more representative of brine from Bryan Mound than the other sites, they enable a comparison of brines originating from five SPR sites. In addition, the available cavern-specific data allow a comparison of brines originating from different caverns at the same SPR site. Bryan Mound and Bayou Choctaw data include cavern-specific records for four (C-1, C-2, C-4, and C-5) and three (BC-6, BC-17, and BC-19) different salt caverns, respectively. As a result, the variability of brine composition at Bryan Mound and Bayou Choctaw can be analyzed.

Most of the sources of brine data do not indicate whether reported concentrations are for dissolved metals or total metals. One of the sources specifies that it provides dissolved metals concentrations and another source specifies that it provides total metals concentrations. Because it generally is not known which data are for total concentrations and which are for dissolved concentrations, these data could not be analyzed separately in the analysis of variance in section M.2 below. Including total metals data in the analysis, however, would be conservative (i.e., leading to a higher estimate of brine toxicity and greater potential impacts) since total metals concentrations are often higher than dissolved metals concentrations.

Several assumptions had to be made in this analysis regarding constituent concentrations that were below detection limits. When detection limits were specified for an undetected quantity, the concentration was reported as less than the detection limit in Table M.1-1 (e.g., <10 or <2 µg/l). In these cases, the full value of the detection limit was used for the purpose of calculating mean concentrations for each constituent. This convention results in an upper bound estimate of constituent concentrations since the actual concentrations of undetected constituents are lower than the full detection limits. In addition, when detection limits were not provided (e.g., values reported as "ND" in Table M.1-1), the data were dropped from further analysis because actual constituent concentrations could not be estimated reasonably. In these cases, sufficient remaining data reporting actual or estimated concentrations were available to complete the statistical analysis. For example, six of the seven sample sets that do not specify detection limits are from Bryan Mound. The 15 other Bryan Mound sample sets that do specify detection limits provide a sufficient amount of data that can be used in lieu of the Bryan Mound data for which no detection limits are reported.

M.2 Analysis of Variance

The analysis of variance (ANOVA) model is a statistical tool for studying the relationship between a dependent variable (e.g., chemical concentrations) and one or more independent variables (e.g., SPR sites and caverns). For a group of SPR sites or caverns, the ANOVA model determines the variability in each chemical's concentration and correlates this variability to random error and to the variation of SPR sites and caverns. Once these correlations are established, the mean concentration of each chemical is calculated for the group of SPR sites and caverns. Differences within this group are then assessed by comparing each chemical's mean value to the chemical's variability within the group.

In order to conduct an analysis of variance, certain data requirements needed to be addressed. First, the ANOVA model operates on the assumption that data are distributed normally. Since these brine concentration data do not satisfy this assumption, they were transformed to logarithmic values, which fit a normal distribution more closely. Therefore, this analysis of variance was performed on the logarithmic values of the concentrations reported in Table M.1-1.

At the same time, an analysis of variance can only be conducted for those constituents with data in each sample set analyzed. In other words, a comparison of three sample sets is limited to those constituents with data in all three sample sets; it cannot include a constituent that is covered by only one or two of the three sample sets. Unfortunately, no sample set in the data has reported concentrations for all constituents, either because of missing data or because detection limits were not specified. Therefore, a comparison between SPR sites or caverns was conducted for only a portion of the constituents for which relatively complete data were available. For example, the analysis of the four Bryan Mound salt caverns can only be done for four constituents (i.e., calcium, chloride, sodium, and sulfate), while the analysis of the C-1 and C-4 caverns can be extended to barium and iron.

This analysis was conducted in two parts. The first part included an analysis of variance of the Bryan Mound and Bayou Choctaw cavern-specific data to determine whether brine composition varies with the cavern of origin. The second part included a comparison of site-specific data to determine whether there is a statistical difference in brine composition across different sites. Key findings from these two analyses are summarized below.

- <u>**Analysis of Variance Across Caverns.**</u> An analysis of variance on Bryan Mound's cavern-specific data (C-1, C-2, C-4, and C-5) indicated that no statistical difference exists between brine from the four salt caverns. In contrast, a statistical analysis of Bayou Choctaw's cavern-specific data (BC-6, BC-17, and BC-19) determined that brine from cavern BC-6 is significantly different from brine originating from caverns BC-17 and BC-19. Brine from caverns BC-17 and BC-19 were not found to be significantly different from one another.

- **Analysis of Variance Across Sites.** Again, brine sampled from cavern BC-6 at Bayou Choctaw was determined to be significantly different from all other brine samples. For example, cadmium, magnesium, manganese, and zinc concentrations in brine from cavern BC-6 are several hundred times greater than the concentrations in other brine examined here. A series of analyses of variance on all the brine data, however, found no significant difference between brine generated at Bryan Mound, Big Hill, Sulfur Mines, West Hackberry, Starks, and caverns BC-17 and BC-19 at Bayou Choctaw.

These results demonstrate that the composition of the brine samples analyzed here are relatively homogenous across caverns and sites, while the brine from cavern BC-6 at Bayou Choctaw is an aberration. In addition, the results for samples known to represent total metals concentrations and samples known to represent dissolved metals concentrations did not appear to be significantly different from all the other available data. Therefore, if the data for cavern BC-6 are excluded, mean constituent concentrations that are developed using the rest of the data in Table M.1-1 would provide a reasonably accurate estimate of typical concentrations in brine from salt domes in the Gulf of Mexico region. These mean concentrations for a model salt dome brine, presented in Table M.2-1, approximate the concentrations of metals and other inorganics likely to be in brine generated at the five candidate expansion sites considered in this DEIS.

M.3 Hazard Analysis of the Model Brine

This section evaluates the hazard of the model brine developed from the statistical analysis in section M.2 by analyzing its potential to result in harmful levels of metals and other inorganics in the Gulf of Mexico. This evaluation follows four major steps:

- First, the maximum increase in constituent concentrations in the Gulf of Mexico caused by SPR brine discharges is estimated by decreasing the model brine concentrations to account for dilution expected at the diffuser ports (section M.3.1);

- Second, background concentrations of brine constituents in the Gulf of Mexico around SPR diffusers are estimated and added to the increased concentrations potentially caused by brine discharges to estimate the total resulting concentration of each constituent near the diffusers (section M.3.2);

- The estimated concentrations near the diffusers are then compared to ambient water quality criteria (AWQCs) for marine systems (section M.3.3); and

- The bioconcentration potential of the brine constituents is evaluated (section M.3.4).

Table M.2-1
Concentrations of Metals and Other Inorganics in a Typical SPR Brine

Constituent	Model Brine Concentration
Major Constituents (mg/l)	
Sodium (Na)	116,729
Potassium (K)	362
Chloride (Cl)	184,942
Sulfate (SO_4)	2,022
Calcium (Ca)	603
Magnesium (Mg)	156
Minor Constituents (µg/l)	
Aluminum (Al)	<26.1
Antimony (Sb)	<2
Arsenic (As)	<3.8
Barium (Ba)	<692.4
Cadmium (Cd)	<2.9
Chromium (Cr)	<2.6
Cobalt (Co)	<0.5
Copper (Cu)	<190.8
Iron (Fe)	2,583
Lead (Pb)	<28
Mercury (Hg)	<1
Nickel (Ni)	<44.8
Manganese (Mn)	219.3
Silver (Ag)	<10
Strontium (Sr)	7,000
Titanium (Ti)	<100
Zinc (Zn)	<67.2

M.3.1 Brine Dilution at the Diffuser

It would be overly conservative to compare the model brine concentrations directly to AWQCs because the brine is significantly diluted as it exits the diffuser in the Gulf of Mexico. Gulf organisms would not be exposed to the full brine strength, but to much reduced concentrations.

To predict the increased chemical concentrations in the Gulf after brine exits the diffuser, the model brine concentrations in Table M.2-1 were decreased by a dilution factor. This factor was derived by assuming that dispersion of the brine's metals and other inorganic constituents can be approximated by the dispersion of the brine's salinity. With this assumption, the dilution factor could be estimated as follows:

Dilution Factor = Brine Salinity Prior to Discharge/Above Ambient Salinity Observed in the Gulf

To estimate the dilution factor in this manner, brine salinity and ambient salinity data obtained during brine plume monitoring at Bryan Mound were used.[1] As a conservative scenario, the analysis included an average brine salinity of 258 ppt and the highest excess salinity contour measured in brine plume monitoring at the Bryan Mound diffuser. This scenario represents the least amount of dispersion and, therefore, leads to relatively high levels of brine constituents at the diffuser. The highest excess salinity measured was a 7 ppt above-ambient salinity contour covering a 0.5 km^2 (123 acre) area around the diffuser. Using these values:

Dilution Factor = 258/7 = 36.9

Dividing the model brine concentrations in Table M.2-1 by this dilution factor yields an estimate of the increased concentrations of brine constituents within a 0.5 km^2 area surrounding the diffuser. These diluted brine concentrations "after diffusion" are presented in Table M.3-1. The constituent concentrations would be smaller at greater distance from the diffuser. As a result, the dilution factor and reported brine concentrations after diffusion only represent conditions likely to exist near the diffuser.

M.3.2 Background Levels in the Gulf of Mexico

Background concentrations must be added to the diluted brine concentrations in order to estimate the total metal concentrations near each diffuser. The background level was estimated for each constituent by calculating the mean of background concentrations reported for various monitoring stations in the Gulf of Mexico (e.g., background monitoring stations at Bryan Mound, West Hackberry, Big Hill, Weeks Island, and Chacahoula). While these background levels may be representative of a large area in the Gulf of Mexico, it is uncertain how well they represent conditions that exist at any particular site. For example, background levels at a particular site can be influenced significantly by outfalls from rivers and offshore oil field activity. Therefore, background levels at the five candidate expansion sites considered in this DEIS may actually be higher or lower than the background levels estimated for this analysis. Table M.3-1 presents the estimated background levels of brine constituents in the Gulf along with the estimated total levels, which represent the sum of the diluted brine and background levels.

Table M.3-1
Comparison of Predicted Chemical Concentrations in the Gulf of Mexico to Ambient Water Quality Criteria (AWQC)

CONSTITUENT	LEVEL IN BRINE	AFTER DIFFUSION (BRINE/36.9)	"BACKGROUND" LEVELS IN GULF	ESTIMATED FINAL LEVELS	MARINE AWQC	
					ACUTE	CHRONIC
Major (mg/l)						
Sodium (Na)	116,729	3,167	9,580	12,747		
Potassium (K)	362	9.8	370	379.8		
Chloride (Cl)	184,942	5,017	17,020	22,037		
Sulfate (SO_4)	2,022	55	2,600	2,655		
Calcium (Ca)	603	16.3	370	386.3		
Magnesium (Mg)	156	4.1	920	924.1		
Minor (µg/l)						
Aluminum (Al)	<26.1	<0.7	7.0	<7.7	750[1,2]	87[1,2]
Antimony (Sb)	<2	<0.1	10.0	<10.1	9,000[1]	16,000[1]
Arsenic (As)	<3.6	<0.1	20	<20.1	69[3]	36[3]
Barium (Ba)	<692.4	<18.6	NA	<18.6		
Cadmium (Cd)	<2.9	<0.1	0.3	<0.4	43	9.3
Chromium (Cr)	<2.6	<0.1	4.1	<4.2	1,100[4]	50[4]
Cobalt (Co)	<0.5	<0.01	NA	<0.02		
Copper (Cu)	<150.8	<5.7	2.0	<7.7	2.9	2.9
Iron (Fe)	2,583	70.1	11.5	81.6	NA	1,000[1]
Lead (Pb)	<25	<0.8	1.8	<2.6	140	5.6
Mercury (Hg)	<1	<0.03	0.3	<0.33	2.1	0.025
Nickel (Ni)	<44.8	<1.2	2.5	<3.7	75	8.3
Manganese (Mn)	219.3	5.9	3.9	9.8		
Silver (Ag)	<10	<0.3	0.5	<0.8	2.3	NA
Strontium (Sr)	7,000	190	NA	>190		
Titanium (Ti)	<100	<2.7	NA	<2.7		
Zinc (Zn)	<67.2	<1.8	4.4	<6.2	96	86

[1] Freshwater AWQCs are used in the absence of marine AWQCs
[2] Value presented is Lowest Observed Effect Level (LOEL) in the absence of a AWQC
[3] AWQC applies to trivalent form of arsenic
[4] AWQC applies to hexavalent form of chromium

M.3.3 Comparison to AWQC

Because AWQCs are not available for all constituents, DOE evaluated the brine's hazard in two different ways. For constituents with AWQCs, the estimated final contaminant levels at the diffuser were compared with the AWQCs. When AWQCs are not available, the incremental increase of the constituents due to the brine discharge was compared to the background level.

Table M.3-1 indicates that, of the 12 constituents with AWQCs, all but two are estimated to exist in concentrations below the criteria near the diffuser. For the two at issue — copper and mercury — the analysis does not show that the resulting concentrations are above the AWQCs, only that they may be above the criteria if it is assumed that the constituents are present in brine at their full detection limit. That is, if copper is actually present in brine at levels well below the detection limits, its predicted concentrations near the diffuser would also fall below the AWQC. Similarly, the predicted mercury concentration would be below the acute criterion, but above the chronic criterion due to the estimated high background levels of mercury.

The estimated copper concentration potentially exceeds both the acute and chronic AWQCs for marine organisms. According to the criteria development documents, if a pollutant's 4-day concentration exceeds its chronic marine AWQC or if its 1-hour average concentration exceeds its acute marine AWQC more than once every 3 years on the average, marine organisms could be detrimentally affected. The estimated copper level in brine (<191.6 μg/l) is highly influenced by one sample set, Bryan Mound's cavern C-1 has a copper content of 3,920 μg/l (see Table M.1-1). Not including this sample in the analysis would decrease the estimated level of copper in the model brine to <28.7 μg/l, and the estimated level of copper at the diffuser (2.7μg/l) would drop below but remain close to the AWQCs. According to the toxicological literature, the acute sensitivities of saltwater organisms to copper range from 5.8 μg/l for the blue mussel to 600 μg/l for the green crab, and the bay scallop was killed in long-term exposures to 5 μg/l of copper.

Conservatively assuming mercury is present in SPR at its full detection limit, the estimated concentration of mercury at the diffuser (<0.33 μg/l) could exceed the chronic AWQC by more than a factor of ten. A large portion of this estimated concentration, however, is due to mercury's background level, which by itself exceeds the chronic AWQC. The estimated mercury level in the undiluted brine (<0.03 μg/l) approaches the chronic AWQC, but the actual mercury concentration in the brine could be well below the chronic AWQC prior to dilution.

Of the remaining 11 constituents that do not have AWQCs, only three were estimated to be added to Gulf waters at levels that are relatively high compared to background levels. Estimated increases in sodium and chloride concentrations due to brine discharges are approximately one-third as high as the background levels. These constituents are key contributors to the excess salinity plumes created by the SPR brine discharges. The estimated increase in manganese is 1.5 times the background level and the estimated increase in iron is six times the background level. In addition, although a background concentration for strontium is not available, the brine discharges would appear to contribute a relatively high level of strontium to the Gulf.

M.3.4 Bioconcentration Potential

There is a potential concern that metals released to the Gulf in SPR brine could concentrate in aquatic organisms through direct exposure to the plume near the diffuser (i.e., bioconcentration). Such bioconcentration could have the effect of transferring the brine constituents to a different and larger area. A common measure of the potential for a chemical to bioconcentrate is the bioconcentration factor (BCF), defined as the concentration of a chemical in tissue divided by the concentration in water. Table M.3-2 presents the ranges of marine BCFs reported in the literature for metals that may be found in SPR brine.

Table M.3-2
Summary of Metals Analysis

CONSTITUENTS	LEVEL ABOVE AWQC AT DIFFUSER?	AWQC ACCOUNT FOR MARINE BCF?	MARINE BCF
Aluminum	No	No	50 - 231[1]
Antimony	No	No	390
Arsenic	No	No	350
Barium	--	--	0.006 - 0.3
Cadmium	No	No	5 - 3,160
Chromium	No	No	86 - 153
Cobalt	--	--	4,000
Copper	Yes	No	28,200
Iron	No	No	1,800 - 30,000
Lead	No	No	17.5 - 2,570
Mercury	Yes	Yes	10,000 - 40,000
Nickel	No	No	261.8 - 675
Manganese	No	Yes[2]	12,000
Silver	No	No	<1 - 240[1]
Strontium	--	--	--
Titanium	--	--	--
Zinc	No	No	3.7 - 23,820

[1] Because marine BCFs are not available, the freshwater BCF is presented.
[2] The BCF was used to calculate a criterion established to protect consumers of marine molluscs.

Bioconcentration is sometimes taken into account in the development of AWQCs. In these cases, contaminant concentrations that fall below the AWQC are also "safe" with respect to bioconcentration. However, most AWQCs do not explicitly account for bioconcentration. In these cases, even though a contaminant concentration may fall below the AWQC, it cannot be concluded that the contaminant does not pose a bioconcentration threat (i.e., that it could not accumulate in harmful levels in the tissue of organisms). According to the AWQC development documents for brine metals, only the AWQCs for mercury and manganese clearly account for bioconcentration (see Table M.3-2). In the case of manganese, it is actually an EPA-recommended limit, not an AWQC, that is based in part on a concern that manganese bioconcentrates in the edible portions of molluscs. Therefore, in addition to evaluating the brine concentrations relative to the AWQC as in section M.3.3 above, it is also necessary to evaluate the potential for brine constituents to bioconcentrate.

In general, inorganics do not bioconcentrate as readily as many organics. For example, the BCF for DDT is on the order of 4 million, although this is an extreme value much higher than the BCF for other organics. Table M.3-2 shows that mercury has a greater potential than the other brine constituents to bioconcentrate in aquatic organisms. Because the predicted level of mercury could exceed the chronic AWQC and because the chronic AWQC for this constituent accounts for bioconcentration, the potential for the bioconcentration of mercury exists. However, the estimated background level of mercury by itself already exceeds the chronic AWQC and the contribution of mercury by brine diffusion may be relatively minor.

The BCF for manganese is moderately high (12,000). The recommended criterion for manganese, 100 µg/l, accounts for a BCF since the criterion was established for the protection of consumers of marine molluscs. The predicted level of manganese at the diffuser, 14 µg/l, is well below the recommended criterion, suggesting that manganese levels contributed by brine discharges do not pose a significant bioconcentration threat.

Table M.3-2 also shows that copper, iron, and zinc have a relatively high tendency to bioconcentrate. Brine disposal may contribute a significant amount of copper and iron in relation to background levels. Aluminum, antimony, arsenic, cadmium, chromium, cobalt, lead, nickel, and silver have only small tendencies to bioconcentrate, while barium is very unlikely to bioconcentrate. BCF data are not available for strontium and titanium; therefore, it cannot be determined whether brine disposal could present a bioconcentration threat from the standpoint of these two constituents.

M.4 Conclusion

Based on this analysis, the metals and other inorganics likely to be discharged to the Gulf of Mexico along with brine from the candidate SPR expansion sites do not appear to represent a significant environmental threat. Conservatively estimated concentrations of virtually every constituent near (within 0.5 km^2 of) the diffuser are estimated to be below EPA criteria to protect marine organisms. The possible exceptions are copper and mercury, but actual copper concentrations are likely to be lower than the conservative values estimated in this analysis and mercury appears to be a problem due to elevated background levels rather than due to SPR brine discharges. Mercury is also a potential concern because of its strong tendency to bioconcentrate. The other brine constituents are significantly less likely to bioconcentrate than mercury, although manganese, copper, iron, and zinc may also tend to bioconcentrate.

ENDNOTES

1. Hann, R.W., Jr., C.P. Giammona, and R.E. Randall, eds., *Offshore Oceanographic and Environmental Monitoring Services for the Strategic Petroleum Reserve: Annual Report for the Bryan Mound Site from September 1983 through August 1984, Volume I*, Texas A&M University and Research Foundation for U.S. Department of Energy, TX, December 1984.

APPENDIX N

HISTORY OF RAW WATER INTAKE AT BIG HILL

Of the five candidate SPR expansion sites considered in this DEIS, only Big Hill has had any prior experience withdrawing raw water for cavern leaching. The source of Big Hill's raw water has been the ICW, as described in detail in section 5.1.3. This appendix reviews the history of raw water intake at Big Hill. It starts with a summary of the Big Hill water use permits and compliance record (section N.1) and then reviews available results regarding the impacts of Big Hill's raw water withdrawals on the ICW (section N.2).

N.1 Big Hill Water Use Permits and Compliance Record

This section outlines the permit limits for Big Hill's raw water intake. It also summarizes the Big Hill water use history and permit compliance.

N.1.1 Water Use Permits for Big Hill

The permit granted by the Texas Water Commission in November 1983 specified raw water intake (RWI) limits for leaching and drawdown phases at Big Hill. At DOE's request, the permit was amended in November 1990 to allow greater intake than originally permitted. Permitted withdrawals are presented in Table N.1-1.

Table N.1-1
Raw Water Withdrawal Permit History at Big Hill

Permit	Permit Limits		
	Total Allocation (million barrels)	Yearly Maximum (million barrels per year)	Maximum Diversion Rate (cubic feet per second)
Texas Water Commission permit 4045, November 1983	Leaching: 1,118 Drawdown: 733	Leaching: 284 Drawdown: 244	90.9
Texas Water Commission permit 4045, as amended November 1990	Leaching: 1,526 Drawdown: 786	Leaching: 542 Drawdown: 366	175

Source: Texas Water Commission Permit 4045.

In 1990, the design capacity of the Big Hill facility was expanded from 140 to 160 million barrels to accommodate the decommissioning of the Sulphur Mines site.[1] This modification increased Big Hill's total demand for raw water, extending the duration of raw water intake for development and operational phases without changing the intake rate (see Table N.1-2).

In addition to the permitted raw water intake, raw water used to clean the fire protection system passes thorough a filter called a hydroclone before release to the ICW at the intake station. A permit regulating this release requires only that the volume and total suspended solids be reported and that the pH be between 6.0 and 9.0.[2]

Table N.1-2
Change in Duration of Raw Water Intake at Big Hill
Due to Expanded Storage Capacity for Sulphur Mines Decommissioning

Mode	Duration for 140 Million Barrels (days)	Duration for 160 Million Barrels (days)
Leach	1,105	1,287
Drawdown	150	173

Source: SPR, *Sulphur Mines Decommissioning and Big Hill Expansion*, Calcasieu Parish, Louisiana and Jefferson County, Texas

N.1.2 Water Use History

Phase III development at Big Hill included leaching 14 storage caverns with a total capacity of 140 million barrels. Cavern leaching was expected to require 687,000 barrels per day for 38 months.[3] Leaching began in October 1987[4] and was completed in September 1991. As shown in Tables N.1-3 and N.1-4, the quantity of raw water taken in each year for leaching at Big Hill has exceeded the annual permit limit; but the diversion rates have been well below the permit levels.[5]

Table N.1-3
Annual Raw Water Intake for Leaching and Permit Compliance at Big Hill

Year	Actual Intake[a] (million barrels)	Permit Limit (million barrels per year)	Percent Over Limit
1988	292	284	3%
1989	450	284	58%
1990	379	284[b]	34%

[a] Source: Boeing Petroleum Services, Inc., monthly brine discharge and raw water reports.
[b] Permit limit changed on 11/11/90 to 542 million barrels per year.

Table N.1-4
Average Raw Water Diversion Rates for Leaching and Permit Compliance at Big Hill

Year	Average Diversion Rate[a] (cubic feet per second)	Permit Limit (cubic feet per second)	Percent Under Limit
1988	58	90.9	36%
1989	83	90.9	9%
1990	70	90.9[b]	23%

[a] Source: Boeing Petroleum Services, Inc., monthly brine discharge and raw water reports.
[b] Permit limit changed on 1/7/90 to 175 cubic feet per second.

The operational aspects of raw water intake for the drawdown phase will be identical to those for leaching, but the rate of intake will be greater. Drawdown after completion of the proposed expansion is expected to require up to 1.5 million barrels of raw water per day (63 million gallons per day). This is 50 percent more than the drawdown rate of 1 million barrels per day permitted for existing operations.[6]

In addition, raw water is used to clean the Big Hill fire protection system. Waste water from this process is designed to be released to the ICW at the RWI structure. To date, however, no such effluent has been released.[7]

N.2 Impacts of Historical Operations

Prior to operations at Big Hill, hydrologic models were used to assess changes to hydrology and salinity in the ICW resulting from raw water intake. Because hydrological parameters (depth, flow, etc.) have not been monitored since raw water intake was initiated at Big Hill, these model results remain the best source of data for hydrological impact assessment. Water quality monitoring data collected during leaching, however, can be used in conjunction with the modeling predictions to assess actual observed impacts to water quality.

N.2.1 Hydrological Impacts

A large withdrawal of water may, in theory, affect the flow, current velocity, and depth of the ICW. The maximum withdrawal permitted by the Texas Water Commission during Phase III leaching was 91 cubic feet per second, which is about 2.3 percent of the typical maximum ICW flow. Using this withdrawal rate as an input, Texas A&M University adapted and used a computer model in 1983 to predict hydrological impacts associated with the proposed raw water intake at Big Hill. This modeling analysis projected that the hydrological impacts would be minor. In the western reach of the ICW from East Galveston Bay to the RWI structure, the estimated maximum daily depth change in the first ten days of withdrawal was a decrease of 0.02 feet. East of the RWI structure to Shell Lake, the maximum decrease was predicted to be 0.04 feet. In the eastern most reach of the ICW from Shell Lake to the Port Arthur Canal, the estimated maximum decrease was 0.01 feet.[8]

These results from the Texas A&M modeling analysis are similar to modeling results obtained from a separate analysis in 1981 using the MIT Water Quality Network Model. The Texas A&M and MIT models analyses were similar in that they modeled salinity and depth in the ICW system from Galveston Bay to the Port Arthur Canal. The Texas A&M model, however, included a more detailed simulation of tributary inputs to the eastern ICW. Results from the MIT modeling analysis indicated that water depth would reach equilibrium within a single day of the start of withdrawal and that the maximum decrease in depth at the intake point would be 0.04 feet. Water velocity was predicted to increase 0.03 feet per second at the RWI structure, and to increase a maximum of 0.05 feet per second at the western end of the ICW.[9]

These models appear to reasonably represent the historical intake operation at Big Hill. Both models were specifically developed to assess impacts of planned raw water intake for operations at Big Hill. The Texas A&M model used an assumed diversion rate of 91 cubic feet per second, the originally permitted diversion rate. Because the average diversion rates during leaching at Big Hill have been well below the modeled diversion (Table N.1-4), the impacts of historical operations would tend to be less than the impacts predicted by modeling. Additionally, the actual diversion rates have been well below the amended permit limit of 175 cubic feet per second. These model results are supported by the fact that no obvious impacts to ICW hydrology have been observed.

N.2.2 Water Quality Impacts

Water quality impacts associated with historical raw water intake at Big Hill can be evaluated by a review of: (1) previous modeling results; and (2) field data collected since raw water withdrawal was initiated. Conclusions from these two sources of information are summarized separately below.

N.2.2.1 Modeled Impacts

Hydrological alterations to the ICW may in turn affect water quality. Of particular importance to biota are shifts in the salinity gradient. Salinity changes in the ICW due to raw water intake were evaluated using both the Texas A&M and the MIT Water Quality Network models. Results of the Texas A&M model indicate that a maximum daily salinity decrease of 0.306 ppt would occur in the western ICW between East Galveston Bay and the RWI structure. East of the RWI structure to Shell Lake, the Texas A&M model projected a maximum daily decrease in salinity of 0.086 ppt. From Shell Lake to the Port Arthur Canal, the model predicted that salinity would increase by a maximum of 0.001 ppt.[10]

Results from the MIT Water Quality Network model also indicate that the raw water intake would have a negligible impact on salinity levels in the ICW. Results from the two models, however, differ in terms of the predicted directions of salinity changes in certain sections of the ICW. Unlike the Texas A&M model, the MIT Water Quality Network model indicated that raw water intake would result in an increase in salinity in the western ICW. These results indicated that salinity would equilibrate within 10 days. Also, the results predicted that, on the 50th day from the start of withdrawal, salinity at the RWI structure would change less than 1 ppt. The maximum salinity change in the ICW would be an increase of 1.8 ppt near the far western end of the ICW.[11] East of the RWI structure, the MIT Water Quality Network model predicted that changes in salinity would be insignificant for a distance of 7.6 miles. Beyond 7.6 miles, salinity was predicted to increase a small amount from the baseline. The greatest salinity increase east of the RWI structure was predicted to be 0.21 ppt at the intersection of the Port Arthur Canal and the ICW.

Discrepancies between the two sets of model predictions may be explained by the differences in freshwater sources included in the models. The Texas A&M model analysis considered tributaries and lakes near the eastern ICW;[12] the MIT modeling analysis considered only Spindletop Ditch and a constant lateral inflow over the entire length of the ICW from East Galveston Bay to the Port Arthur Canal.[13] Another possible explanation for the discrepancies is the time period represented. The MIT results are reported for the 50th day of withdrawal; the Texas A&M results are reported for the first ten days of withdrawal.

These model predictions are based on an assumed set of conditions that appear to be a reasonable representation of the conditions that have actually existed since the intake began. Therefore, they still appear to be a valid indicator of the actual water quality impacts and, as discussed in the following section, have been validated by field monitoring data.

N.2.2.2 Monitoring Results

Since 1989, DOE has monitored salinity and other water quality parameters at the RWI structure during the periods when water has been withdrawn from the ICW. These monitoring results can be compared to water quality data collected near the RWI structure prior to Big Hill development to assess actual impacts of Phase III leaching (Table N.2-1). The extent of the comparison is limited, however, by small sample sizes. Data prior to leaching are based on two samples collected at the RWI structure in separate studies and one sample collected elsewhere in the ICW. Monitoring data during the leaching phase are based on ten samples collected between July 1989 and November 1990, at intervals of at least one month.

Recognizing the limited quantity of data, the water quality observed prior to and during leaching is quite similar. Salinity has varied roughly from 1 to 12 ppt both prior to and during leaching. This range is typical of euryhaline gulf estuaries. Biota inhabiting these estuaries are adapted to wide salinity ranges[14] and are not likely to be affected adversely by the minor (if any) changes in salinity due to the raw water intake. Also, temperature, dissolved oxygen, pH, and total organic carbon appear to change insignificantly during leaching. During the leaching period, temperature and total organic carbon have varied widely, but the mean observed values have been essentially the same as the values observed in the ICW prior to leaching. Mean dissolved oxygen and pH levels observed during leaching also are very similar to the pre-withdrawal levels.

The Texas Water Commission also collected surface water quality data from the ICW in the Big Hill area prior to and during leaching[15] and reported no changes in water quality parameters. The only monitored parameter that did not meet water quality criteria was dissolved oxygen. The water quality values reported by the Texas Water Commission are similar to the Big Hill monitoring results summarized above (Table N.2-2).

Table N.2-1
Observed and Predicted Water Quality Changes in the ICW Caused by Raw Water Intake at Big Hill

Parameter	Observed and Predicted Changes in Parameter		
	Observed at RWI Prior to Leaching (pre-October 1987)	Observed at RWI During Leaching (July 1988 to December 1990)[b]	Predicted Maximum Changes During Leaching
Salinity (ppt)	max: 12.2[a] mean: 4.4 min: 0.2[a]	max: 12.0 mean: 7.1 min: 1.1	MIT model[c]: at RWI: change < 1.0 ppt west ICW: + 1.6 ppt Texas A&M model[f]: west ICW: - 0.306 ppt middle ICW: - 0.086 ppt east ICW: + 0.001 ppt
Flow velocity (feet/second)			MIT model[c]: at RWI: + 0.08 ft./sec. west ICW: + 0.05 ft./sec.
Depth (feet)			MIT model[c]: at RWI: - 0.04 ft. Texas A&M model[f]: west ICW: - 0.02 ft. middle ICW: - 0.04 ft. east ICW: - 0.01 ft.
Temperature (degrees C)	29.5[d] 20.0[e]	max: 32 mean: 25 min: 11	
Dissolved oxygen (mg/l)	8.06[d] 7.0[e]	max: 8.4 mean: 8.0 min: 5.2	
pH	6.75[d] 8.7[e]	max: 7.6 mean: 7.0 min: 5.9	
Total organic carbon (mg/l)	9[e]	max: 21.0 mean: 9.0 min: 0.0	
Conductivity (umho/cm)	250[d] 1,300[e] 1,900[e]		
Turbidity (JTU)	55[e]		

a Source: SPR, *Final EIS, Phase III*, Table 3-2

b Source: Boeing Petroleum Services, *1991 Site Environmental Report*

c Source: *Final EIS, Phase III*, Appendix B. Values reported are projected increases (+) or decreases (-) of parameter values on the 50th day of intake relative to the day just prior to intake (day 0).

d Source: *Final EIS, Phase III*, Table D.6-2

e Source: *Final EIS, Phase III*, Table D.6-4

f Source: Texas A and M University and Research Foundation, *SPR Brine Disposal Studies in the Gulf of Mexico*. Values reported are the average projected increases (+) or decreases (-) of the parameter during model days 9 through 10 of withdrawal relative to the average for the simulated period without withdrawal.

Table N.2-2
Surface Water Quality in the ICW Near the Big Hill Site, as Measured by the Texas Water Commission (TWC)

Parameter	Water Quality Criteria[a]	Observed in ICW by TWC (October, 1985 to September, 1989)[b]	Big Hill Monitoring Data (July, 1988 to December, 1990)[c]
Dissolved oxygen (mg/l)	4.0	max: 10.3 mean: 5.7 min: 2.3	max: 8.4 mean: 8.0 min: 5.2
Temperature (°C)	35.0	max: 31.0 mean: 19.1 min: 6.5	max: 32 mean: 23 min: 11
pH	6.5 to 9.0	max: 8.1 mean: 7.5 min: 6.5	max: 7.6 mean: 7.0 min: 5.9
Salinity (ppt)	N/A	max: 24.9 mean: 9.3 min: 0.8[d]	max: 12.0 mean: 7.1 min: 1.1

a State of Texas Water Quality Criteria.
b Source: The State of Texas Water Quality Inventory, TWC, 1990.
c Source: Boeing Petroleum Services, 1991 Site Environmental Report.
d Salinities converted from reported chlorinities.

N.2.3 Direct Impacts to Biota

The most important direct impact of the raw water intake on the ICW ecosystem is the potential for entrainment of aquatic organisms. The raw water intake was designed to limit entrainment. Fish and other large animals are blocked from the intake by trash bars and traveling screens with a 0.5-inch mesh. Furthermore, the intake velocity of 0.5 feet per second is slower than the swimming speed of most fish.[16] Live macrocrustaceans are collected from the traveling screens each hour during operation and are returned to the ICW. Small organisms able to pass through the 0.5-inch screens are unavoidably entrained. Such organisms include phytoplankters, zooplankters, larval fish, and benthic organisms. Entrainment of these organisms is considered a minor impact[17] because the volume of water removed from the ICW contains only a small portion of the planktonic community of the ICW and associated wetlands.

ENDNOTES

1. U.S. Department of Energy, *Strategic Petroleum Reserve, Sulphur Mines Decommissioning and Big Hill Expansion, Calcasieu Parish, Louisiana, and Jefferson County, Texas, Environmental Assessment*, Washington, DC, January 1990, Document Number DOE/EA-0401.

2. Boeing Petroleum Services, Inc., *1988 Annual Environmental Monitoring Report, U.S. Department of Energy, Strategic Petroleum Reserve*, U.S. Department of Energy, New Orleans, LA, June 1989, Document Number D506-02197-09.

3. U.S. Department of Energy, *Strategic Petroleum Reserve, Final Environmental Impact Statement. Texoma Group Salt Domes (West Hackberry Expansion, Black Bayou, Vinton, Big Hill), Cameron and Calcasieu Parishes, Louisiana and Jefferson County, Texas*, November 1978, Document Number DOE/EIS-0029.

4. Boeing Petroleum Services, Inc., *1989 Annual Environmental Monitoring Report, U.S. Department of Energy, Strategic Petroleum Reserve*, U.S. Department of Energy, New Orleans, LA, June 1990, Document Number D506-02502-09.

5. Texas Water Quality Commission, *Texas Water Commission Permit 4045*, amended November 11, 1991.

6. *Ibid.*

7. Boeing Petroleum Services, Inc., *1988 Annual Environmental Monitoring Report, U.S. Department of Energy, Strategic Petroleum Reserve*, U.S. Department of Energy, New Orleans, LA, June 1989, Document Number D506-02197-09.

   Boeing Petroleum Services, Inc., *1989 Annual Environmental Monitoring Report, U.S. Department of Energy, Strategic Petroleum Reserve*, U.S. Department of Energy, New Orleans, LA, June 1990, Document Number D506-02502-09.

   Boeing Petroleum Services, Inc., *1990 Annual Site Environmental Report, U.S. Strategic Petroleum Reserve*, U.S. Department of Energy, Strategic Petroleum Reserve Project Management Office, New Orleans, LA, June 1991, Document Number D506 02799-09.

8. Texas A&M University and Research Foundation, *Strategic Petroleum Reserve Brine Disposal Studies in the Gulf of Mexico: Technical Directive #1: Salinity Changes in Surface Waters Associated with the Big Hill Strategic Petroleum Reserve Site*, September 1983.

9. U.S. Department of Energy, *Strategic Petroleum Reserve, Final Supplement to Final Environmental Impact Statement, Phase III Development, Texoma and Seaway Group Salt Dome (Cameron Parish, Louisiana and Brazoria and Jefferson Counties, Texas)*, October 1981, Document Number DOE/EIS-0075.

10. Texas A&M University and Research Foundation, *Strategic Petroleum Reserve Brine Disposal Studies in the Gulf of Mexico: Technical Directive #1: Salinity Changes in Surface Waters Associated with the Big Hill Strategic Petroleum Reserve Site*, September 1983.

11. U.S. Department of Energy, *Strategic Petroleum Reserve, Final Supplement to Final Environmental Impact Statement, Phase III Development, Texoma and Seaway Group Salt Dome (Cameron Parish, Louisiana and Brazoria and Jefferson Counties, Texas)*, October 1981, Document Number DOE/EIS-0075.

12. Texas A&M University and Research Foundation, *Strategic Petroleum Reserve Brine Disposal Studies in the Gulf of Mexico: Technical Directive #1: Salinity Changes in Surface Waters Associated with the Big Hill Strategic Petroleum Reserve Site*, September 1983.

13. U.S. Department of Energy, *Strategic Petroleum Reserve, Final Supplement to Final Environmental Impact Statement, Phase III Development, Texoma and Seaway Group Salt Dome (Cameron Parish, Louisiana and Brazoria and Jefferson Counties, Texas)*, October 1981, Document Number DOE/EIS-0075.

14. *Ibid.*

15. Texas Water Quality Commission, *The State of Texas Water Quality Inventory*, tenth edition, 1990, Document Identification Number LP90-06.

16. U.S. Department of Energy, *Strategic Petroleum Reserve, Final Supplement to Final Environmental Impact Statement, Phase III Development, Texoma and Seaway Group Salt Dome (Cameron Parish, Louisiana and Brazoria and Jefferson Counties, Texas)*, October 1981, Document Number DOE/EIS-0075.

17. *Ibid.*

APPENDIX O

WATER QUALITY IMPACTS CAUSED BY ENHANCED SOIL EROSION FROM SITE CONSTRUCTION ACTIVITIES

O.1 Introduction

As discussed in Chapter 2 of this DEIS, construction of the selected expansion sites will include a variety of site preparation activities. Large portions of the sites will first be cleared of surface vegetation and other material and then grubbed. Grubbing includes the removal of roots, stumps, brush, general debris, and in many cases, topsoil. Grading and general embankment, stabilization, and compaction operations will begin as soon as clearing and grubbing of the site are completed. All of these site preparation activities will temporarily expose the land surface to the elements and potentially lead to enhanced soil erosion. Depending on the specific conditions at each site, the soil may migrate into nearby surface water bodies and cause adverse water quality impacts.

To determine the potential water quality impacts of this enhanced soil erosion, two distinct aspects must be analyzed:

(1) The amount of eroded soil that may enter nearby water bodies, and

(2) The resulting suspended solids concentrations in affected waters.

This appendix analyzes both of these aspects of the potential problem. Section O.2 estimates the magnitude of potential soil loss due to runoff during construction of the candidate expansion sites, the expanded terminal at St. James, and the new terminal at Pascagoula. This section also identifies surface water bodies that are likely to receive eroded soil from each site, and estimates the amount of soil that may actually reach the nearest surface waters. Section O.3 of this appendix addresses the resulting increase in suspended solids concentrations in the affected water bodies.

O.2 Estimation of Soil Erosion Potential

The U. S. Department of Agriculture (USDA) universal soil loss equation (USLE), developed by Wischmeier and Smith, is widely used to estimate soil erosion on construction sites and farm land.[1] The USLE estimates average annual soil loss as the product of six quantifiable factors, as follows:

$$A = R \cdot K \cdot L \cdot S \cdot C \cdot P$$

Where:
- A = Average annual soil loss, in tons/acre/year
- R = Rainfall factor, dimensionless
- K = Soil erodibility factor, tons/acre per unit of R
- L = Length-slope factor, dimensionless
- S = Slope-steepness factor, dimensionless
- C = Cover management factor, dimensionless
- P = Erosion control practice factor, dimensionless

Values for each of the input parameters in the USLE can be obtained from readily available figures and tables, if a few site-specific parameters are known. Section O.2.1 describes the sources and rationale used to obtain values for each of the USLE input parameters at the five candidate expansion sites, the St. James Terminal, and the Pascagoula Terminal. Section O.2.2 uses these input values to estimate the total mass of soil that may be lost from each site during the construction phase. Finally, section O.2.3 estimates the fraction of this lost soil that may actually migrate into a nearby water body.

O.2.1 Input Values

Values for each of the USLE input parameters are derived in turn below for the five candidate expansion sites, the St. James Terminal, and the Pascagoula Terminal.

O.2.1.1 Rainfall Factor (R)

This factor expresses the erosion potential of average rainfall in a given locality. It accounts for two physical processes: the kinetic energy of rainfall that detaches soil, and the turbulent surface flow produced by an excess of rainfall over infiltration that moves soil from a field. This factor is usually calculated from local climatological data and can be obtained from local Soil Conservation Offices or from regional maps showing the distribution of this parameter. For the continental U.S., these values vary from 20 to 550, depending on geographical location. A value of 20 indicates a lesser soil erosion potential (e.g., in the Northwest), and a value of 550 indicates a greater potential for soil erosion (e.g., in the Southeast). Table O.2-1 lists rainfall factors, obtained from the literature, for each site.

Table O.2-1
Rainfall Factors

Site Name	Rainfall Factor (R)
Weeks Island, LA	525
Cote Blanche, LA	525
Big Hill, TX	450
Stratton Ridge, TX	425
St. James Terminal, LA	525
Richton, MS	500
Pascagoula Terminal, MS	550

Source: U.S. DOA, 1978. Predicting Rainfall Erosion Losses.

O.2.1.2 Soil Erodibility Factor (K)

This factor represents the average soil loss for a given soil type in a unit plot (a plot 72.6 feet long with 9 percent slope). It is a site-specific parameter that can be obtained from the local Soil Conservation Service office. The factor typically ranges from 0.05 to 0.6, with 0.6 representing a higher potential for erosion. K values, as a function of USDA soil types and organic matter content, have been tabulated in the literature. For all of the candidate sites, it appears reasonable to assume that the organic matter content of the surface soil is 1 percent, because the surface soils at these sites are likely to be highly vegetated. (Based on the literature, 1 percent is a typical value for the organic matter content of surface soils not saturated with water.) Using this value along with the site-specific soil types, K values have been derived and are presented in Table O.2-2.

Table O.2-2
Soil Types and Erodibility Factors

Site Name	Soil Type	Soil Erodibility Factor (K)
Weeks Island, LA	Silt loam	0.460
Cote Blanche, LA	Silt loam	0.460
Big Hill, TX	Silt loam	0.460
Stratton Ridge, TX	Fine sandy loam	0.334
St. James Terminal, LA	Silty clay loam	0.353
Richton, MS	Sandy loam	0.260
Pascagoula Terminal, MS	Sandy loam	0.260

Source: U.S. EPA, 1982. Evaluating Cover Systems for Solid and Hazardous Waste.

O.2.1.3 Length-slope and Slope-steepness Factors (LS)

The length-slope factor (L) is the ratio of soil loss from the field slope length to that from a 72.6-foot length of the same soil type and gradient. The slope-steepness factor (S) is the ratio of soil loss from the field gradient to that from a field with a 9 percent slope. The product of the length-slope factor and the slope-steepness factor is generally referred as the LS factor. The appropriate LS factor can be obtained from the literature using a known percent slope and slope length. Generally, the LS factor is calculated from the known slope length and slope angle using the following formulation:

$$LS=\left(\frac{L_s}{72.6}\right)^m\left(\frac{430x^2+30x+0.43}{6.57415}\right)$$

Where	L_s	=	slope length (feet)
	m	=	0.5 if slope $\geq$ 5 percent
			0.4 if slope = 4 percent
			0.3 if slope $\leq$ 3 percent
	x	=	Sin Θ
	Θ	=	angle of slope

USGS topographic maps were reviewed for each of the candidate expansion sites, the St. James Terminal, and the Pascagoula Terminal. Based on the contours on these maps, each construction site was divided into several slope faces, and for each of the slope faces, slope angles and slope lengths were estimated using the contour and scale information provided on the maps. Table O.2-3 provides the slope angles, slope lengths, and LS parameters calculated for each of the sites.

Table O.2-3
Slopes, Slope Lengths, and LS Values

Site Name	Slope Face	Slope (%)	Slope Length (feet)	LS Factor
Weeks Island	SE1	8.5	820	3.1
	NE	5.0	910	1.6
	SE2	4.0	1180	1.1
	NW	2.0	1090	0.4
Cote Blanche	NE	2.5	1730	0.6
	SE	1.0	3600	0.4
Big Hill	West	2.0	2750	0.5
	East	2.0	2250	0.5
Stratton Ridge	South	0.1	3100	0.2
St. James Terminal	SW	0.1	1200	0.2
Richton	NW	5.0	630	1.4
	West	4.0	1580	1.2
	NE	3.0	1020	0.6
	East	5.0	790	1.5
Pascagoula Terminal	SE	2.5	1010	0.5

Source: USGS Topographic Map.

O.2.1.4 Cover Management Factor (C)

This factor represents the ratio of soil loss from a field cropped under specific conditions to that from clean-tilled, continuous fallow (i.e., a measure of the fraction of the surface that is bare and the type of vegetation). It combines effects of vegetation, crop sequence, management, and agricultural erosion control practices. Proposed construction plans indicate that construction will include clearing and grubbing.[2] These activities will result in fields temporarily without vegetation or special erosion-reducing cover. For such site conditions, the literature recommends a value of 1 for C, the highest possible value. Hence, it has been assumed that no cropping management will be used at any of the sites during construction, although the sites will be re-vegetated in non-occupied areas soon after construction. This approach is considered generally realistic, although slightly conservative (i.e., tending to overestimate actual erosion slightly).

O.2.1.5 Erosion Control Practice Factor (P)

This factor is the ratio of soil loss associated with contouring, stripcropping, or terracing to that with straight-row farming (i.e., up-and-down slope). It is similar to the cover management factor except that it accounts for additional erosion-reducing effects of land management practices that are superimposed on the cultural practices (e.g., contouring and irrigated furrows). For the purpose of this analysis, it has been conservatively assumed that there will be no additional erosion control practices at the candidate sites during construction. Hence, a P value of 1 is used for all sites.

O.2.2 Calculation of Soil Loss During Construction

Using the above values for the six input variables, the USLE can be used to estimate the rate of soil loss per unit area. Table O.2-4 shows sediment yield calculations, on each slope face, for all seven SPR sites of interest.

The total amount of soil erosion (E, in tons) can be calculated knowing the rate of soil loss (A, from Table O.2-4), duration of construction (T, in years), and area of disturbance (A_d, in acres), using the following equation:

$$E = A \cdot T \cdot A_d$$

Calculations deriving the total amount of soil erosion, on each of the slope faces at each of the candidate sites, are provided in the following sections. The areas disturbed due to construction on each slope face have been estimated from USGS site maps and conceptual plans for site-specific construction activities.[3] These areas represent the total area that will be cleared and grubbed as part of <u>initial site preparation activities only</u>, not the entire areas to be occupied by the sites.[4] For example, conceptual plans indicate that a 15-cavern facility will occupy a total of 300 acres, although only 130 acres will need to be cleared and grubbed for initial construction. Although 90 percent or more of the remaining acreage will ultimately be cleared for reasons of security, site drainage, grass cutting, etc., this clearing is not necessary for construction. This additional clearing and grubbing is not considered in this analysis because it will occur in a piece-meal fashion (i.e., sporadically and in small areas at a time), and thus will likely cause only a small amount of additional soil erosion relative to the erosion expected from initial site construction. In addition, construction plans indicate that soil in the cleared and grubbed areas will be exposed

Table O.2-4
Sediment Yield Calculations

Site Name	Slope Face	R	K (tons/acre)	LS	C	P	A (tons/acre/year)
Weeks Island	SE1	525	0.46	3.10	1	1	750
	NE	525	0.46	1.60	1	1	390
	SE2	525	0.46	1.10	1	1	260
	NW	525	0.46	0.40	1	1	100
Cote Blanche	NE	525	0.46	0.60	1	1	140
	SE	525	0.46	0.40	1	1	90
Big Hill	West	450	0.46	0.50	1	1	110
	East	450	0.46	0.50	1	1	110
Stratton Ridge	South	425	0.33	0.20	1	1	30
St. James Terminal	SW	525	0.35	0.20	1	1	30
Richton	NW	500	0.26	1.40	1	1	180
	West	500	0.26	1.20	1	1	160
	NE	500	0.26	0.60	1	1	80
	East	500	0.26	1.50	1	1	200
Pascagoula Terminal	SE	550	0.26	0.50	1	1	70

Note: Due to rounding, reported values for A may not equal exactly the product of the six USLE parameters.

(i.e., not covered), and thus potentially subject to erosion, for about 6 months during construction at all of the candidate sites.

O.2.2.1 Weeks Island

The potential rate of soil loss, as derived in Table O.2-4 above, varies from roughly 100 to 750 tons/acre/year at Weeks Island, depending on which slope face is considered. The areas on each slope face that are likely to be disturbed by initial construction activities and the resulting total amount of soil erosion are shown in Table O.2-5.

Table O.2-5
Areas of Disturbance and Resulting Soil Erosion at Weeks Island

Slope Face	A (tons/ acre/ year)	Area disturbed (acres)	Amount of soil erosion (tons)
SE1	750	27	10,110
NE	390	30	5,870
SE2	260	43	5,610
NW	100	30	1,490
	Total:	130	23,080

The above calculations indicate that 23,080 tons of soil will be lost from about 130 acres during the 6-month construction period. If it is assumed that this soil loss is evenly distributed across the entire construction area, this would result in 1.1 inches (23,080x0.0062/130) of soil loss from a flat surface. These calculations assume a soil density of 2,300 lb/yd^3, which is typical for the silty loam present at Weeks Island. Of this amount, the soil eroded from the SE1 slope face may directly enter Warehouse Bayou, the nearest water body to the site. Soil eroded from the other slopes is likely to be deposited on nearby marsh lands, which according to USGS maps have a very flat surface topography. Some of the soil from the other slopes, however, also may eventually migrate into Warehouse Bayou, which wraps around the northern and eastern boundaries of the proposed construction site. The distance from the proposed construction site to Warehouse Bayou ranges from 160 feet to 2,500 feet (with an average of about 1,320 feet).

O.2.2.2 Cote Blanche

Two major slope faces have been identified at this site. The areas on each slope face that are likely to be disturbed by construction activities and the resulting soil erosion are shown in Table O.2-6.

Table O.2-6
Areas of Disturbance and Resulting Soil Erosion at Cote Blanche

Slope Face	A (tons/acre/year)	Area disturbed (acres)	Amount of soil erosion (tons)
NE	140	50	3,440
SE	90	80	3,670
	Total:	130	7,110

The above calculations indicate that roughly 7,110 tons of soil will be eroded from 130 acres during the 6-month construction period. If it is assumed that this soil loss is evenly distributed across the entire construction area, this would result in about 0.3 inches (7,110x0.0062/130) of soil loss from a flat surface. Again, these calculations assume a soil density of 2,390 lb/yd^3, which is typical for the silty loam present at Cote Blanche. Of this amount, some of the soil eroded from the NE slope may enter a surface water body. The ICW is the nearest water body that may receive soil eroding in this direction. Soil eroded from the SE slope may get deposited on adjacent marsh lands, which are likely to retain the soil and keep it from entering West Cote Blanche Bay located further in that direction.

O.2.2.3 Big Hill

Two major slope faces have been identified at this site. The areas on each slope face that are likely to be disturbed by construction activities and the resulting soil erosion are shown in Table O.2-7 below.

Table O.2-7
Areas of Disturbance and Resulting Soil Erosion at Big Hill

Slope Face	A (tons/acre/year)	Area disturbed (acres)	Amount of soil erosion (tons)
West	110	27	1,510
East	110	23	1,210
	Total:	50	2,720

The calculations in Table O.2-7 indicate that 2,720 tons of soil will be eroded from about 50 acres during the 6-month construction period. If it is assumed that this soil loss is evenly distributed across the entire construction area, this would result in 0.3 inches (2,720x0.0062/50) of soil loss from a flat surface. These calculations assume a soil density of 2,390 lb/yd^3, a typical value for silty loam like that found at Big Hill. Site design maps indicate that the soil eroded from this site would settle in nearby marsh lands and gullies, rather than erode into a surface water body. This is confirmed by the EIS for the original Big Hill site development, which states that soil loss due to construction on the eastern portion of the dome would settle in the marsh south and east of the dome.[5]

O.2.2.4 Stratton Ridge

One slope face has have been identified at this site. The area of this slope face that is likely to be disturbed by construction activities and the resulting soil erosion are shown in Table O.2-8.

Table O.2-8
Areas of Disturbance and Resulting Soil Erosion at Stratton Ridge

Slope Face	A (tons/acre/year)	Area disturbed (acres)	Amount of soil erosion (tons)
South	30	153	2,300

The above calculations indicate that about 2,300 tons of soil will be lost from 153 acres during the 6-month construction period. If it is assumed that this soil loss is evenly distributed across the entire construction area, this would result in 0.09 inches (2,300 x 0.006/153) of soil loss from a flat surface. These calculations assume a soil density of 2,500 lb/yd^3, which is typical for fine sandy loam like that present at Stratton Ridge. The entire amount is likely to erode towards Oyster Creek.

O.2.2.5 St. James Terminal

Construction associated with expansion of the St. James Terminal will be limited to about 33 acres in an area located between the Mississippi River and the existing terminal. The construction area is located on a mild, southwest slope terrain. As the calculations in Table O.2-4 indicate, the characteristics of this area result in a low soil erosion potential (the least among all the sites considered in this appendix). Soil erosion that is likely to result from construction at St. James is outlined below in Table O.2-9.

Table O.2-9
Areas of Disturbance and Resulting Soil Erosion at St. James Terminal

Slope Face	A (tons/acre/year)	Area disturbed (acres)	Amount of soil erosion (tons)
SW	30	33	520

The above calculations indicate that 520 tons of soil will be lost from about 33 acres during the 6-month construction period. If it is assumed that this soil loss is evenly distributed across the entire construction area, this would result in 0.10 inches (520x0.0065/33) of soil loss from a flat surface. This estimate assumes a soil density of 2,300 lb/yd^3, which is typical for the silty clay loam present at the St. James Terminal.

The two nearest (within 2 miles) surface water bodies are: the Mississippi River at about 0.8 miles and St. James Canal at about 1.6 miles. The Mississippi River is located east of the construction site, which is not in the direction of surface runoff. Moreover, there is a levee between the construction site and the river. Therefore, there is virtually no potential for the sediment laden runoff associated with site construction to reach the Mississippi River directly.

St. James Canal is located southwest of construction site, in the downgradient direction for surface runoff. Site-specific topographic maps indicate that the area between the construction site and this canal is used for agricultural activities. Given the large distance to the St. James Canal, as well as the fact that standing crops are likely to act as good sediment barriers, St. James Canal is not likely to receive an enhanced sediment load due to site construction. Instead, the soil lost from the construction site is likely to be deposited on the area between the site and St. James Canal. Because this area is very flat, the soil that is likely to be deposited in the area is likely to stay there, and is not expected to enter St. James Canal in large volumes.

O.2.2.6 Richton

Four major slope faces have been identified at this site. The areas on each slope face that are likely to be disturbed by initial construction activities and the resulting soil erosion are shown in Table O.2-10. These calculations indicate that about 10,800 tons of soil will be lost from 130 acres during the 6-month construction period. If it is assumed that this soil loss is evenly distributed across the entire construction area, this would result in 0.5 inches (10,800x0.006/130) of soil loss from a flat surface. This estimate assumes a soil density of 2,500 lb/yd^3, which is typical for the sandy loam present at Richton.

Table O.2-10
Areas of Disturbance and Resulting Soil Erosion at Richton

Slope Face	A (tons/acre/year)	Area disturbed (acres)	Amount of soil erosion (tons)
NW	180	9	800
West	160	70	5,500
NE	80	10	400
East	200	41	4,100
	Total:	130	10,800

There are no major surface water bodies in the vicinity of the proposed construction site at Richton. The two nearest (within 5 miles) permanent water bodies are Bogue Homo and Thompson Creek. However, there are several intermittent creeks adjacent to the site. Each of the slope faces identified above discharges directly to an intermittent creek -- the NW slope face drains to Linda Creek, the NE slope face drains to Fox Branch, the East slope face drains to Pine Branch, and the West slope face drains to Harpers Branch. Harpers Branch and Linda Creek, in turn, connect to Bogue Homo at a distance of about 3.5 miles from the site. (Bogue Homo eventually discharges to the Leaf River.) Fox Branch and Pine Branch discharge to Thompson Creek at about 5 miles from the site. Because the area between the construction site and Thompson Creek is relatively flat, only a very small amount of the soil that is likely to erode from the East and NE slope faces may reach Thompson Creek. The soil that is eroded from the West and NW slopes, however, is more likely to reach Bogue Homo due to its closer distance and the steeper topography in these directions.

O.2.2.7 Pascagoula Terminal

The construction site for the proposed terminal is located in the northeast corner of the Jackson County Airport. This site is adjacent to a wetland, which separates the airport from Bangs Lake. Construction associated with the Pascagoula Terminal will be limited to about 58 acres on a mild, southeast slope terrain. As the calculations in Table O.2-4 indicate, the characteristics of this area result in a low soil erosion potential. Total soil erosion that is likely to result from construction at the Pascagoula Terminal is outlined below in Table O.2-11.

Table O.2-11
Areas of Disturbance and Resulting Soil Erosion at Pascagoula Terminal

Slope Face	A (tons/acre/year)	Area disturbed (acres)	Amount of soil erosion (tons)
SE	70	58	2,030

The above calculations indicate that 2,030 tons of soil will be lost from about 58 acres during the 6-month construction period. If it is assumed that the soil loss is evenly distributed across the entire construction area, it would result in 0.21 inches (2,030x0.006/58) of soil loss from a flat surface. This estimate assumes a soil density of 2,500 lb/yd^3, which is typical for the sandy loam present in the vicinity of the proposed Pascagoula Terminal.

The nearest surface water body is Bangs Lake, which is located about 1 mile away in a southeast direction from the construction site. Site-specific topographic maps indicate that the area between the construction site and Bangs Lake is very flat with a slope of less than 0.15%. Moreover, there is a wetland between the construction site and the lake that is likely retain the eroded soil. Therefore, it is very unlikely that significant quantities of sediment-laden runoff associated with site construction would reach Bangs Lake directly. Instead, the soil lost from the construction site is likely to be deposited on the area between the site and Bangs Lake.

O.2.3 Calculation of Amount of Soil Reaching Water Bodies

Not all of the soil eroded from the sites during construction will necessarily enter nearby water bodies. As outlined above, some of the soil may not reach water because of the great distance and/or flat topography between the construction sites and the closest water body. Even when the distance and topography are favorable for enhanced sediment loads to nearby streams or creeks, some of the eroding soil may deposit or settle out on the land before reaching the water body. Generally, a sediment delivery ratio is used to represent the reduction in soil mass delivered to a water body due to redeposition between the source area and the water body. The sediment delivery ratio can be estimated using the following equation:[6]

$$S_d = D_d^{-0.22}$$

Where S_d = sediment delivery ratio (dimensionless)

D_d = the overland distance between the site and the receiving water body (feet)

Sediment delivery ratios, therefore, can be estimated easily from the known overland distance between the site and the receiving water bodies. Table O.2-12 below shows the amount of soil reaching water bodies near each construction site, taking into account the fraction of eroding soil that is deposited on and retained by the land between each site and nearby water bodies. Big Hill, the St. James Terminal, and the Pascagoula Terminal are not included in this table because, as outlined in section O.2.2 above, eroded soil from these sites is not expected to enter any nearby water bodies. Furthermore, the following table addresses only those nearby waters for which there is a non-zero S_d (other waters, such as West Cote Blanche Bay near Cote Blanche and the Mississippi River near St. James, are not expected to receive an enhanced sediment load). Section O.3 of this appendix analyzes the expected increase in suspended solids in each of these waters caused by the sediment loading shown below.

Table O.2-12
Estimated Amount of Soil Reaching Water Bodies

Site	Affected water body	D_d (feet)	S_d (dimensionless)	Potential soil erosion from site (tons)	Actual soil erosion reaching water body (tons)
Weeks Island	Warehouse Bayou	1,320	0.21	23,080	4,850
Cote Blanche	ICW	2,640	0.18	3,440	620
Stratton Ridge	Oyster Creek	30	0.47	2,300	1,100
Richton	Bogue Homo	17,160	0.11	6,300	690

O.3 Increase in Suspended Solids in Surrounding Water Bodies Due to Site Construction

Section O.2 above estimates the total amount of soil that may erode into nearby water bodies due to initial construction activities at the five candidate expansion sites, the St. James Terminal, and the Pascagoula Terminal. Overall, DOE believes that these estimates are conservative, because they do not account for erosion containment measures (ditches and other devices that can trap or divert eroding soil) that will be used during site construction. This section uses the estimates developed above to calculate the resulting increase in suspended solids concentrations in the receiving water bodies. Section O.3.1 describes the methods for these calculations and section O.3.2 summarizes the results.

O.3.1 Methods for Estimating Suspended Solids Increases

The increase in sediment concentrations in receiving water bodies depends on several site-specific parameters, including distance from the construction site, amount of runoff, time, etc. In addition, the estimated concentrations in the water body vary with time, and vary depending on what time frame is considered in the calculations, either: (1) during construction; or (2) after construction ceases.

Assuming there is sufficient rainfall to generate runoff during the construction period, there will be a steady supply of sediment resulting from site clearing and grubbing activities. In the literature, this phase is generally referred to as a phase with "mass transport" of sediment.

Suspended sediment concentrations in receiving water bodies tend to increase during this phase, eventually reaching a steady-state level. After construction, even if there is runoff, there will be little sediment to erode from the site due to site management activities (i.e., revegetation, covering, storm water collection and treatment systems, etc.). This phase is generally referred to as a phase "without mass transport." This later phase is also important in the analysis, however, because after construction ceases the suspended solids concentrations in affected waters return to original (pre-construction) levels.

The equations for estimating concentrations of suspended sediment during and after construction in surrounding water bodies are well established. A complete derivation of these equations is provided in Appendix D.17 of "SPR, Final Environmental Impact Statement, Texoma Group Salt Domes, Cameron and Calcasieu Parishes, Louisiana and Jefferson County, Texas, U.S. DOE, November 1978, Volume 4 of 5. Doc Number: DOE/EIS-0029." The final equations as derived in that document are presented below:

(i) Equation for conservation of sediment with mass transport:

$$\rho_p = \frac{Q}{v_p A_L}\left[1 - \exp\left(\frac{-v_p t}{D_L}\right)\right]$$

(ii) Equation for conservation of sediment without mass transport:

$$\rho_p = (\rho_p)_0 \exp\left(-\frac{v_p (t - t_0)}{D_L}\right)$$

Where

ρ_p	=	Mass density of suspended particles (lb/ft^3)
Q	=	Mass rate of sediment transport into the water body (lb/day)
v_p	=	Settling velocity (ft/day)
D_L	=	Depth of water body (ft) = V_L/A_L
V_L	=	Volume of water (ft^3)
A_L	=	Surface area of water body (ft^2)
t	=	Time (days)
t_0	=	Time that construction ceases (days)
$(\rho_p)_0$	=	Initial mass density of suspended particles (lb/ft^3)

Settling velocity or fall velocity of sediment particles in water is the key indicator of the interaction of sediment with the flow in a water body. Graphs and equations showing the relationship of settling velocity as a function of nominal diameter of the particle are available in the literature. Stokes' law, given by the following equation, is widely used to calculate settling velocity of a spherical particles in quiescent water.

$$v_s = \frac{g}{18}\frac{(s_s - 1)}{\nu}d^2$$

Where

v_s = "Stokes' velocity" of spherical particle
g = Gravity constant (cm/sec^2)
s_s = Specific gravity of particle (dimensionless)
υ = Kinetic viscosity of water (cm^2/sec)
d = Diameter of particle (cm)

Suspended matter in water is rarely spherical. Most often irregular particles of rod-like and disk-like particles may be eroded from construction sites. These irregular particles possess greater surface area per unit volume than spherical particles, and settle more slowly than spheres of equivalent volume. Also, settling velocities observed in typical environmental settings are less than settling velocities observed in laboratory settings. Hence, more realistic estimates of settling velocities are typically obtained by reducing velocities calculated by Stokes' law by a factor of 5. Surface soil characteristics, Stokes' velocities, and settling velocities (i.e., Stokes' velocities divided by 5) in water bodies near the construction sites are presented in the Table O.3-1. Big Hill and St. James are not covered in this table because, as outlined in section O.2.2, soil erosion from these sites is not expected to enter a water body. These values are used along with the above equations to estimate the increased concentration of suspended solids due to site construction at each site.

O.3.2 Results of Calculations

The following sections provide detailed calculations for suspended sediment concentrations in water bodies near the candidate sites. These calculations use the equations outlined in section O.3.1 above with the data presented in section O.2.3. Each section addresses two basic topics: (1) the basic characteristics of the affected water body at the site; and (2) the calculation of suspended solids concentrations, both during and after the initial construction activities.

O.3.2.1 Warehouse Bayou Near Weeks Island

This bayou ranges from about 160 feet to 2,500 feet from the proposed expansion site at Weeks Island. It wraps around the northern and eastern boundaries of the proposed site, such that it may receive soil eroding from all of the expected sloping faces during construction. As estimated in section O.2.3, conservatively assuming no erosion control measures are used, Warehouse Bayou may receive as much as 4,850 tons of eroded soil from the site during the six-month construction period.

<u>Bayou Characteristics:</u>

Width	=	200 ft (Source: Table 5.3-3 of this DEIS)
Depth	=	20 ft (Source: Table 5.3-3 of this DEIS)
Affected length	=	10,800 ft (Source: Estimated from USGS maps)
Annual avg. flow	=	Tidal (Source: Table 5.3-3 of this DEIS)

Table O.3-1
Calculation of Settling Velocities

Site Name	Surface Soil Type	Particle Diameter (cm)	Stokes' Velocity, v_s,[1] ft/day	Settling Velocity, v_p, (ft/day)
Weeks Island	Silt loam	0.001	25	5
Cote Blanche	Silt loam	0.001	25	5
Stratton Ridge	Fine sandy loam	0.005	630	126
Richton	Sandy loam	0.005	630	126

These calculations assume a gravity constant (g) of 981 cm/sec^2, specific gravity (s_s) of 2.65, and a kinetic viscosity (ν) of 0.0101 cm^2/sec (assuming a water temperature of 20°C).

Quantitative flow information for Warehouse Bayou is not available, although available information indicates that the bayou is tidally influenced. Hence, it is assumed that the bayou may act like a lake, i.e., standing water with zero velocity. From a USGS map of the site, it is estimated that eroding soil may affect, at most, about 10,800 feet of the bayou, or a water volume of approximately 43.2 million cubic feet. This estimate assumes that the whole bayou along the proposed expansion site will receive eroded soil from the site.

Calculation of Suspended Sediment Concentrations:

The following input values were used in Equations (i) and (ii) above to estimate the resulting increases in suspended sediment concentrations in Warehouse Bayou.

Mass rate of sediment transport into the water body (lb/day) (Q)	= 4,850x2,000/(6x30)
	= 53,900
Surface area of water body (ft^2) (A_L = length•width)	= 2,160,000

Results of the calculations are shown in Tables O.3-2 and O.3-3. Table O.3-2 presents mass density and resulting concentrations of suspended sediment particles with mass transport (i.e., during the construction period). These calculations indicate that a steady-state concentration of almost 80 ppm is reached 39 days after the start of construction, and remains at that level during the rest of the clearing and grubbing phase of the construction period (141 days). Note that it is inherently assumed, as a worst-case scenario, that there will be a rainfall event starting on the first day of construction to carry soil to the water body, and that the resulting runoff continues throughout the duration of the clearing and grubbing phase. Hence, the estimates presented in Table O.3-2 are believed to overestimate the actual suspended sediment concentrations.

Table O.3-2
Mass Density and Resulting Concentration of Suspended Sediment Particles in Warehouse Bayou Near Weeks Island, With Mass Transport (i.e., Concentrations up to 180 Days)

t (days)	ρ_p (lb/ft^3)	C (ppm)
0.1	1.23e-04	1.97
0.5	5.86e-04	9.38
1.0	1.10e-03	17.66
2.0	1.96e-03	31.41
5.0	3.56e-03	56.96
10.0	4.57e-03	73.28
15.0	4.87e-03	77.95
25.0	4.97e-03	79.68
35.0	4.98e-03	79.82
39.0	4.98e-03	79.83
75.0	4.98e-03	79.83
100.0	4.98e-03	79.83
150.0	4.98e-03	79.83
180.0	4.98e-03	79.83

Table O.3-3 provides the estimated mass density and resulting concentrations of suspended sediment particles without mass transport (i.e., after the clearing and grubbing phase ceases). These calculations indicate that the elevated concentrations return to pre-construction levels in a short period, about 40 days, after construction activities at the site are stopped (i.e., after the soil is revegetated or covered).

Table O.3-3

Mass Density and Resulting Concentration of Suspended Sediment Particles in Warehouse Bayou Near Weeks Island, Without Mass Transport (i.e., Concentrations After 180 Days)

$(t-t_0)$ (days)	ρ_p (lb/ft^3)	C (ppm)
0.5	4.40e-03	70.45
1.0	3.88e-03	62.17
2.0	3.02e-03	48.42
5.0	1.43e-03	22.87
10.0	4.09e-04	6.55
15.0	1.17e-04	1.88
25.0	9.62e-06	0.15
35.0	7.90e-07	0.01
40.0	2.26e-07	0.00

O.3.2.2 ICW Near Cote Blanche

A section of the ICW is located adjacent (approximately 0.5 miles) to the proposed Cote Blanche site (see section 5.4.3 of this DEIS). As estimated in section O.2.3, this water body may receive about 620 tons of soil from the Cote Blanche site during the six-month clearing and grubbing phase of the construction period.

<u>ICW Characteristics:</u>

Width	=	400 ft (Source: Table 5.4-3 of this DEIS)
Depth	=	12 ft (Source: Table 5.4-3 of this DEIS)
Affected length	=	5,280 ft (Source: Estimated from USGS maps)
Annual avg. flow	=	2,500 cfs (Source: Table 5.4-3 of this DEIS)

From the USGS map of the site, it is estimated that eroding soil may affect at most about 5280 feet of the ICW. This assumes that the eroding soil will have an impact on only the stretch of the ICW that is along the site boundary.

<u>Calculation of Suspended Sediment Concentrations:</u>

The following input values were used in Equations (i) and (ii) to estimate the resulting increases in suspended sediment concentrations in the ICW.

Mass rate of sediment transport into the water body (lb/day) (Q)	= 620 x 2,000/(6x30)
	= 6,900
Surface area of water body (ft^2) (A_L = length*width)	= 2,112,000

Results of the calculations are shown in Tables O.3-4 and O.3-5. Table O.3-4 lists mass density and resulting concentrations of suspended sediment particles with mass transport (i.e., during the construction period). These calculations indicate that a steady-state concentration of about 10 ppm is reached 20 days after the start of construction, and remains at that level during the remainder of the clearing and grubbing phase of the construction period (160 days). Again, DOE believes these estimates are conservative because the calculations assume a rainfall event starting on the first day of construction and continuing throughout the entire construction period.

Table O.3-4
Mass Density and Resulting Concentration of Suspended Sediment Particles in the ICW Near Cote Blanche, With Mass Transport (i.e., Concentrations up to 180 Days)

t (days)	ρ_p (lb/ft^3)	C (ppm)
0.0	0.00	0.00
0.1	2.61e-05	0.42
0.5	1.20e-04	1.93
1.0	2.18e-04	3.49
2.0	3.62e-04	5.79
3.0	4.56e-04	7.31
4.0	5.19e-04	8.31
5.0	5.60e-04	8.97
6.0	5.87e-04	9.41
8.0	6.17e-04	9.88
10.0	6.30e-04	10.09
15.0	6.38e-04	10.23
20.0	6.40e-04	10.25
100.0	6.40e-04	10.25
180.0	6.40e-04	10.25

Table O.3-5 provides the estimated density and concentration of suspended sediment particles without mass transport (i.e., after clearing and grubbing ceases). These calculations indicate that the concentrations return to pre-construction levels in about 20 days after clearing and grubbing activities at the site are stopped (i.e., after the soil is revegetated or covered).

Table O.3-5
Mass Density and Resulting Concentration of Suspended Sediment Particles in the ICW Near Cote Blanche, Without Mass Transport (i.e., Concentrations After 180 Days)

$(t-t_0)$ (days)	ρ_p (lb/ft^3)	C (ppm)
0.0	6.40e-04	10.25
0.1	6.14e-04	9.83
0.5	5.19e-04	8.32
1.0	4.22e-04	6.76
2.0	2.78e-04	4.45
5.0	7.97e-05	1.28
10.0	9.92e-06	0.16
15.0	1.23e-06	0.02
20.0	1.54e-07	0.00

O.3.2.3 Oyster Creek Near Stratton Ridge

Oyster Creek is located about 30 feet from the proposed Stratton Ridge construction site (see section 5.2.3 of this DEIS). As discussed in section O.2.3, this creek is estimated to receive about 1,100 tons of soil from the Stratton Ridge site during the six-month clearing and grubbing phase of the construction period.

Creek Characteristics:

Width	=	100 ft (Source: Table 5.2-3 of this DEIS)
Depth	=	3 ft (Source: Table 5.2-3 of this DEIS)
Affected length	=	2,380 ft (Source: Estimated from USGS maps)
Annual avg. flow	=	329 cfs (Source: Table 5.2-3 of this DEIS)

From the USGS map of the site, it is estimated that eroding soil may affect about 2,400 feet of Oyster Creek. This assumes that the eroding soil will have an impact on only the stretch of the creek that is near the proposed site boundary.

Calculation of Suspended Sediment Concentrations:

The following input values were used in Equations (i) and (ii) to estimate the resulting increases in suspended sediment concentrations in Oyster Creek.

Mass rate of sediment transport into the water body (lb/day) (Q) = 1,100x2,000/(6x30) = 12,220

Surface area of water body (ft^2) (A_L = length•width) = 240,000

Results of the calculations are shown in Tables O.3-6 and O.3-7. Table O.3-6 lists mass density and resulting concentrations of suspended sediment particles with mass transport (i.e., during the construction period). These calculations indicate that a steady-state concentration of approximately 6.5 ppm is reached 12 hours after the start of the construction, and remains at that level during the rest of the clearing and grubbing phase of the construction period (179.5 days).

Table O.3-6
Mass Density and Resulting Concentration of Suspended Sediment Particles in Oyster Creek Near Stratton Ridge, With Mass Transport (i.e., Concentrations up to 180 Days)

t (days)	ρ_p (lb/ft^3)	C (ppm)
0.0	0.00	0.00
0.05	3.58e-04	5.73
0.1	4.02e-04	6.43
0.5	4.08e-04	6.53
1.0	4.08e-04	6.53
2.0	4.08e-04	6.53
5.0	4.08e-04	6.53
10.0	4.08e-04	6.53
15.0	4.08e-04	6.53
25.0	4.08e-04	6.53
50.0	4.08e-04	6.53
75.0	4.08e-04	6.53
100.0	4.08e-04	6.53
150.0	4.08e-04	6.53
180.0	4.08e-04	6.53

Table O.3-7 provides the estimated mass density and concentration of suspended sediment particles without mass transport (i.e., after clearing and grubbing ceases). These calculations indicate that the concentrations return to pre-construction levels in about 7 hours after stopping clearing and grubbing activities at the site (i.e., after the site is revegetated or covered).

Table O.3-7
Mass Density and Resulting Concentration of Suspended Sediment Particles in Oyster Creek Near Stratton Ridge, Without Mass Transport (i.e., Concentrations After 180 Days)

$(t-t_0)$ (days)	ρ_p (lb/ft^3)	C (ppm)
0.0	4.08e-04	6.53
0.1	6.11e-06	0.10
0.2	7.49e-07	0.01
0.3	1.12e-08	0.00
0.4	2.06e-11	0.00
0.5	3.09e-13	0.00
0.6	4.64e-15	0.00
0.8	1.04e-18	0.00
1.0	2.34e-22	0.00
2.0	1.35e-40	0.00

O.3.2.4 Bogue Homo Near the Richton Dome

Harpers Branch and Linda Creek, which may directly receive enhanced sediment loads due to construction of the proposed Richton site, connect to Bogue Homo at a distance of about 3.5 miles from the site (see section 5.5.3 of this DEIS). As discussed in section O.2.3, Bogue Homo is estimated to receive about 690 tons of soil from the Richton site during the six-month clearing and grubbing phase of the construction period.

Bogue Homo Characteristics:

Width	=	200 ft (Source: Table 5.5-3 of this DEIS)
Depth	=	4 ft (Source: Table 5.5-3 of this DEIS)
Affected length	=	2,640 ft (Source: Estimated from USGS maps)
Annual avg. flow	=	770 cfs (Source: Table 5.5-3 of this DEIS)

Calculation of Suspended Sediment Concentrations:

The following input values were used in Equations (i) and (ii) to estimate the resulting increases in suspended sediment concentrations in Bogue Homo.

Mass rate of sediment transport into the water body (lb/day) (Q) = 690x2,000/(6x30)
= 7,700

Surface area of water body (ft^2) (A_L = length*width) = 528,000

Results of the calculations are shown in Tables O.3-8 and O.3-9. Table O.3-8 lists mass density and resulting concentrations of suspended sediment particles with mass transport (i.e., during the construction period). These calculations indicate that a steady-state concentration of almost 2 ppm is reached 10 hours after the start of the construction, and remains at that level during the rest of the clearing and grubbing phase of the construction period (179.5 days).

Table O.3-8
Mass Density and Resulting Concentration of Suspended Sediment Particles in Bogue Homo Near Richton, With Mass Transport (i.e., Concentrations up to 180 Days)

t (days)	ρ_p (lb/ft^3)	C (ppm)
0.0	0.00	0.00
0.1	1.07e-04	1.72
0.2	1.12e-04	1.79
0.4	1.12e-04	1.80
1.0	1.12e-04	1.80
2.0	1.12e-04	1.80
5.0	1.12e-04	1.80
10.0	1.12e-04	1.80
15.0	1.12e-04	1.80
25.0	1.12e-04	1.80
50.0	1.12e-04	1.80
75.0	1.12e-04	1.80
100.0	1.12e-04	1.80
150.0	1.12e-04	1.80
180.0	1.12e-04	1.80

Table O.3-9 provides the estimated mass density and concentration of suspended sediment particles without mass transport (i.e., after clearing and grubbing ceases). These calculations indicate that the concentrations return to pre-construction levels in about 7 hours after stopping clearing and grubbing activities at the site (i.e., after the site is revegetated or covered).

Table O.3-9
Mass Density and Resulting Concentration of Suspended Sediment Particles in Bogue Homo Near Richton, Without Mass Transport (i.e., Concentrations After 180 Days)

$(t-t_0)$ (days)	ρ_p (lb/ft^3)	C (ppm)
0.0	1.12e-04	1.80
0.1	4.80e-06	0.08
0.2	9.94e-07	0.02
0.3	8.82e-09	0.00
0.4	3.78e-10	0.00
0.5	1.62e-11	0.00
0.6	6.94e-13	0.00
0.8	1.27e-15	0.00
1.0	2.34e-18	0.00
2.0	4.89e-32	0.00

ENDNOTES

1. Wischmeier, W.H. and Smith, D.D., *Predicting Rainfall Erosion Losses -- A Guide to Conservation Planning*, U.S. Department of Agriculture, Agriculture Handbook No. 537, 1978.

2. PB-KBB, Inc., *Typical Surface Facility Construction at an Strategic Petroleum Reserve Site*, Austin, TX, 1991.

3. *Ibid.*

4. Memorandum, *Acreage for Clearing and Grubbing for Construction of the Expansion Sites*, from: R. Benefield, PB-KBB, Houston, TX, February 10, 1992.

5. *U.S. Department of Energy, Strategic Petroleum Reserve, Final Environmental Impact Statement, Texoma Group Salt Domes (West Hackberry Expansion, Black Bayou, Vinton, Big Hill), Cameron and Calasiew Parishes, Louisiana and Jefferson County, Texas*, November 1978, Document Number DOE/EIS-0029, Volume 4 of 5.

6. U.S. Environmental Protection Agency, *Superfund Exposure Assessment Manual*, Office of Remedial Response, April 1988, EPA/520/1-88/001.

APPENDIX P

FLOODPLAINS AND WETLANDS MITIGATION

Much of the text contained in this appendix is reproduced from chapters in the DEIS and is represented here in a format that combines floodplains and wetlands impacts and mitigation discussions. Table P.0-1 provides a roadmap detailing where in the DEIS supporting information for each section of this appendix is found. In many instances the DEIS contains an additional level of detail (e.g., figures illustrating floodplain boundaries, tables specifying wetland type).

P.1 Description of Proposed Action

DOE is proposing to expand the SPR to one billion barrels by selecting two sites at which to develop the additional 250-MMB capacity. This DEIS discusses five alternative sites being considered by DOE: Big Hill and Stratton Ridge, Texas; Weeks Island and Cote Blanche, Louisiana; and Richton, Mississippi. For a more detailed discussion of the proposed action, see Chapters 2 and 3.

P.2 Executive Order 11988: Floodplain Management

According to Executive Order 11988 (May 24, 1977), Federal agencies "shall consider alternatives to avoid adverse effects and incompatible development in the floodplain." If there is no "practicable alternative" to locating a project in a floodplain, an agency is to "design or modify its action in order to minimize potential harm to or within the floodplain." Natural and beneficial floodplain values to be protected include natural moderation of floods, water quality maintenance, groundwater recharge, support of living resources (marshes, fish and wildlife), cultural richness (archeological, historical, recreational, scientific), and agricultural, aquacultural, and forestry production.

P.3 Executive Order 11990: Protection of Wetlands

Executive Order 11990 (May 24, 1977) requires Federal agencies to avoid construction in wetlands (e.g., Coastal Marshes) unless "there is no practicable alternative" and "all practicable measures to minimize harm" are included.

Both Executive Orders require that the Federal agency proposing an action go through a process of selection that compares the proposed action's potential impact on floodplains and wetlands to other practicable alternatives that may exist. The Federal agency must demonstrate that "no practicable alternative" exists if it intends to continue development in a floodplain or wetland.

This DEIS simultaneously addresses five sites; only two will eventually be chosen and developed. DOE does not intend to make final site decisions until issuance of the Final EIS. Therefore, the current discussion of impacts to and associated mitigations for floodplains and wetlands will not be able to evaluate DOE's full consideration of alternative sites because a preferred site has not yet been identified.

Table P.0-1
Cross Reference Guide between Appendix P and DEIS

FLOODPLAINS			**WETLANDS**		
Title	**Section in Appendix**	**Section in DEIS**	**Title**	**Section in Appendix**	**Section in DEIS**
Proposed Action	P.1	Chapters 2 and 3	Proposed Action	P.1	Chapters 2 and 3
Big Hill Determination	P.4.1.1	5.1.6	Big Hill Determination	P.4.1.2	5.1.5 7.1.5
Stratton Ridge Determination	P.4.2.1	5.2.6	Stratton Ridge Determination	P.4.2.2	5.2.5 7.2.5
Weeks Island Determination	P.4.3.1	5.3.6	Weeks Island Determination	P.4.3.2	5.3.5 7.3.5
Cote Blanche Determination	P.4.4.1	5.4.6	Cote Blanche Determination	P.4.4.2	5.4.5 7.4.5
Richton Determination	P.4.5.1	5.5.6	Richton Determination	P.4.5.2	5.5.5 7.5.5
Pipeline Determination	P.4.6.1	5.X.6[1]	Pipeline Determination	P.4.6.2	5.X.5[1]
Site Impacts	P.5.1	7.X.6[1]	Site Impacts	P.5.2	7.X.5[1]
Pipeline Impacts	P.5.3	7.X.6[1]	Pipeline Impacts	P.5.3	7.X.5.2[1]
Mitigation of Impacts	P.6.1	8.2.1.5	Mitigation of Impacts	P.6.2	8.2.1.5
Mitigation of Pipeline Impacts	P.6.3	8.2.1.5	Mitigation of Pipeline Impacts	P.6.3	8.2.1.5

1 The "X" can be replaced with the following key:

1 – Big Hill
2 – Stratton Ridge
3 – Weeks Island
4 – Cote Blanche
5 – Richton

P.4 Site Specific Discussion of Floodplains and Wetlands

This section will individually address each proposed site with regard to the presence of floodplains and wetlands. All pipeline scenarios proposed in this DEIS cross at least one water body, where floodplains tend to exist. Therefore, regardless of which sites and pipeline scenarios DOE chooses, floodplains would be involved. With regard to wetlands, the sections below qualify the acreage of wetlands affect within the 150-foot ROW.

P.4.1 Big Hill

P.4.1.1 Floodplain Determination

An expansion at Big Hill would cover about 150 acres on an elevation of approximately 13 meters above msl. The proposed Big Hill storage site is entirely outside any floodplains. Thus, the Big Hill storage site would require no further floodplains assessment.

Because the proposed action at the Big Hill site is an expansion of an existing site rather than the creation of a new facility, existing structures and systems would be used. A Big Hill expansion would take advantage of the existing raw water and brine disposal pipelines and RWI structure without modifications. As a result, no further floodplain assessment is necessary for these structures.

P.4.1.2 Wetlands Determination

Under the 270-day drawdown criterion, no wetlands would be affected by development of the Big Hill site.

Under a 180-day drawdown criterion, a crude oil distribution pipeline would be constructed along one of two alternative routes. If the Trinity Bay route was selected, a total of 148 acres of wetlands could be affected. The majority of these (87 acres) would be palustrine (emergent and scrub-shrub) wetlands. Approximately 41 acres of estuarine wetlands would also be affected. If the I-10 route was selected, a total of 235 acres of wetlands could be affected. For this route, the majority would also be palustrine (emergent and scrub-shrub) wetlands, with smaller amounts of riverine, lacustrine and unclassified wetlands potentially impacted.

P.4.2 Stratton Ridge

P.4.2.1 Floodplain Determination

The Stratton Ridge storage site would cover approximately 200 acres at an elevation of approximately ten to 15 feet msl. The site itself lies upon a floodplain region. In addition, a RWI structure would be constructed in a floodplain at the ICW.

P.4.2.2 Wetland Determination

A total of 162 acres of wetlands would be potentially affected by development at Stratton Ridge: 46 acres of on-site palustrine emergent and forested wetlands, and 116 acres of primarily estuarine wetlands associated with pipeline construction.

P.4.3 Weeks Island

P.4.3.1 Floodplain Determination

The storage site at Weeks Island would cover approximately 300 acres at an elevation of about 17 meters. The proposed site covers both floodplain and non-floodplain areas. The southernmost one-third of the site is in a non-floodplain area; the remaining two-thirds are in a floodplain. In addition, a RWI structure would be constructed in a floodplain at the ICW.

P.4.3.2 Wetlands Determination

Under the 270-day drawdown criterion, a total of 102 acres of wetlands could potentially be impacted by development of the Weeks Island expansion site: 6 acres of palustrine forested wetlands associated with the site and 96 acres of wetlands (various types) associated with pipeline and pump station construction. Under the 180-day drawdown criterion, an additional 98 acres of wetlands would potentially be affected by pipeline and pump station construction.

P.4.4 Cote Blanche

P.4.4.1 Floodplain Determination

The Cote Blanche site would cover 300 acres at an elevation of up to 25 meters. This storage site would be located in a floodplain. An RWI structure would be constructed in a floodplain on the ICW.

P.4.4.2 Wetland Determination

There are no wetlands on the proposed Cote Blanche site. Under the 270-day drawdown criterion, a total of 223 acres of wetlands could be affected, 140 acres of which would be estuarine emergent, subtidal, and intertidal, and 83 of which would be palustrine forested wetlands.

Under a 180-day criterion, an additional 98 acres of wetlands would be affected by construction of the spur to the Texas 22" pipeline and an additional pump station.

P.4.5 Richton

P.4.5.1 Floodplains Determination

An SPR site at Richton would cover approximately 300 acres at an elevation of 60 to 80 meters above msl. The proposed site at Richton is entirely outside any floodplains and would, therefore, require no further floodplains assessment. The proposed RWI structure location on the Leaf River is in a floodplain. The proposed tank farm, to be located northeast of Pascagoula, is in a floodplain.

P.4.5.2 Wetlands Determination

Approximately 30 acres of wetlands would be located within the proposed site boundary for Richton and could potentially be impacted if the site is developed. In addition, if the Richton to Liberty oil distribution pipeline was selected, a total of 552 acres of wetlands would be affected by pipeline construction. The majority of these (approximately 400 acres) would be palustrine forested wetlands, with lesser amounts of other types of palustrine wetlands potentially affected. If the Liberty route was selected, no additional pipelines would be required to attain a 180-day drawdown criterion. The addition of a pump station and one dock and one tank at St. James would not impact any additional wetland areas.

If the Richton to Mobile oil distribution pipeline was selected, a total of 462 acres of wetlands could be affected. The majority of these (approximately 271 acres) would be palustrine forested wetlands, although 118 acres of emergent wetlands and 24 acres of lacustrine wetlands also could be affected. The construction associated with a proposed crude oil terminal in Pascagoula in order to attain the 180-day drawdown under this option could impact 45 additional acres of wetlands. Most of these wetlands are either palustrine forested or palustrine emergent. The majority of these impacts would likely result from construction of connective pipelines; construction of the proposed terminal itself would be expected to have little impact.

If the Pascagoula terminal distribution alternative were selected, 419 acres of wetlands could be affected. The majority of wetlands possibly impacted by the dual purpose pipeline from Richton to Pascagoula would be palustrine forested (approximately 209 acres). As mentioned above, 45 acres of wetlands in Pascagoula could possibly be impacted by construction of pipelines associated with the crude oil terminal. If the Pascagoula terminal alternative were selected, no additional enhancements would be required to meet a 180-day drawdown criterion.

P.5 Potential Impacts to Floodplains and Wetlands

This discussion of impacts to floodplains and wetlands is presented in non site-specific terms because potential impacts would be similar in all locations (e.g., potential impacts to the floodplain at Weeks Islands would be no different than those at Stratton Ridge).

It should be noted, however, that potential impacts to floodplains are only relevant to discussions regarding Stratton Ridge, Weeks Island, and Cote Blanche. Big Hill and Richton are not located in floodplains.

P.5.1 Impacts of Site Construction on Floodplains

DOE would use rough grading as a part of site preparation. This practice consists of removing dirt from higher elevations at a site and placing it in lower sections. Rough grading may change the elevation of certain site areas. Other actions that may affect floodplains include construction of roadways, wellpads, and buildings. DOE would complete all construction activities in compliance with Executive Order 11988, which guarantees mitigation, preservation, and restoration of floodplains. Therefore, most impacts to floodplains from construction activities would be short-term, and none of these effects would be significant enough to increase the risk to lives or property or alter the natural and beneficial floodplain values.

If DOE were not committed to mitigation, preservation, and restoration of floodplains, however, potential impacts to the floodplain could include sedimentation on or below the construction site. Sediment deposition's positive impact is the addition of rich nutrients to the floodplain soil and prevention of sediment-associated pathogens from entering the water. This same sedimentation, however, can destroy biological communities supported on the floodplain because it contributes to nutrient overloading, decreased dissolved oxygen, increased water temperature, and serious impairment of photosynthetic productivity.

P.5.2 Impacts of Site Construction on Wetlands

As part of the construction of a proposed site, vegetation within the site boundary would be partially or completely cleared, the site would be fenced for security reasons. Any wetlands on the site property would be included within the security zone. If possible, DOE would locate permanent site construction (e.g., well ponds, buildings) on non-wetland areas. If unavoidable, on-site wetland areas would be permanently filled.

Construction impacts on the plant communities surrounding a proposed site would likely be minimal. Based on soil erosion calculations presented in Appendix O, soil could be lost from a site during construction if no mitigation were performed. Wetlands near the margins of a proposed site could be impacted by deposition of sediment around vegetation with possible smothering of some of the less robust vegetation. Because mitigation measures (as discussed below and in Chapter 8) would be used to reduce the total amount of soil eroding from a site, the majority of the vegetation would recover, such that the impacts would probably be temporary, with no permanent adverse effects.

P.5.3 Impacts of Pipeline and RWI Structure Construction on Floodplains and Wetlands

P.5.3.1 Floodplains

All pipelines pass through a floodplain for at least part of their length; therefore, construction crews would take measures to minimize and mitigate impacts to floodplains. Normal construction would include the temporary use of fill, spoil generation, and construction of temporary platforms.

The effects of the proposed action on the floodplain would be direct, minor, and short-term. Construction activities would disturb wildlife habitat within the construction ROW as it would continue to be kept clear of woody vegetation to allow for maintenance. Because the pipelines would be buried, there would be no interference with natural moderation of floods, water quality maintenance, ground water recharge, or agricultural production. Similarly, there would be no increase in the threat to life or property from flooding as a result of the buried pipeline.

Although the RWI structure would be located on a water body (e.g., the ICW) and therefore, within a floodplain, it would require only minimal construction area. The RWI structure would not significantly alter the floodplain or floodplain action. Construction of the RWI structure would require dredging about 10,000 cubic yards of spoil from the intake canal to guarantee adequate depth and uninterrupted water supply. Spoil could be placed in an upland spoil disposal area that would be diked to prevent runoff. In addition, the banks under and around the RWI structure would be stabilized to prevent erosion.

P.5.3.2 Wetlands

Potential wetlands impacts resulting from pipeline or RWI construction would be similar to those described for site construction, including altered surface drainage patterns and destruction of vegetation. During pipeline construction, disruption of the surrounding wetlands would be minimized, and efforts made to restore the soil over the pipelines so as to prevent alteration of surface topography and flow. The pipeline ROW would be allowed to revegetate naturally. It is possible, however, that the species composition would differ from that prior to construction, particularly in forested areas, where trees would be removed from pipeline ROWs.

An additional potential impact could be alteration of hydrology and introduction of saltwater into freshwater wetlands. This could result in loss of some salt-intolerant plant species, and a shift in community structure towards more salt-tolerant plant species.

P.6 Mitigation of Impacts to Floodplains and Wetlands

Like the impacts discussion, this discussion will not be site-specific because mitigation efforts would be similar regardless of what sites are chosen. The same mitigation practices would be used at all of the proposed sites.

P.6.1 Mitigation of Site Construction Impacts on Floodplains

To ensure that the agency complies with Executive Order 11988, which guarantees the mitigation, preservation, and restoration of floodplains, DOE would follow the Water Resources Council's Floodplain Management Guidelines while planning its mitigation strategy for the proposed SPR sites. Those plans include:

- the use of minimum grading requirements to save as much of the site from compaction as possible;
- relocating nonconforming structures and facilities out of the floodplain;
- returning the site to normal contours;
- preserving free natural drainage when designing and constructing bridges, roads, fills, and large built-up centers;
- maintaining wetland and floodplain vegetation buffers to reduce sedimentation and delivery of chemical pollutants to nearby water bodies;
- constructing impoundments to minimize any alteration in natural drainage and flood flow; and
- controlling the practice of clear-cutting.

P.6.2 Mitigation of Site Construction Impacts on Wetlands

Although some impacts to wetlands cannot be avoided (e.g., removal of vegetation during site or pipeline construction), many can be mitigated through the use of appropriate engineering designs, and good operating procedures. DOE would mitigate impacts throughout construction of the SPR expansion sites. At SPR sites, mitigation techniques can be divided into three categories: (1) impact avoidance, including preventative steps, site selection, and care in locating structures; (2) minimization, meaning the use of low-impact methods or containment measures; and (3) restoration, which includes replanting, rehabilitation, and other post-damage mitigation. Mitigation of impacts to wetlands would be specified in the CWA section 404 permit for a proposed action.

Impact Avoidance. This mitigation option consists of avoiding damage to sensitive areas, such as wetlands, by concentrating activities and construction in less sensitive areas. This is accomplished by "clustering" the buildings, utilizing "low-impact" construction techniques and materials (e.g., using specially modified all-terrain vehicles that exert little pressure on sensitive soils), and by carefully scheduling the timing of construction so that it does not interfere with, for example, bird mating and nesting seasons.[1] Specific impact avoidance techniques include:

- Conducting surveys to determine the presence and sensitivity of endangered species, sensitive habitat, or cultural resources in the project area.

- Avoiding construction during mating, nesting, and young-bearing seasons. Carefully timed construction can reduce greatly the impact to sensitive wildlife.

- Locating facilities (such as roads, bridges, buildings, and dredged spoils disposal areas) so that previously cleared areas are used first and sensitive areas are avoided.

Impact Minimization. Minimization of impacts includes any action designed to have as little direct impact on the environment as possible. This is often used in conjunction with actions that cannot be avoided, such as the laying of pipelines or emissions associated with oil storage. DOE would employ a number of impact minimization techniques that were used during the construction and operation of existing SPR sites, including:

- "Double-ditching" during construction, which minimizes the mixing of surface and subsurface soils by back-filling with top spoil. This would help reduce erosion and accelerate natural revegetation.

- Minimizing sediment transport and erosion by grading, diking, and installing interceptor ditches so that migrating sediment would not smother wetland areas or significantly affect receiving water bodies (e.g., Warehouse Bayou near the Weeks Island expansion site).

- Constructing water-control structures to prevent saltwater intrusion into fresh or intermediate marshes. This can help preserve the native flora and fauna.

Restoration. Restoration involves rehabilitation of impacted areas that have undergone significant change (due to hydrological modification, filling, contamination, etc.) back to their natural functioning capacity. At the SPR expansion sites, DOE would restore impacted areas to their prior functioning capacity, to the extent practical. Restoration usually involves some of the following activities:

- Revegetation of disturbed areas and restoring natural contours.[2] This would restore ecological, aesthetic, and hydrologic values.

- Restoration of soil and substrate (e.g., excavating and grading the site to the correct elevation, contouring to the correct shape, removing toxins, salvaging and transplanting wetland soils, fertilizing, etc.).

- Modification of vegetation (allowing natural revegetation, seeding or planting desired species, eradicating undesired species, controlling of herbivores and disease, installing buffers and protective structures, etc.).[3]

Enhancement and Creation. To compensate for an unavoidable impact to wetlands resulting from SPR construction and operation, the Corps of Engineers may require that DOE enhance or create wetlands off the site. DOE would use these two mitigation techniques to the extent necessary, as stipulated in the section 404 permit.

Enhancement involves selectively modifying an area to upgrade one desirable attribute, such as waterfowl habitat, over another, such as flood control. For example, rather than attempt to replicate a forested wetland, which may take over 50 years, it may be prudent to create a marsh that can be established in a shorter period of time and that may be more valuable to fish or wildlife that the previous wetland.[4] This process can involve, for example, the purchase of areas adjacent to existing refuges, enhancing their habitat value, and deeding them to the care of an appropriate regulatory agency in perpetuity.[5] Wetland creation is often the most controversial of the mitigation options available because of disagreements within the scientific and regulatory communities as to its effectiveness, long-term viability, and standards for determining the success of these efforts. It is often difficult, if not impossible, to recreate the delicate interdependencies among wetlands plants and animals; in addition, the range of these functions and interdependencies is not fully known.

P.6.3 Mitigation of Pipeline Construction Impacts to Floodplains and Wetlands

DOE would minimize pipeline impacts on floodplains and wetlands by backfilling onshore ditches so that there is no appreciable difference in elevation between the pipeline ROW and surrounding areas after settling, and by using double ditching techniques to conserve topsoil and facilitate revegetation. Pipeline construction mitigation techniques would include the following:

- Returning pipeline trenches to the natural topography which maintains natural drainage patterns and prevents the formation of new water courses where the pipelines cross surface waters. This is a particular concern in areas where the pipelines would cross agricultural lands (e.g., rice fields), which are highly dependent on water from natural drainage.

- Using "push-ditch" construction methods rather than flotation canals for pipelines crossing wet areas. Flotation canals often result in the creation of permanent open-water habitat and the loss of marsh areas.

- Using horizontal directional-drilling of pipeline under waterways, roads, and other permanent obstructions. This can help minimize impacts to adjacent areas. It can also help avoid existing pipelines, such as the numerous pipelines that already cross Trinity Bay in Texas.

- Minimizing sediment transport and erosion by grading, diking, and installing interceptor ditches so that migrating sediment would not smother wetland areas or significantly affect receiving water bodies (e.g., Warehouse Bayou near the Weeks Island expansion site).

- Installing pipelines in existing ROWs where possible, thereby avoiding unnecessary duplication of clearing efforts.

F.7 Conclusion

Design, construction, operation, and maintenance of proposed SPR facilities would be in accordance with all applicable permits and amendments authorizing the proposed action, thus ensuring that potential effects on floodplains and wetlands would be minimized and temporary.

ENDNOTES

1. Salvesen, D., *Wetlands: Mitigating and Regulating Development Impacts*, Urban Land Institute, Washington, DC, 1990, pp. 70-71, p. 88.

2. U.S. Department of Energy, *Strategic Petroleum Reserve, Seaway Group Salt Domes, Brazoria County, Texas, Final Environmental Impact Statement*, 3 Volumes, Office of Strategic Petroleum Reserve, Washington, DC, 1978, Document Number DOE/EIS-0021.

   U.S. Department of Energy, *Strategic Petroleum Reserve, Capline Group Salt Domes, Iberia, Iberville, and Lafourche Parishes, Louisiana, Final Environmental Impact Statement*, 4 Volumes, Office of Strategic Petroleum Reserve, Washington, DC, 1978, Document Number DOE/EIS-0024.

   U.S. Department of Energy, *Strategic Petroleum Reserve, Texoma Group Salt Domes, Cameron and Calcasieu Parishes, Louisiana, and Jefferson County, Texas, Final Environmental Impact Statement*, 5 Volumes, Office of Strategic Petroleum Reserve, Washington, DC, 1978, Document Number DOE/EIS-0029.

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3. King, D., *Wetland Creation and Restoration: A Framework for Evaluating Costs, Performance, and Compensation Ratios*, U.S. Environmental Protection Agency, Office of Policy Planning and Evaluation, 1990.

4. Salvesen, D., *Wetlands: Mitigating and Regulating Development Impacts*, Urban Land Institute, Washington, DC, 1990, p. 89.

5. Personal communication, *Conversation with B. Bozzo*, Boeing Petroleum Services, Inc., July 16, 1991.

PREDICTED AREAL EXTENT

OF

BRINE PLUMES

FOR

STRATEGIC PETROLEUM RESERVE

EXPANSION SITES

FINAL REPORT

Submitted

by

Robert E. Randall
1306 Augustine Ct.
College Station, Texas 77840

to

ICF Incorporated
9300 Lee Highway
Fairfax, Virginia 22031-1207

(Included as Appendix O in DEIS on the SPR Expansion)

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CHAPTER 1

INTRODUCTION

The U.S. Department of Energy's (U.S. DOE) proposed plan to expand the Strategic Petroleum Reserve (SPR) capacity to one billion barrels requires the addition of offshore brine discharge sites. The objective of this report is to predict the areal extent of the brine plumes for the proposed expansion sites using an empirical model developed by Randall and Price (1985). The current proposed expansion sites are tabulated in Table 1.

Table 1
Proposed SPR Expansion Sites

Site Name	Site Location Lat. - Long.	Depth ft(m)
Stratton Ridge (Offshore Freeport, TX)	28° 56.0' N 95° 13.57'W	36 (11.0)
Weeks Island/Cote Blanche (West of Marsh Island)	29° 24.8' N 92° 16.1' W	25 (7.62)
Richton (Offshore Pascagoula, MS)	30° 10.40' N 88° 37.33' W	47 (14.33)

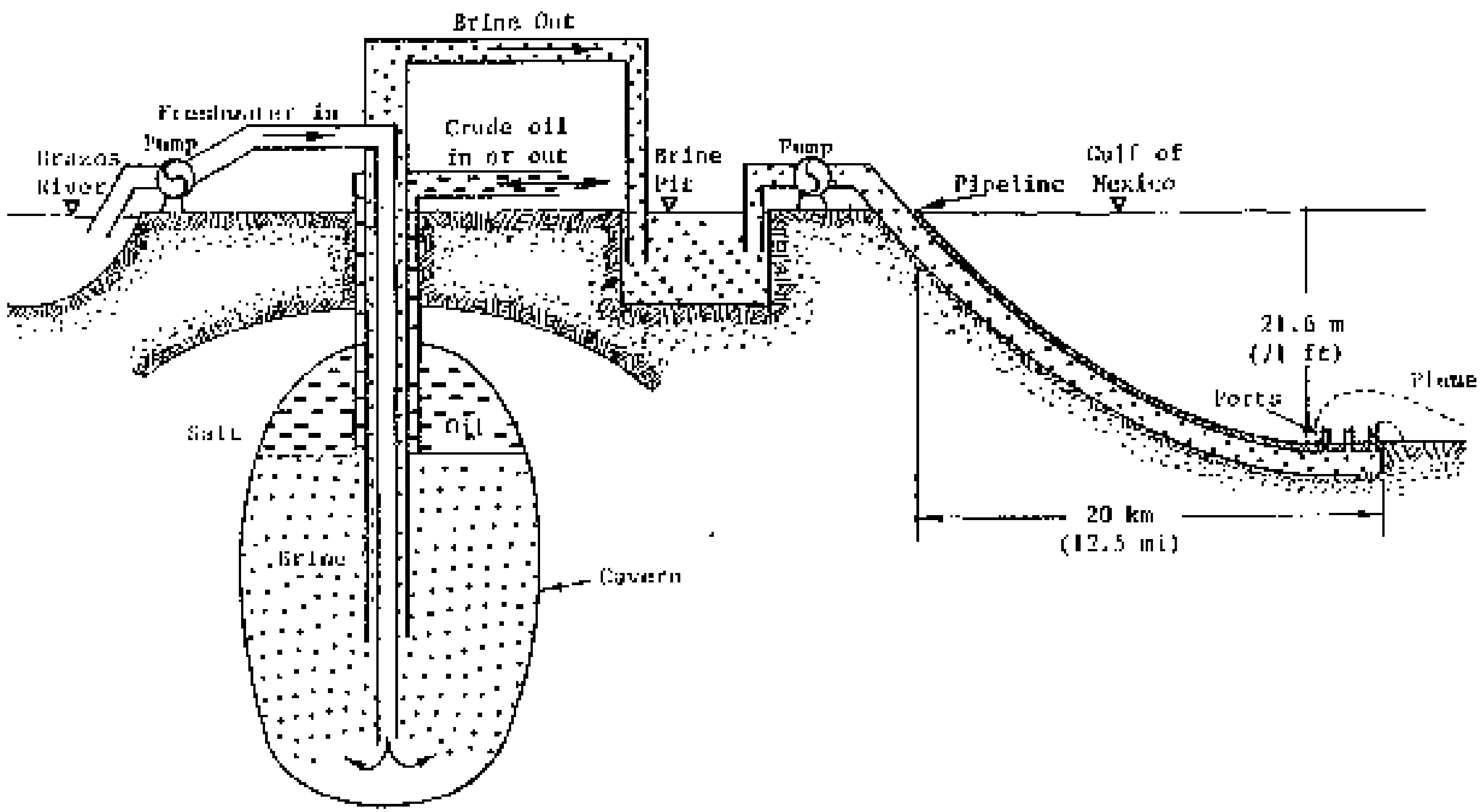
A leaching process is used to excavate storage caverns in underground salt domes. The resulting brine is pumped to the Gulf of Mexico through a buried pipeline as shown in Figure 1. In March 1980, DOE began discharging brine at the first SPR site, Bryan Mound, through a multiport diffuser, which is located in 71 ft (21.6 m) of water and 10.8 nm (20 km) offshore of Freeport, Texas. The brine plume measurements have been described in several reports (Randall, 1981; Randall, 1982; Randall and McLellan, 1983; Randall and Price, 1984a, 1985b). Another discharge activity began in May 1981 through the West Hackberry multiport diffuser located in 32 ft (9.8 m) of water and 5.4 nm (10 km) offshore of Holly Beach, Louisiana. The West Hackberry brine plumes were also measured and reported in several studies (Randall 1983, Randall and Price, 1984b, 1985c). The brine plume measurements from the Bryan Mound and West Hackberry sites were used to develop empirical models, which predict the brine plume areal extent, the vertical extent of the brine jet, and the above-ambient salinity contours. The models are described in the reports mentioned above and in Randall and Price (1985a).

The third brine disposal site, Big Hill, is located in 33 ft (10 m) of water and 3.5 nm (6.5 km) offshore the Texas coast near Port Arthur, Texas. The brine plume prediction models referred to above were used to predict the Big Hill brine plume areal extent, its vertical extent, and the above-ambient salinity contours (Randall and Kelly, 1982). These models have been used in analyses to estimate the plume sizes for the currently proposed expansion sites - Stratton Ridge, Weeks Island/Cote Blanche, and Richton - and for a proposed new Bryan Mound diffuser location (Randall, 1991b). The location of the three current and four proposed expansion SPR sites are shown in Figure 2.

The last 933 m, 1354 m, and 988 m, of Bryan Mound's, Big Hill's, and West Hackberry's brine pipelines are multiport diffusers, respectively. The Bryan Mound, West Hackberry, and Big Hill diffusers have 52, 55, and 75 diffuser ports, respectively, extending 4 ft (1.2 m) vertically above the ocean floor. The diffuser ports are spaced 60 ft (18.3 m) apart and have a 3 in (7.62 cm) inside diameter. Initially, as the brine exits the diffuser ports, jet mixing results in brine dilution. As the brine travels further from the diffuser, the effect of jet mixing decreases and gravity causes the brine to sink to the ocean bottom as it spreads laterally. Currents and turbulence then disperse the plume by advection and diffusion, respectively.

Baseline physical oceanography data were collected at the Bryan Mound and West Hackberry sites and reported by Kelly and Randall (1980) and Kelly et al (1982). At the Big Hill site, data were collected by Science Applications Inc. (SAI) and reported in SAI (1981). Dames and Moore reported physical oceanography data at a site near the proposed Weeks Island sites (Dames and Moore, 1980). These data are used in this report for the evaluation of the proposed Weeks Island/Cote Blanche site. Since the proposed Stratton Ridge site has a water depth similar to that of the Big Hill site, baseline data from the Big Hill area (SAI, 1981) is used to evaluate Stratton Ridge. Although no site-specific data are available for the proposed Richton diffuser site, several studies have been conducted in its general vicinity (Dinnel, 1988; Vittor and Associates, 1985; Kjerfve and Sneed, 1984; Eleuterius, 1973). In addition, an environmental impact statement (COE and USN, 1991) and a feasibility report (COE, 1984) for a nearby dredged material disposal area located offshore Horn Island and a Corps of Engineers study of the Mississippi Sound (COE, 1980) are used in this study to determine the baseline oceanographic conditions.

Figure 1
Schematic of the Brine Discharge Operation for the Bryan Mound Site[1]



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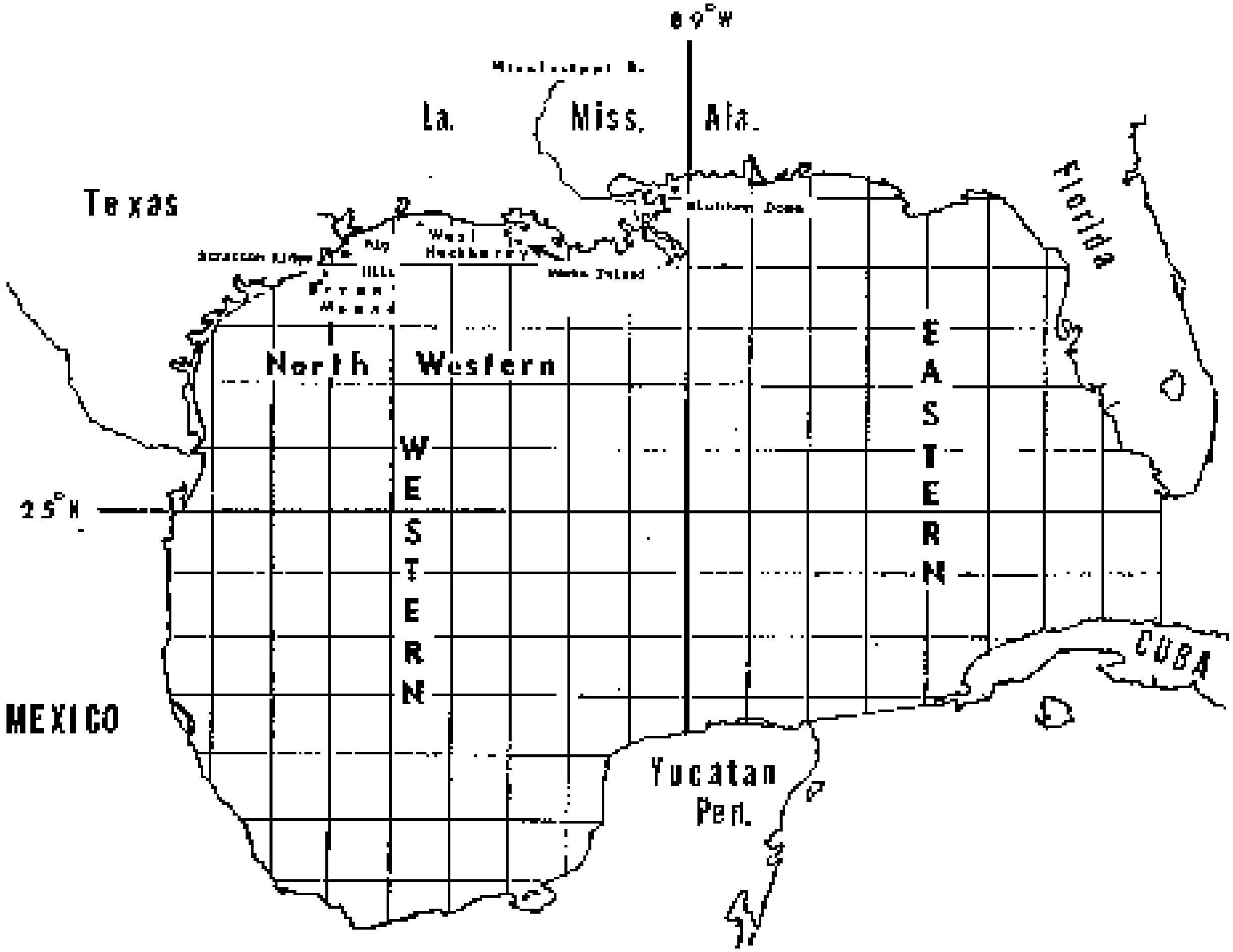
[1] (The schematic of the brine discharge operations at West Hackberry and Big Hill are similar to the schematic shown here)

Figure 2
Location of Existing and Proposed Brine Diffuser Sites in the Northwestern Gulf of Mexico



CHAPTER 2

DESCRIPTION OF PREDICTION MODEL

A model was developed to predict the areal extent and above-ambient concentration, or dilution, of the brine plume emanating from the proposed SPR brine disposal sites. Experimental results of Tong and Stolzenbach (1979), the numerical model of Adams et al (1975), and various field measurements indicate that certain parameters can be used to describe plume behavior: bottom current speed (V_c) and direction, brine salinity (S_b), ambient bottom salinity (S_a), brine exit velocity (V_e), and brine discharge rate (Q). Empirical equations using dimensionless groupings of these parameters were developed to estimate the brine plume's areal extent, general dimensions, maximum above-ambient bottom salinity, and the number of salinity contours.

Field measurements indicate that an ellipse is a reasonable estimate of the shape of above-ambient bottom salinity contours. Therefore, empirical equations were derived to model the relationship of the plume's upstream length (U_j), downstream length (D_j), and maximum width (W_j) with the dimensionless groups of physical parameters affecting plume formation. The plume's dimensions (i.e., U_j, D_j, and W_j) define the axes of an ellipse as illustrated in Figure 3. The upstream length (U_j) is measured in the opposite direction of the bottom current from the center of the diffuser to the desired above-ambient bottom salinity contour. The downstream length (D_j) is measured in the direction of the bottom current from the center of the diffuser to the desired above-ambient bottom salinity contour. The width (W_j) is measured normal to the direction of the bottom current and is bisected by the line extending through the center of the diffuser in the direction of the bottom current. Plume measurements indicate that the maximum width of a contour is usually located about 1/3 of the contour's downstream length (D_j) from the diffuser center. The endpoints of U_j, D_j, and W_j are connected by the arc of an ellipse, which defines the estimated above-ambient bottom salinity contour.

The following empirical relationship best fits the data:

$$\left.\begin{array}{l} D_j \\ U_j \\ W_j \end{array}\right. = M\,(Q/V_c)^{1/2}(S_b/S_a) + B \qquad (1)$$

where Q, V_c, S_b, and S_a are the brine discharge rate (m^3/s), average bottom current (m/s), brine salinity and ambient bottom salinity (o/oo), respectively. An empirical equation of a similar form,

$$A_j = (1/M)(Q/V_c)(S_b/S_a) + B \qquad (2)$$

is the best fit for predicting the plume's areal extent (D_j, U_j, and W_j are measured in meters and A_j is measured in square kilometers). Brine plume measurements, bottom current measurements (taken 6.0 ft above the ocean floor), and brine discharge data (from May 1981 through November

1983) collected at West Hackberry were used to determine the coefficients, M and B, for Equations 1 and 2. The resulting coefficients and their correlation coefficients are tabulated in Table 2. The scatter of the data about the regression line and the low correlation coefficients indicate that the equations are only reasonable estimates.

In addition, the number of above-ambient bottom salinity contours are estimated. The maximum above-ambient bottom salinity is a function of brine salinity, ambient bottom salinity, bottom current, exit velocity of the brine, port diameter, brine density, and ambient bottom water density. Laboratory experiments conducted by Tong and Stolzenbach (1979) show that the maximum above-ambient bottom salinity can be estimated using

$$\Delta S = 0.5\Delta S_m V_r (F^2)^{-0.67} \tag{3}$$

where:

ΔS	=	bottom salinity - ambient salinity (o/oo)
ΔS_m	=	brine salinity - ambient salinity (o/oo)
V_r	=	V_c/V_e
V_c	=	bottom current (m/s)
V_e	=	jet exit velocity (m/s)
F	=	$V_e/[g(\rho_b - \rho_a/\rho_a)D]^{1/2}$
g	=	9.81 m/s
ρ_b	=	brine density (g/cm^3)
ρ_a	=	ambient sea water density (g/cm^3)
D	=	port inside diameter (m)

The brine plume, brine discharge, and current data collected from the Bryan Mound and West Hackberry brine disposal operations have been used to determine an empirical relationship similar to Equation 3 using linear regression techniques (Randall and McLellan, 1983). The result is

$$\Delta S = 0.444\Delta S_m V_r (F^2)^{-0.539} \tag{4}$$

The correlation coefficient, 0.89, indicates that Equation 4 is a good fit to the data. Thus, Equation 4 can be used to estimate the maximum above-ambient bottom salinity. The result of Equation 4 is truncated to the nearest part per thousand (o/oo) to determine the number of above-ambient bottom salinity contours for the predicted plume.

The plume prediction procedures require physical data such as bottom currents, brine discharge characteristics (e.g., salinity, temperature, volumetric flow rate), brine diffuser characteristics (e.g., number of open ports and port diameter) and an estimate of the ambient bottom salinity and temperature. Since plume measurement requires eight hours, the plume predictions apply to an eight-hour period. A computer program has been developed to input the necessary physical data and compute the plume's physical dimensions, areal extent, and the above-ambient bottom salinity contour for each eight-hour period. Randall and Price (1985a) have compared the results of this model to empirical observations.

Although the prediction model does not account for a sloping bottom, the West Hackberry data used to evaluate the coefficients used in the plume prediction equations were taken from a site with a small cross-shelf slope (e.g., 1:2500). Nevertheless, SPR experience has never found plumes approaching land where large bottom slopes were encountered.

The plume prediction model (equations 1 through 4) assumes that the vertical salinity distribution is constant. At shallow sites (e.g., Big Hill, West Hackberry, and the proposed Richton site), stable stratification (i.e., decreasing salinity with increasing depth) is frequently observed. Furthermore, vertical salinity gradients ranging from 5 to 10 o/oo have been observed at West Hackberry (Kelly et al, 1982, Randall and Kelly, 1982). When these vertical salinity gradients are present, there is more brine dilution and, consequently, the maximum above-ambient bottom salinity is lower than that predicted by Equation 3, there is a lower number of above-ambient salinity contours, and the plume covers a smaller area. Thus, the model is conservative (i.e., tends to estimate a larger plume and higher maximum above-ambient salinity) when salinity stratification is present.

Figure 3
Schematic of the Ellipse Used to Predict the Areal Extent of the Brine Plume.
(U_i is the upstream length. D_i is the downstream length. W_i is the maximum width.)

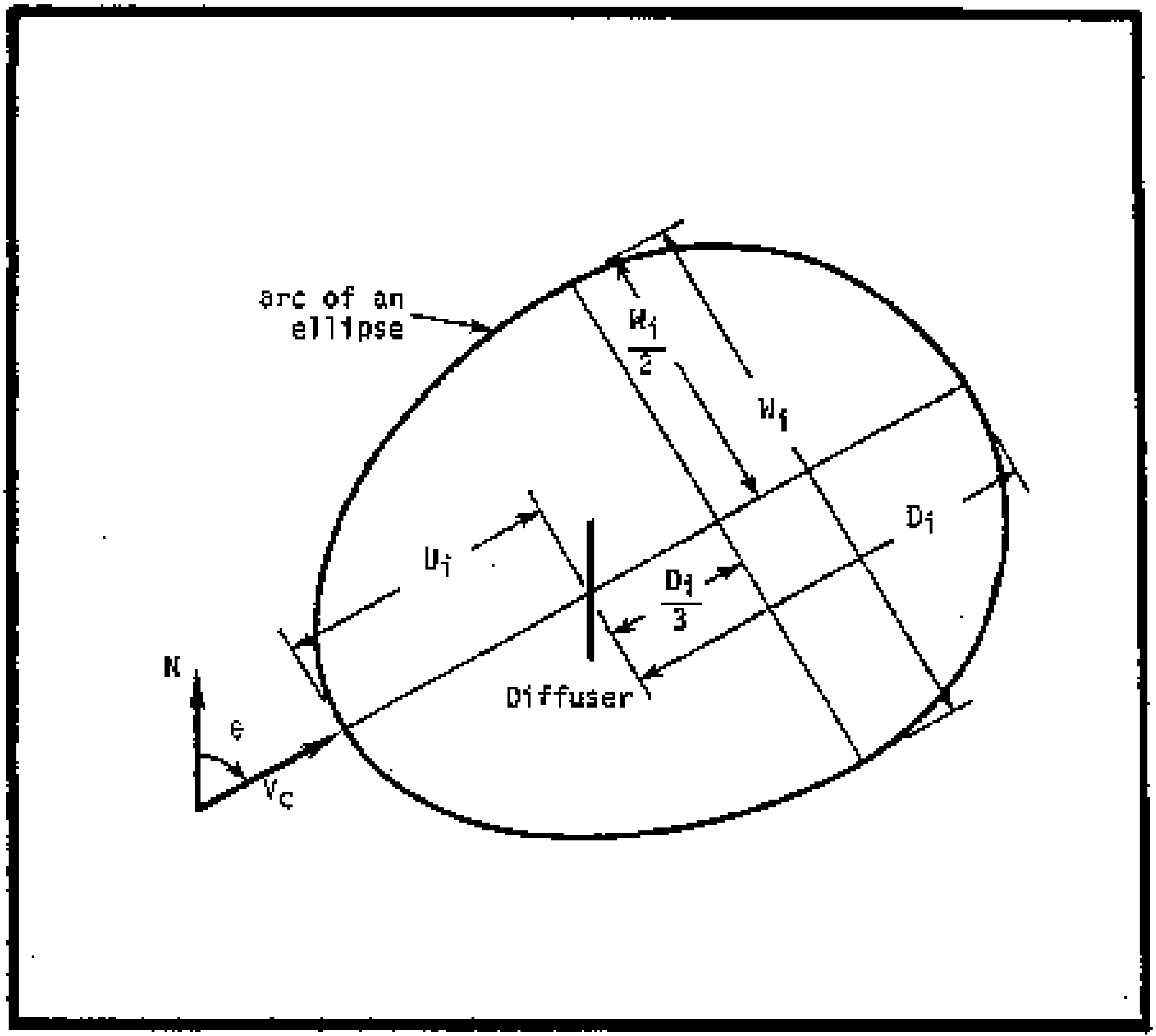


Table 2
Coefficients for Brine Plume Prediction Equations
Based on Data for West Hackberry Brine Disposal Site

Equation Type	Coefficient M	Coefficient B	Correlation Coefficient r
Area			
A_1	10.3	3.02	0.20
A_2	17.9	1.04	0.20
A_3	34.0	0.21	0.22
A_4	56.2	0	0.17
A_5	127.4	0	0.06
A_6	196.3	0	0.01
Width			
W_1	71.1	1,804	0.47
W_2	59.9	1,045	0.53
W_3	41.0	629	0.52
W_4	34.7	136	0.54
W_5	18.7	55	0.28
W_6	13.8	52	0.33
Downstream Length			
D_1	56.5	1,051	0.26
D_2	41.3	683	0.16
D_3	32.5	406	0.10
D_4	27.0	332	0.42
D_5	22.3	289	0.36
D_6	19.7	177	0.62
Upstream Length			
U_1	39.7	0	0.66
U_2	28.0	0	0.75
U_3	20.5	0	0.74
U_4	15.1	0	0.74
U_5	13.0	0	0.52
U_6	12.4	0	0.82

Note: The subscripts indicate the above-ambient salinity contour.

CHAPTER 3

EMPIRICAL PREDICTION OF SITE-SPECIFIC WORST, TYPICAL AND BEST CASE PLUME CHARACTERISTICS

The empirical brine plume prediction model described in Chapter 2 was used to predict the negatively buoyant brine plume characteristics for a range of site-specific scenarios for the three proposed diffuser locations at Stratton Ridge, Weeks Island/Cote Blanche, and Richton (see Table 3). These scenarios were developed using different sources of information that provide baseline data for areas near the proposed diffuser sites. The following describes the data and assumptions used in developing these scenarios for each of the proposed sites.

Stratton Ridge and Weeks Island/Cote Blanche Sites. No site-specific baseline oceanographic data are available for these proposed sites, but there are extensive baseline data available from the Bryan Mound site (Kelly and Randall, 1980), from the West Hackberry site (Kelly et al, 1982; 1984; 1985), and from the Big Hill site (Randall and Kelly, 1982 and SAI, 1981). Dames and Moore (1980) reported baseline oceanographic data for the Weeks Island area. The above sources were used to identify the ambient bottom salinities and temperatures, and bottom current velocities for a large (worst-case) plume, an average (typical-case) plume, and a small (best-case) plume. Brine salinities are based on SPR's past experience at the Bryan Mound and West Hackberry sites and previous studies by Randall and Price (1985) and Randall and Kelly (1982).

The conditions for the large, average, and small plumes are defined by varying the ambient bottom temperature and salinity, brine salinity, jet exit velocity, and the number of open ports. The largest (worst-case) plumes occur with the highest exit velocity (30 ft/s), a saturated brine salinity (263 o/oo at 20 ^{0}C), the lowest bottom current (0.03 m/s), the lowest ambient bottom salinity and ambient temperature. Average (typical-case) plume sizes are expected when the brine salinity is 233 o/oo, the exit velocity is 27 ft/s, the bottom current is 0.09 m/s, and the ambient bottom salinity and temperature are near average. Small plumes occur with the lowest exit velocity (24 ft/s), the lowest brine salinity (204 o/oo), a large bottom current (0.18 m/s), and a high ambient bottom salinity and temperature. The exit velocity values in this analysis are based on the proposed diffuser's exit velocity of 27 ft/s with an allowable variation of +/- 10 percent.

Richton. Dinnel (1988), Eleuterius (1973), Kjerfve and Sneed (1984) and Vittor and Associates (1985) reported baseline oceanographic data for the proposed Richton diffuser site area. In addition, an environmental impact statement (COE and USN, 1991), a feasibility report (COE, 1984) for a nearby dredged material disposal area offshore Horn Island, and a Corps of Engineers study of the Mississippi Sound (COE, 1980) are available for determining baseline data for the Richton site.

These sources were used to identify the ambient bottom salinity, ambient bottom temperature, and bottom current velocity for a large (worst-case) and two average (typical-case) plumes. Receiving water salinities are based on the studies of Kjerfve and Sneed (1984), SPR experience at Bryan Mound and West Hackberry, and previous studies by Randall and Price

(1985a), Randall and Kelly (1982) and Randall (1991a). Bottom currents, the most important determinant of the plume size, are based on data provided by Kjerfve and Sneed (1984).

The conditions for the large and average plumes are defined by varying the ambient bottom temperature, the ambient bottom salinity, and the ambient bottom current. Unlike bottom current data used for the other proposed sites, Kjerfve and Sneed data show little difference in the occurrence frequencies for the worst-case bottom current velocity (0.03 m/s) and the typical-case bottom current velocity (0.06 m/s). In order to consider a less frequent scenario, another typical-case scenario was defined using a less frequent bottom current velocity (0.09 m/s). The largest (worst-case) plumes occurred when the exit velocity was 27 ft/s, the brine salinity was at its saturated condition of 263 o/oo at 20 °C, the bottom current was 0.03 m/s and the ambient bottom salinity and temperature were lowest. Typical plume sizes were determined when the brine salinity was 263 o/oo, exit velocity was 27 ft/s, bottom current was 0.06 and 0.09 m/s, and the ambient bottom salinity and temperature were average values of 31 o/oo and 22 °C, respectively. The exit velocity value was based upon the proposed diffuser design exit velocity of 27 ft/s.

Table 3
Selected Scenarios for Brine Plume Predictions at the Proposed Stratton Ridge, Weeks Island/Cote Blanche, and Richton Diffuser Sites

	Cases		
	worst	typical	best
STRATTON RIDGE			
RECEIVING WATER			
Ambient Bottom Salinity o/oo	25	30	35
Ambient Bottom Temperature (°C)	15	22	28
Depth (ft)	36	36	36
Ambient Bottom Current (m/s)	0.03	0.09	0.18
BRINE CHARACTERISTICS			
Brine Salinity (o/oo)	263	233	204
Brine Temperature (°C)	20	20	20
Jet Exit Velocity (ft/s)	30	27	24
DIFFUSER CHARACTERISTICS			
Number of Open Ports	75,55,35	75,55,35	75,55,35
Port Diameter (in)	3	3	3
WEEKS ISLAND/COTE BLANCHE			
RECEIVING WATER			
Ambient Bottom Salinity (o/oo)	20	28	35
Ambient Bottom Temperature (°C)	11	20	28
Depth (ft)	25	25	25
Ambient Bottom Current (m/s)	0.03	0.09	0.18
BRINE CHARACTERISTICS			
Brine Salinity (o/oo)	263	233	204
Brine Temperature (°C)	20	20	20
Jet Exit Velocity (ft/s)	30	27	24

Table 3 (continued)
Selected Scenarios for Brine Plume Predictions at the Proposed
Stratton Ridge, Weeks Island/Cote Blanche, and Richton Dome Diffuser Sites

	Cases		
	worst	typical	best
DIFFUSER CHARACTERISTICS			
Number of Open Ports	75,55,35	75,55,35	75,55,35
Port Diameter (in)	3	3	3

	Cases		
	worst	typical	typical
Richton			
RECEIVING WATER			
Ambient Bottom Salinity (o/oo)	25	31	31
Ambient Bottom Temp. (°C)	15	22	22
Depth (ft)	47	47	47
Ambient Bottom Current (m/s)	0.03	0.06	0.09
BRINE CHARACTERISTICS			
Brine Salinity (o/oo)	263	263	263
Brine Temperature (°C)	20	20	20
Jet Exit Velocity (ft/s)	27	27	27
DIFFUSER CHARACTERISTICS			
Number of Open Ports	55	55	55
Port Diameter (in)	3	3	3

STRATTON RIDGE

This section summarizes the conditions and results for the worst-, typical , and best-case scenarios at Stratton Ridge. Although the diffuser design calls for as many as 75 ports, the model was run separately for 75, 55, and 35 open ports within each of the three scenarios (i.e., worst-case, typical-case, and best-case) to account for a possible variation in the number of open diffuser ports during operation. However, because the use of 55 open diffuser ports is most representative of past SPR operations, only the predicted brine plumes resulting from disposal through 55 open ports are plotted on bathymetric maps.

Worst-Case Results. The worst-case (large) plume occurs at Stratton Ridge with an ambient bottom salinity of 25 o/oo, an ambient bottom temperature of 15 °C, and a bottom current of 0.03 m/s. The brine is saturated with a temperature of 20 °C and a salinity of 263 o/oo and exits the diffuser vertically through 3-inch diameter ports at 30 ft/s.

The maximum above-ambient bottom salinity is predicted to be 4.7 o/oo and, therefore, there are four above-ambient bottom salinity contours. When 75 diffuser ports are open (see Table 4), the bottom plume is predicted to cover 31.9, 18.2, 9.5, and 5.7 nm^2 for the +1, 2, 3, and 4 o/oo contours, respectively. The maximum plume widths for these contours are 5.1, 4.0, 2.7, and 2.1 nm, respectively. The plume extends downstream 3.8, 2.8, 2.1, and 1.7 nm and upstream 2.3, 1.6, 1.2 and 0.9 nm for the +1 through 4 o/oo contours, respectively. The vertical extent (i.e., height) of the brine jet is predicted to reach 18.4 feet above the ocean floor and 17.6 feet below the water surface. The plume area and dimensions decrease as the number of open diffuser ports decrease as shown in Table 5 and 6 for the 55 and 35 open port conditions, respectively.

Figure 4 presents the worst case brine plume when 55 diffuser ports are open. Since the exit velocity remains at 30 ft/s, the predicted maximum above-ambient bottom salinity remains at 4.7 o/oo and, therefore, the highest above-ambient bottom salinity contour remains +4 o/oo. The ambient bottom current is 3 cm/s in the downcoast direction. The +1 o/oo contour extends 3.4 nm from the center of the diffuser and extends to the outer portion of the Freeport ship channel. The +2, +3, +4 o/oo contours extend 2.4, 1.8, and 1.5 nm, respectively. The predicted areal extent for the +1 through 4 o/oo contours are 23.6, 13.4, 6.9 and 4.2 nm^2, respectively. The widths are 4.5, 3.5, 2.4 and 1.8 nm and the upstream lengths are 2.0, 1.4, 1.0 and 0.7 nm for the +1 to 4 o/oo contours, respectively. Although, the +1 contour reaches within 1 nm of Surfside Beach, the bottom slope is expected to prevent the plume from extending as close to shore.

As shown in baseline oceanographic data, the bottom current moves in all compass directions with some preference for the alongshore direction. To account for this variability, the maximum extent of the downstream length is used as the radius of a circle with its origin at the diffuser center for each above-ambient bottom salinity contour (i.e., no preference is shown for any direction) (see figure 5). Although the model predicts that the +1 contour will reach the Freeport ship channel and a coastal area near Surfside, Texas, this event is unlikely. The empirical model does not account for the sloping bottom approaching the coast and the current in the onshore direction is usually not strong enough to force brine up the beach slope.

Typical-Case Results. The average or typical brine plume characteristics occur when the ambient bottom salinity and temperature are 30 o/oo and 22 °C, respectively. The bottom current is 0.09 m/s and the brine salinity and temperature are 233 o/oo and 20 °C, respectively. The predicted brine plume dimensions for these typical conditions are tabulated in Tables 7 through 9. While the brine exit velocity and brine salinity are lower than those of the worst-case scenario, the predicted maximum above-ambient bottom salinity decreases to 3.8 o/oo and, therefore, 3 above-ambient salinity contours result. In Figure 6, the 3 above-ambient salinity contours for the 55 open port diffuser are shown as circles of a radius equal to the downstream lengths of 1.7, 1.2, and 0.9 nm for the +1 through 3 o/oo contours, respectively. The predicted areas within the actual elliptical plume contours are 5.9, 3.2 and 1.6 nm^2 which are nearly 4 times smaller than those predicted for the worst-case scenario.

Best-Case Results. The typical small plume is expected to occur when the ambient bottom salinity and temperature are 35 o/oo and 28 ^0C with a bottom current of 0.18 m/s. The brine salinity and temperature are 204 o/oo and 20 ^0C, respectively. The results are shown in Tables 10 through 12 for the 75, 55 and 35 open ports, respectively. The results for the scenario with 55 open diffuser ports are illustrated in Figure 7. The +1 through 3 o/oo radii extend 1.1, 0.8 and 0.5 nm downstream and the predicted areal extents are 2.6, 1.3 and 0.6 nm^2, respectively. The maximum above-ambient bottom salinity is expected to be 3.1 o/oo and the vertical extent of the brine jet reaches near mid-depth at 17.6 ft above the ocean floor.

Table 4
Characteristics of Large (Worst-Case) Brine Plume at Stratton Ridge for 75 Open Ports

Ambient Bottom Salinity (o/oo)	25.00
Ambient Bottom Temperature (°C)	15.00
Depth (ft)	36.00
Ambient Bottom Current (m/s)	.03
Ambient Top Salinity (o/oo)	25.00
Brine Salinity (o/oo)	263.00
Brine Temperature (°C)	20.00
Number of open ports	75.00
Jet Exit Velocity (ft/s)	30.00
Port Diameter (in)	3.00
Brine discharge rate (m^3/s)	3.1
Brine discharge rate (barrel/day x 10^6)	1.7
Maximum above-ambient bottom salinity (o/oo)	4.7
Vertical extent (m)	5.6
Vertical extent (ft)	18.4

Plume Areal Extent	(km^2)	(nm^2)	(acres x 10^3)
+1o/oo contour	109.5	31.9	27.1
+2o/oo contour	62.3	18.2	15.4
+3o/oo contour	32.5	9.5	8.0
+4o/oo contour	19.5	5.7	4.8

Plume Width	(km)	(nm)
+1o/oo contour	9.4	5.1
+2o/oo contour	7.5	4.0
+3o/oo contour	5.0	2.7
+4o/oo contour	3.9	2.1
Plume Downstream Length	**(km)**	**(nm)**
+1o/oo contour	7.1	3.8
+2o/oo contour	5.1	2.8
+3o/oo contour	3.9	2.1
+4o/oo contour	3.2	1.7
Plume Upstream Length	**(km)**	**(nm)**
+1o/oo contour	4.3	2.3
+2o/oo contour	3.0	1.6
+3o/oo contour	2.2	1.2
+4o/oo contour	1.6	.9

Table 5
Characteristics of Large (Worst-Case) Brine Plume at Stratton Ridge for 55 Open Ports

Ambient Bottom Salinity (o/oo)	25.00
Ambient Bottom Temperature (°C)	15.00
Depth (ft)	36.00
Ambient Bottom Current (m/s)	.03
Ambient Top Salinity (o/oo)	25.00
Brine Salinity (o/oo)	263.00
Brine Temperature (°C)	20.00
Number of open ports	55.00
Jet Exit Velocity (ft/s)	30.00
Port Diameter (in)	3.00
Brine discharge rate (m^3/s)	2.3
Brine discharge rate (barrel/day x 10^6)	1.2
Maximum above-ambient bottom salinity (o/oo)	4.7
Vertical extent (m)	5.6
Vertical extent (ft)	18.4

Plume Areal Extent	(km^2)	(nm^2)	(acres x 10^3)
+1o/oo contour	81.1	23.6	20.0
+2o/oo contour	46.0	13.4	11.4
+3o/oo contour	23.9	6.9	5.9
+4o/oo contour	14.3	4.2	3.5

Plume Width	(km)	(nm)
+1o/oo contour	8.3	4.5
+2o/oo contour	6.6	3.5
+3o/oo contour	4.4	2.4
+4o/oo contour	3.4	1.8
Plume Downstream Length	**(km)**	**(nm)**
+1o/oo contour	6.2	3.4
+2o/oo contour	4.5	2.4
+3o/oo contour	3.4	1.8
+4o/oo contour	2.8	1.5
Plume Upstream Length	**(km)**	**(nm)**
+1o/oo contour	3.7	2.0
+2o/oo contour	2.6	1.4
+3o/oo contour	1.9	1.0
+4o/oo contour	1.4	.7

Table 6
Characteristics of Large (Worst-Case) Brine Plume at Stratton Ridge for 35 Open Ports

Ambient Bottom Salinity (o/oo)	25.00
Ambient Bottom Temperature (°C)	15.00
Depth (ft)	36.00
Ambient Bottom Current (m/s)	.05
Ambient Top Salinity (o/oo)	25.00
Brine Salinity (o/oo)	263.00
Brine Temperature (°C)	20.00
Number of open ports	35.00
Jet Exit Velocity (ft/s)	30.00
Port Diameter (in)	3.00
Brine discharge rate (m^3/s)	1.5
Brine discharge rate (barrel/day x 10^6)	.8
Maximum above-ambient bottom salinity (o/oo)	4.7
Vertical extent (m)	5.6
Vertical extent (ft)	18.4

Plume Areal Extent	(km^2)	(nm^2)	(acres x 10^3)
+1o/oo contour	52.7	15.3	13.0
+2o/oo contour	29.6	8.6	7.3
+3o/oo contour	15.3	4.4	3.8
+4o/oo contour	9.1	2.7	2.2

Plume Width	(km)	(nm)
+1o/oo contour	7.0	3.8
+2o/oo contour	5.4	2.9
+3o/oo contour	3.6	2.0
+4o/oo contour	2.7	1.5
Plume Downstream Length	(km)	(nm)
+1o/oo contour	5.2	2.8
+2o/oo contour	3.7	2.0
+3o/oo contour	2.8	1.5
+4o/oo contour	2.3	1.2
Plume Upstream Length	(km)	(nm)
+1o/oo contour	2.9	1.6
+2o/oo contour	2.1	1.1
+3o/oo contour	1.5	.8
+4o/oo contour	1.1	.6

Figure 4
Predicted Large (Worst Case) Elliptical Shape Brine Plume Contours for Proposed Stratton Ridge Diffuser Site for Selected Bottom Current Direction

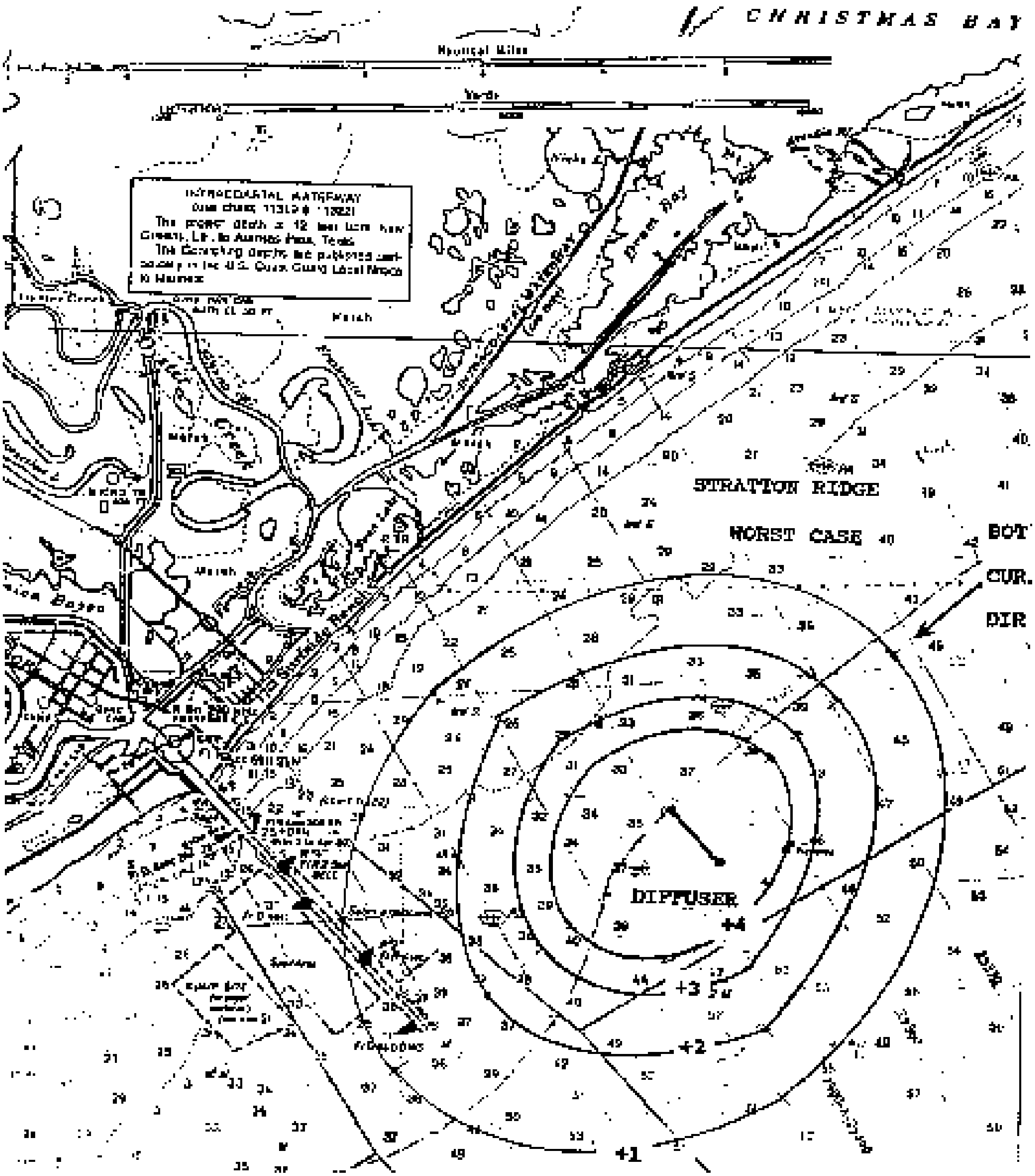


Figure 5
Predicted Radial Extent of Large (Worst-Case) Brine Plume Contours for Proposed Stratton Ridge Diffuser Site

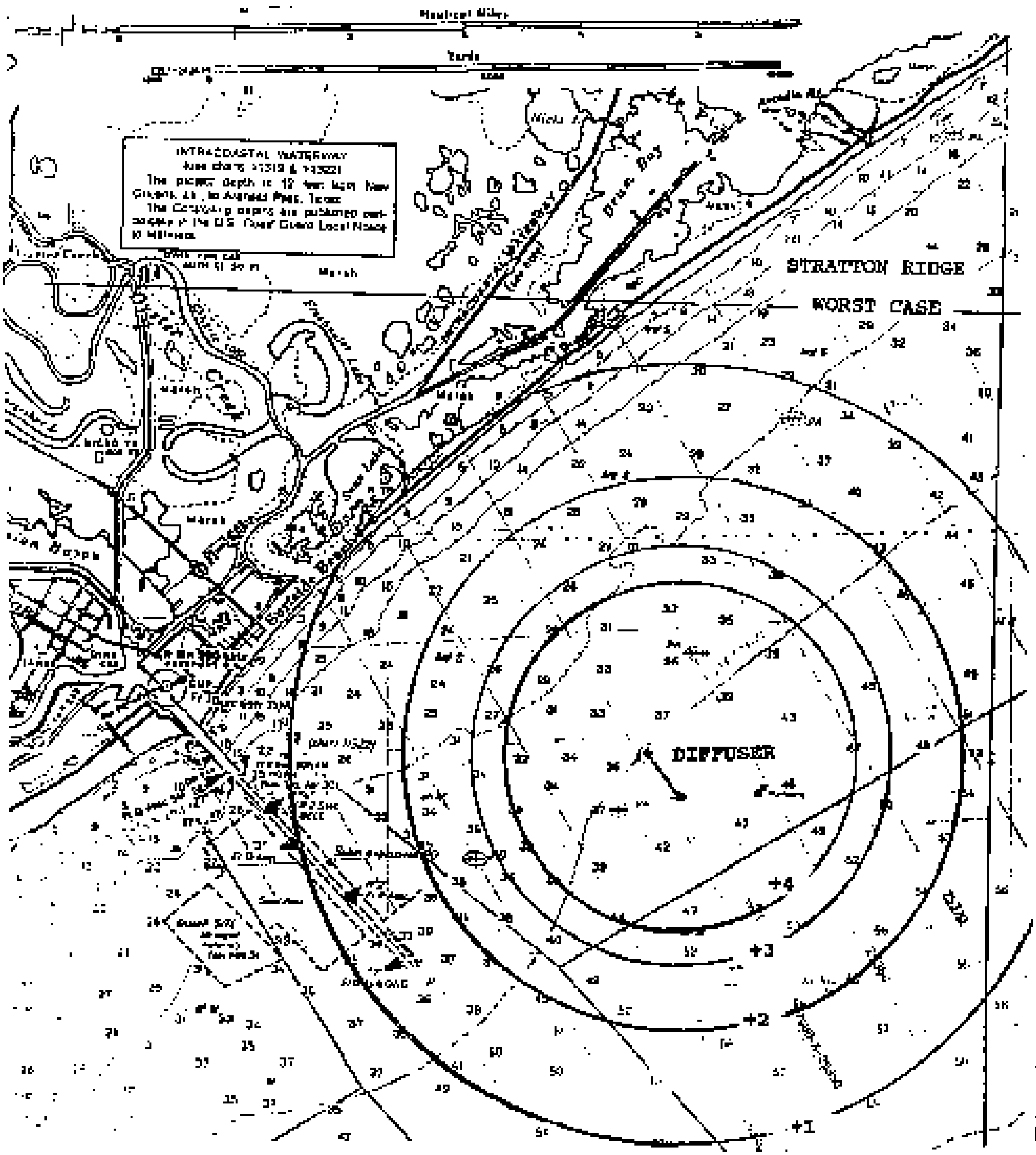


Table 7
Characteristics of Average (Typical-Case) Brine Plume at Stratton Ridge for 75 Open Ports

Ambient Bottom Salinity (o/oo)	30.00
Ambient Bottom Temperature (°C)	22.00
Depth (ft)	36.00
Ambient Bottom Current (m/s)	.09
Ambient Top Salinity (o/oo)	30.00
Brine Salinity (o/oo)	233.00
Brine Temperature (°C)	20.00
Number of open ports	75.00
Jet Exit Velocity (ft/s)	27.00
Port Diameter (in)	3.00
Brine discharge rate (m^3/s)	2.8
Brine discharge rate (barrel/day x 10^6)	1.5
Maximum above-ambient bottom salinity (o/oo)	3.8
Vertical extent (m)	5.5
Vertical extent (ft)	18.0

Plume Areal Extent	(km^2)	(nm^2)	(acres x 10^3)
+1o/oo contour	26.6	7.7	6.6
+2o/oo contour	14.6	4.3	3.6
+3o/oo contour	7.4	2.1	1.8

Plume Width	(km)	(nm)
+1o/oo contour	4.9	2.6
+2o/oo contour	3.6	2.0
+3o/oo contour	2.4	1.3
Plume Downstream Length	**(km)**	**(nm)**
+1o/oo contour	3.5	1.9
+2o/oo contour	2.5	1.3
+3o/oo contour	1.8	1.0
Plume Upstream Length	**(km)**	**(nm)**
+1o/oo contour	1.7	.9
+2o/oo contour	1.2	.7
+3o/oo contour	.9	.5

Table 8
Characteristics of Average (Typical-Case) Brine Plume at Stratton Ridge for 55 Open Ports

Ambient Bottom Salinity (o/oo)	30.00
Ambient Bottom Temperature (°C)	22.00
Depth (ft)	36.00
Ambient Bottom Current (m/s)	.09
Ambient Top Salinity (o/oo)	30.00
Brine Salinity (o/oo)	233.00
Brine Temperature (°C)	20.00
Number of open ports	55.00
Jet Exit Velocity (ft/s)	27.00
Port Diameter (in)	3.00
Brine discharge rate (m^3/s)	2.1
Brine discharge rate (barrel/day x 10^6)	1.1
Maximum above-ambient bottom salinity (o/oo)	3.8
Vertical extent (m)	5.5
Vertical extent (ft)	18.0

Plume Areal Extent	(km^2)	(nm^2)	(acres x 10^3)
+1o/oo contour	20.3	5.9	5.0
+2o/oo contour	11.0	3.2	2.7
+3o/oo contour	5.4	1.6	1.3

Plume Width	(km)	(nm)
+1o/oo contour	4.4	2.4
+2o/oo contour	3.3	1.8
+3o/oo contour	2.2	1.2
Plume Downstream Length	(km)	(nm)
+1o/oo contour	3.2	1.7
+2o/oo contour	2.2	1.2
+3o/oo contour	1.6	.9
Plume Upstream Length	(km)	(nm)
+1o/oo contour	1.5	.8
+2o/oo contour	1.0	.6
+3o/oo contour	.8	.4

Table 9
Characteristics of Average (Typical-Case) Brine Plume at Stratton Ridge for 35 Open Ports

Ambient Bottom Salinity (o/oo)	30.00
Ambient Bottom Temperature (°C)	22.00
Depth (ft)	36.00
Ambient Bottom Current (m/s)	.09
Ambient Top Salinity (o/oo)	30.00
Brine Salinity (o/oo)	235.00
Brine Temperature (°C)	20.00
Number of open ports	35.00
Jet Exit Velocity (ft/s)	27.00
Port Diameter (in)	3.00
Brine discharge rate (m^3/s)	1.3
Brine discharge rate (barrel/day x 10^6)	.7
Maximum above-ambient bottom salinity (o/oo)	3.8
Vertical extent (m)	5.5
Vertical extent (ft)	18.0

Plume Areal Extent	(km^2)	(nm^2)	(acres x 10^3)
+1o/oo contour	14.0	4.1	3.5
+2o/oo contour	7.4	2.1	1.8
+3o/oo contour	3.5	1.0	.9

Plume Width	(km)	(nm)
+1o/oo contour	3.9	2.1
+2o/oo contour	2.8	1.5
+3o/oo contour	1.8	1.0
Plume Downstream Length	**(km)**	**(nm)**
+1o/oo contour	2.7	1.5
+2o/oo contour	1.9	1.0
+3o/oo contour	1.4	.7
Plume Upstream Length	**(km)**	**(nm)**
+1o/oo contour	1.2	.6
+2o/oo contour	.8	.4
+3o/oo contour	.6	.3

Figure 6
Predicted Radial Extent of Average (Typical-Case) Brine Plume Contours for Proposed Stratton Ridge Diffuser Site

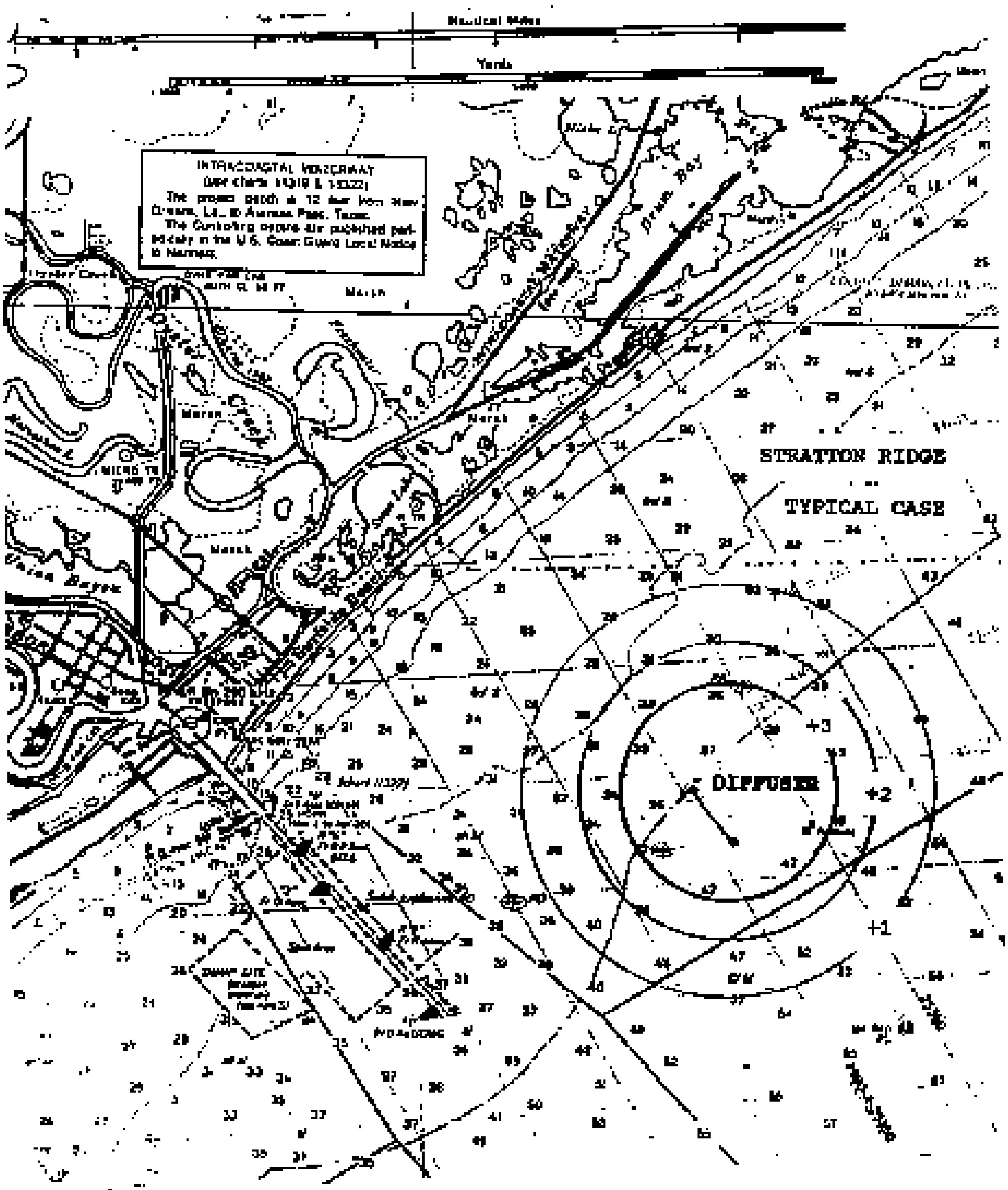


Table 10
Characteristics of a Small (Best-Case) Brine Plume at Stratton Ridge for 75 Open Ports

Ambient Bottom Salinity (o/oo)	35.00
Ambient Bottom Temperature (°C)	28.00
Depth (ft)	36.00
Ambient Bottom Current (m/s)	.18
Ambient Top Salinity (o/oo)	35.00
Brine Salinity (o/oo)	204.00
Brine Temperature (°C)	20.00
Number of open ports	75.00
Jet Exit Velocity (ft/s)	24.00
Port Diameter (in)	3.00
Brine discharge rate (m^3/s)	2.5
Brine discharge rate (barrel/day x 10^6)	1.3
Maximum above-ambient bottom salinity (o/oo)	3.1
Vertical extent (m)	5.4
Vertical extent (ft)	17.6

Plume Areal Extent	(km^2)	(nm^2)	(acres x 10^3)
+1o/oo contour	10.9	3.2	2.7
+2o/oo contour	5.6	1.6	1.4
+3o/oo contour	2.6	.8	.6

Plume Width	(km)	(nm)
+1o/oo contour	3.3	1.8
+2o/oo contour	2.3	1.3
+3o/oo contour	1.5	.8
Plume Downstream Length	(km)	(nm)
+1o/oo contour	2.3	1.2
+2o/oo contour	1.6	.9
+3o/oo contour	1.1	.6
Plume Upstream Length	(km)	(nm)
+1o/oo contour	.9	.5
+2o/oo contour	.6	.3
+3o/oo contour	.4	.2

Table 11
Characteristics of a Small (Best-Case) Brine Plume at Stratton Ridge for 55 Open Ports

Ambient Bottom Salinity (o/oo)	35.00
Ambient Bottom Temperature (°C)	28.00
Depth (ft)	36.00
Ambient Bottom Current (m/s)	.18
Ambient Top Salinity (o/oo)	35.00
Brine Salinity (o/oo)	204.00
Brine Temperature (°C)	20.00
Number of open ports	55.00
Jet Exit Velocity (ft/s)	24.00
Port Diameter (in)	3.00
Brine discharge rate (m^3/s)	1.8
Brine discharge rate (barrel/day x 10^6)	1.0
Maximum above-ambient bottom salinity (o/oo)	3.1
Vertical extent (m)	5.4
Vertical extent (ft)	17.6

Plume Areal Extent	(km^2)	(nm^2)	(acres x 10^3)
+1o/oo contour	8.8	2.6	2.2
+2o/oo contour	4.4	1.3	1.1
+3o/oo contour	2.0	.6	.5

Plume Width	(km)	(nm)
+1o/oo contour	3.1	1.7
+2o/oo contour	2.2	1.2
+3o/oo contour	1.4	.8
Plume Downstream Length	**(km)**	**(nm)**
+1o/oo contour	2.1	1.1
+2o/oo contour	1.5	.8
+3o/oo contour	1.0	.5
Plume Upstream Length	**(km)**	**(nm)**
+1o/oo contour	.7	.4
+2o/oo contour	.5	.3
+3o/oo contour	.4	.2

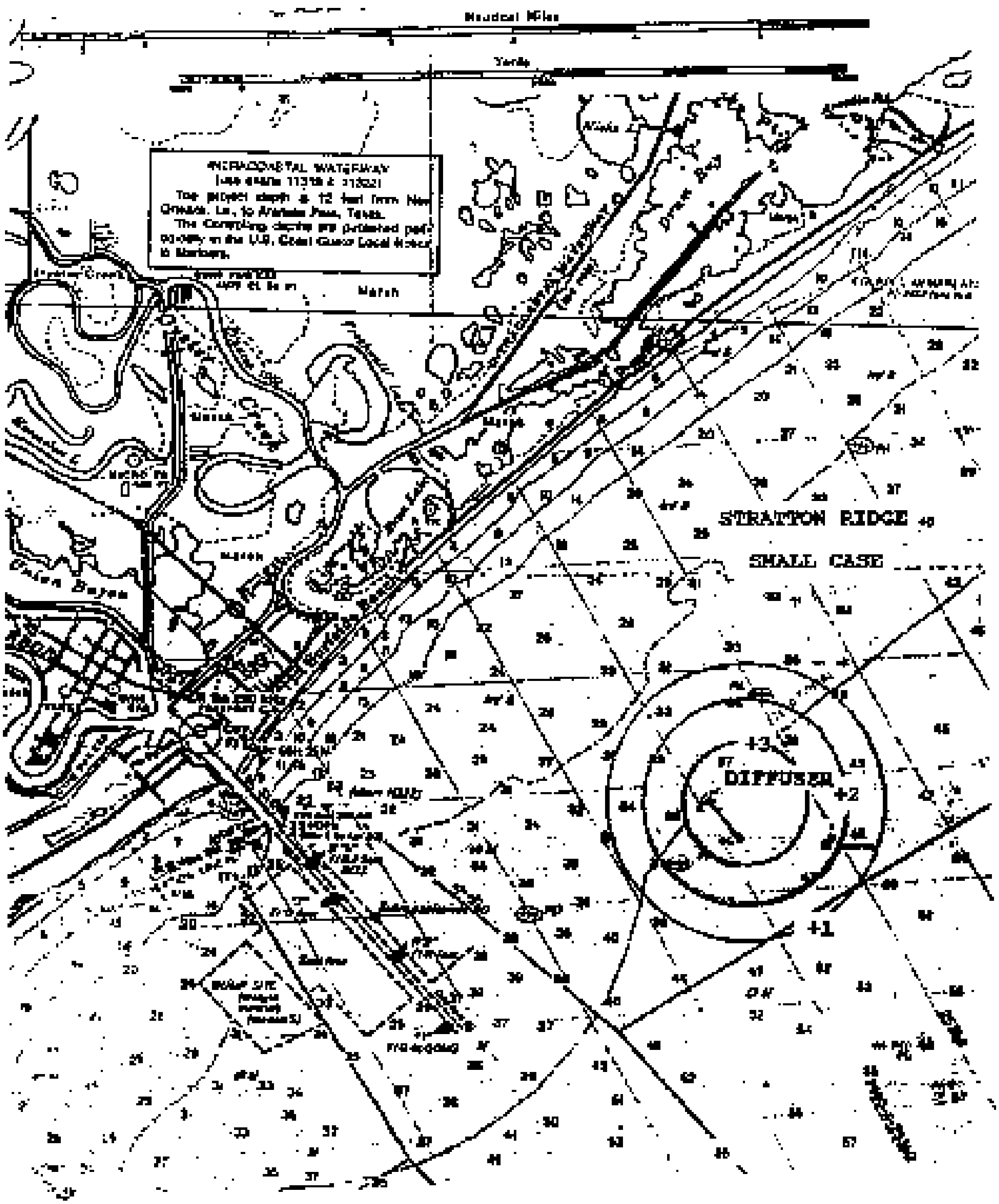
Table 12
Characteristics of a Small (Best-Case) Brine Plume at Stratton Ridge for 35 Open Ports

Ambient Bottom Salinity (o/oo)	35.00
Ambient Bottom Temperature (°C)	28.00
Depth (ft)	36.00
Ambient Bottom Current (m/s)	.18
Ambient Top Salinity (o/oo)	35.00
Brine Salinity (o/oo)	204.00
Brine Temperature (°C)	20.00
Number of open ports	35.00
Jet Exit Velocity (ft/s)	24.00
Port Diameter (in)	3.00
Brine discharge rate (m^3/s)	1.2
Brine discharge rate (barrel/day x 10^6)	.6
Maximum above-ambient bottom salinity (o/oo)	3.1
Vertical extent (m)	5.4
Vertical extent (ft)	17.6

Plume Areal Extent	(km^2)	(nm^2)	(acres x 10^3)
+1o/oo contour	6.7	1.9	1.7
+2o/oo contour	3.2	.9	.8
+3o/oo contour	1.3	.4	.3

Plume Width	(km)	(nm)
+1o/oo contour	2.9	1.5
+2o/oo contour	1.9	1.0
+3o/oo contour	1.2	.7
Plume Downstream Length	(km)	(nm)
+1o/oo contour	1.9	1.0
+2o/oo contour	1.3	.7
+3o/oo contour	.9	.5
Plume Upstream Length	(km)	(nm)
+1o/oo contour	.6	.3
+2o/oo contour	.4	.2
+3o/oo contour	.3	.2

Figure 7
Predicted Radial Extent of Small (Best-Case) Brine Plume Contours for Proposed Stratton Ridge Diffuser Site



WEEKS ISLAND/COTE BLANCHE

This section presents the conditions and results for the three scenarios at the proposed Weeks Island/Cote Blanche site. Dames and Moore (1980) data were used to determine the ambient receiving water characteristics for the proposed site. The model was run separately for 75, 55, and 35 open diffuser ports within each of the three scenarios (i.e., worst-case, typical-case, and best-case). Only the predicted brine plumes resulting from disposal through 55 open ports are plotted on bathymetric maps.

Worst-Case Results. Tables 13 through 15 provide the worst-case plume predictions for 75, 55, and 35 open diffuser ports, respectively. Under worst-case conditions, the ambient bottom salinity is 20 o/oo, the bottom temperature is 11 °C, and the bottom current is 0.03 m/s. The brine temperature and salinity are 20°C and 263 o/oo, respectively. The brine exits the 3-inch diameter diffuser ports at an exit velocity of 30 ft/s. For the 75 port worst-case scenario, the maximum above-ambient bottom salinity is 4.9 o/oo and there are 4 above-ambient bottom salinity contours. The predicted areal extents are 39.6, 22.6, 11.8 and 7.1 nm^2 for the −1 through 4 o/oo contours. The downstream distances to the +1 to 4 o/oo contours are 4.7, 3.4, 2.6, and 2.1 nm, respectively. The vertical extent of the brine jet is predicted to reach 18.2 ft or, 6.8 ft below the water surface. This exceeds the recommendation of maintaining a 10 ft clearance between the ocean surface and highest point of the jet.

The worst-case predicted elliptical shape plumes for 55 open ports are illustrated in Figure 8. These elliptical shaped contours cover an area of 29.3, 16.7, 8.7 and 5.2 nm^2 for the +1 through 4 contours, respectively. The bottom current direction is alongshore to the west. The plume is about 4.5 nm from the nearest shoreline and does not impact the Freshwater Bayou channel. The +1 through 4 contours have a maximum width of 5.4, 4.3, 2.9, and 2.3 nm and a total maximum length (downstream plus upstream lengths) of 6.6, 4.6, 3.5 and 2.8 nm, respectively.

As previously shown for Stratton Ridge, the bottom current moves in all compass directions with some preference for the alongshore direction. To account for this, it is beneficial to use the maximum extent of the downstream length as the radius of a circle with its origin at the diffuser center for each above-ambient bottom salinity contour. This is shown in Figure 9 for the 55 port worst-case scenario. The radii are 4.1, 2.9, 2.2, and 1.9 nm for the +1 through 4 contours, respectively. The +1 contour reaches within about 1 nm of the Freshwater Bayou channel and within 3 nm of the nearest shoreline. Again, as explained for Stratton Ridge, this is unlikely since the empirical model does not account for the sloping bottom approaching the coast and since the current in the onshore direction is usually not strong enough to force brine up the beach slope.

Typical-Case Results. The average or typical brine plume characteristics occur when the ambient bottom salinity and temperature are 28 o/oo and 20 °C. The bottom current is 0.09 m/s and the brine salinity, temperature, and exit velocity are 233 o/oo, 20 °C, and 27 ft/s, respectively. This lower exit velocity results in a lower maximum above-ambient bottom salinity of 3.9 o/oo meaning that the brine plume comprises three bottom salinity contours. The results for 75, 55 and 35 open ports are provided in Tables 16 through 18. Figure 10 illustrates the 3 above-ambient salinity contours resulting for 55 open diffuser ports at the Weeks Island/Cote Blanche diffuser site. These contours are plotted as circles with radii equal to their downstream lengths. The predicted areas covered by the elliptical plume contours are 6.3, 3.4 and 1.7 nm^2 for the respective +1 through 3 o/oo contours. These contours are nearly 4 times smaller than those predicted for the worst-case scenario.

Best-Case Results. A typical small plume occurs when the ambient bottom salinity, temperature, and current are 35 o/oo, 28 ^{o}C and 0.18 m/s. The brine salinity, temperature, and exit velocity are 204 o/oo, 20 ^{o}C and 24 ft/s, respectively. The results for the 75, 55, and 35 open diffuser port results are tabulated in Tables 19 through 21. Figure 11 illustrates the 3 above-ambient salinity contours produced by 55 open diffuser ports at the Weeks Island/Cote Blanche diffuser site. The +1, +2, +3 contours are plotted as circles with radii equal to their downstream lengths of 1.1, 0.8, 0.5 nm. respectively. The areas covered by the actual +1 through 3 o/oo elliptical plume contours are predicted to be 2.6, 1.3 and 0.6 nm^2. These are nearly 3 times smaller than those predicted for the typical-case scenario.

Table 13
Characteristics of Large (Worst-Case) Brine Plume at Weeks Island/Cote Blanche for 75 Open Ports

Ambient Bottom Salinity (o/oo)	20.00
Ambient Bottom Temperature (°C)	11.00
Depth (ft)	25.00
Ambient Bottom Current (m/s)	.03
Ambient Top Salinity (o/oo)	20.00
Brine Salinity (o/oo)	263.00
Brine Temperature (°C)	20.00
Number of open ports	75.00
Jet Exit Velocity (ft/s)	30.00
Port Diameter (in)	3.00
Brine discharge rate (m^3/s)	3.1
Brine discharge rate (barrel/day x 10^6)	1.7
Maximum above-ambient bottom salinity (o/oo)	4.9
Vertical extent (m)	5.6
Vertical extent (ft)	18.2

Plume Areal Extent	(km^2)	(nm^2)	(acres x 10^3)
+1o/oo contour	136.1	39.6	33.6
+2o/oo contour	77.7	22.6	19.2
+3o/oo contour	40.5	11.8	10.0
+4o/oo contour	24.4	7.1	6.0

Plume Width	(km)	(nm)
+1o/oo contour	11.4	6.1
+2o/oo contour	9.1	4.9
+3o/oo contour	6.1	3.3
+4o/oo contour	4.8	2.6
Plume Downstream Length	**(km)**	**(nm)**
+1o/oo contour	8.6	4.7
+2o/oo contour	6.2	3.4
+3o/oo contour	4.8	2.6
+4o/oo contour	4.0	2.1
Plume Upstream Length	**(km)**	**(nm)**
+1o/oo contour	5.3	2.9
+2o/oo contour	3.8	2.0
+3o/oo contour	2.8	1.5
+4o/oo contour	2.0	1.1

Table 14
Characteristics of Large (Worst-Case) Brine Plume at Weeks Island/Cote Blanche for 55 Open Ports

Ambient Bottom Salinity (o/oo)	20.00
Ambient Bottom Temperature (°C)	11.00
Depth (ft)	25.00
Ambient Bottom Current (m/s)	.03
Ambient Top Salinity (o/oo)	20.00
Brine Salinity (o/oo)	263.00
Brine Temperature (°C)	20.00
Number of open ports	55.00
Jet Exit Velocity (ft/s)	30.00
Port Diameter (in)	3.00
Brine discharge rate (m^3/s)	2.3
Brine discharge rate (barrel/day x 10^6)	1.2
Maximum above-ambient bottom salinity (o/oo)	4.9
Vertical extent (m)	5.6
Vertical extent (ft)	18.2

Plume Areal Extent	(km^2)	(nm^2)	(acres x 10^3)
+1o/oo contour	100.6	29.3	24.9
+2o/oo contour	57.2	16.7	14.1
+3o/oo contour	29.8	8.7	7.4
+4o/oo contour	17.9	5.2	4.4

Plume Width	(km)	(nm)
+1o/oo contour	10.0	5.4
+2o/oo contour	7.9	4.3
+3o/oo contour	5.3	2.9
+4o/oo contour	4.2	2.3
Plume Downstream Length	**(km)**	**(nm)**
+1o/oo contour	7.5	4.1
+2o/oo contour	5.4	2.9
+3o/oo contour	4.1	2.2
+4o/oo contour	3.4	1.9
Plume Upstream Length	**(km)**	**(nm)**
+1o/oo contour	4.6	2.5
+2o/oo contour	3.2	1.7
+3o/oo contour	2.4	1.3
+4o/oo contour	1.7	.9

Table 15
Characteristics of Large (Worst-Case) Brine Plume at Weeks Island/Cote Blanche for 35 Open Ports

Ambient Bottom Salinity (o/oo)	20.00
Ambient Bottom Temperature (°C)	11.00
Depth (ft)	25.00
Ambient Bottom Current (m/s)	.03
Ambient Top Salinity (o/oo)	20.00
Brine Salinity (o/oo)	263.00
Brine Temperature (°C)	20.00
Number of open ports	35.00
Jet Exit Velocity (ft/s)	30.00
Port Diameter (in)	3.00
Brine discharge rate (m^3/s)	1.5
Brine discharge rate (barrel/day x 10^6)	.8
Maximum above-ambient bottom salinity (o/oo)	4.9
Vertical extent (m)	5.6
Vertical extent (ft)	18.2

Plume Areal Extent	(km^2)	(nm^2)	(acres x 10^3)
+1o/oo contour	65.1	19.0	16.1
+2o/oo contour	36.8	10.7	9.1
+3o/oo contour	19.0	5.5	4.7
+4o/oo contour	11.4	3.3	2.8

Plume Width	(km)	(nm)
+1o/oo contour	8.3	4.5
+2o/oo contour	6.5	3.5
+3o/oo contour	4.4	2.4
+4o/oo contour	3.4	1.8
Plume Downstream Length	**(km)**	**(nm)**
+1o/oo contour	6.2	3.4
+2o/oo contour	4.5	2.4
+3o/oo contour	3.4	1.8
+4o/oo contour	2.8	1.5
Plume Upstream Length	**(km)**	**(nm)**
+1o/oo contour	3.6	2.0
+2o/oo contour	2.6	1.4
+3o/oo contour	1.9	1.0
+4o/oo contour	1.4	.7

Figure 8
Predicted Large (Worst-Case) Elliptical Shape Brine Plume Contours for the Weeks Island/Cote Blanche Diffuser Site for Selected Bottom Current Direction

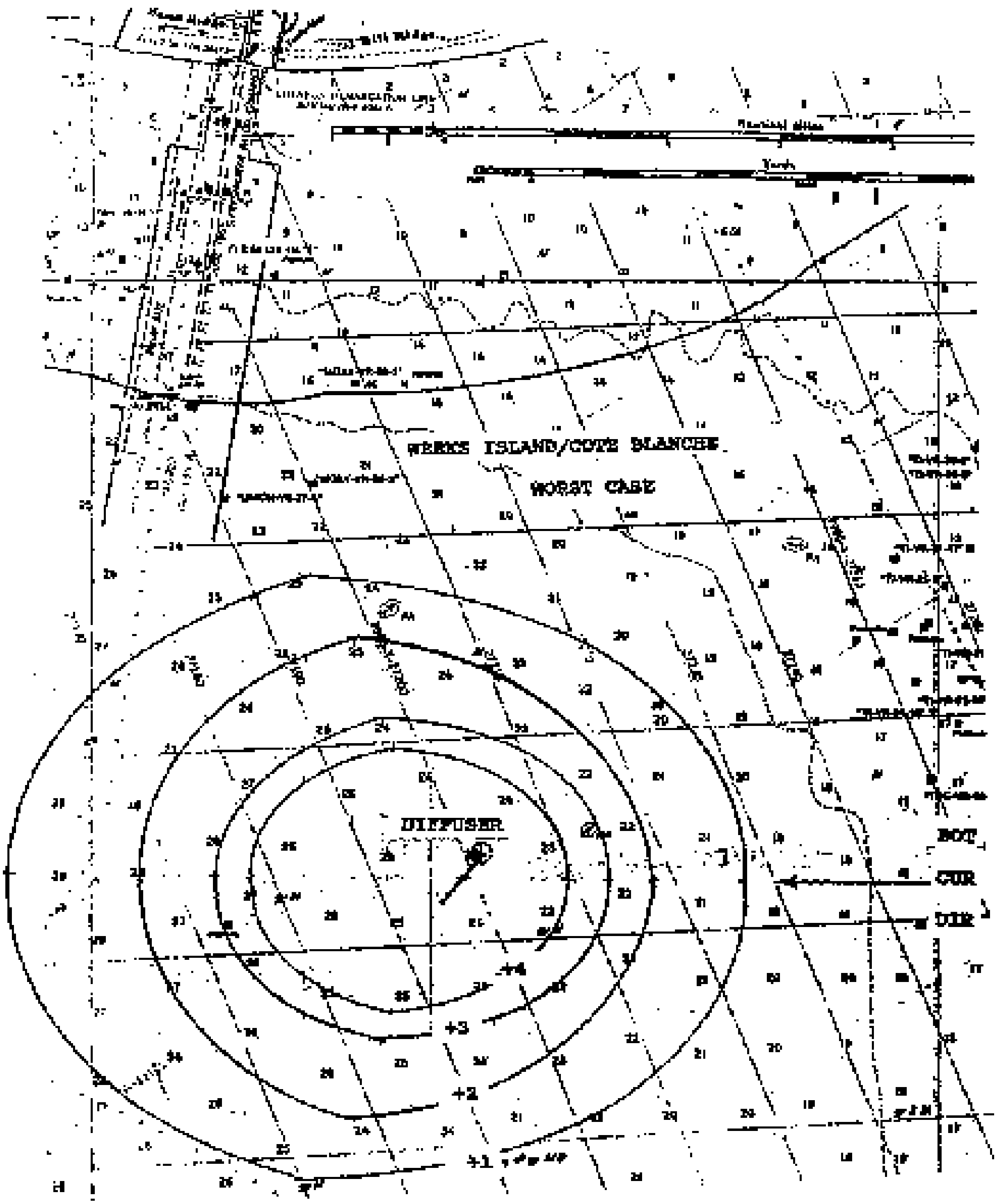


Figure 9
Predicted Radial Extent of Large (Worst-Case) Brine Plume Contours for the Weeks Island/Cote Blanche Diffuser Site

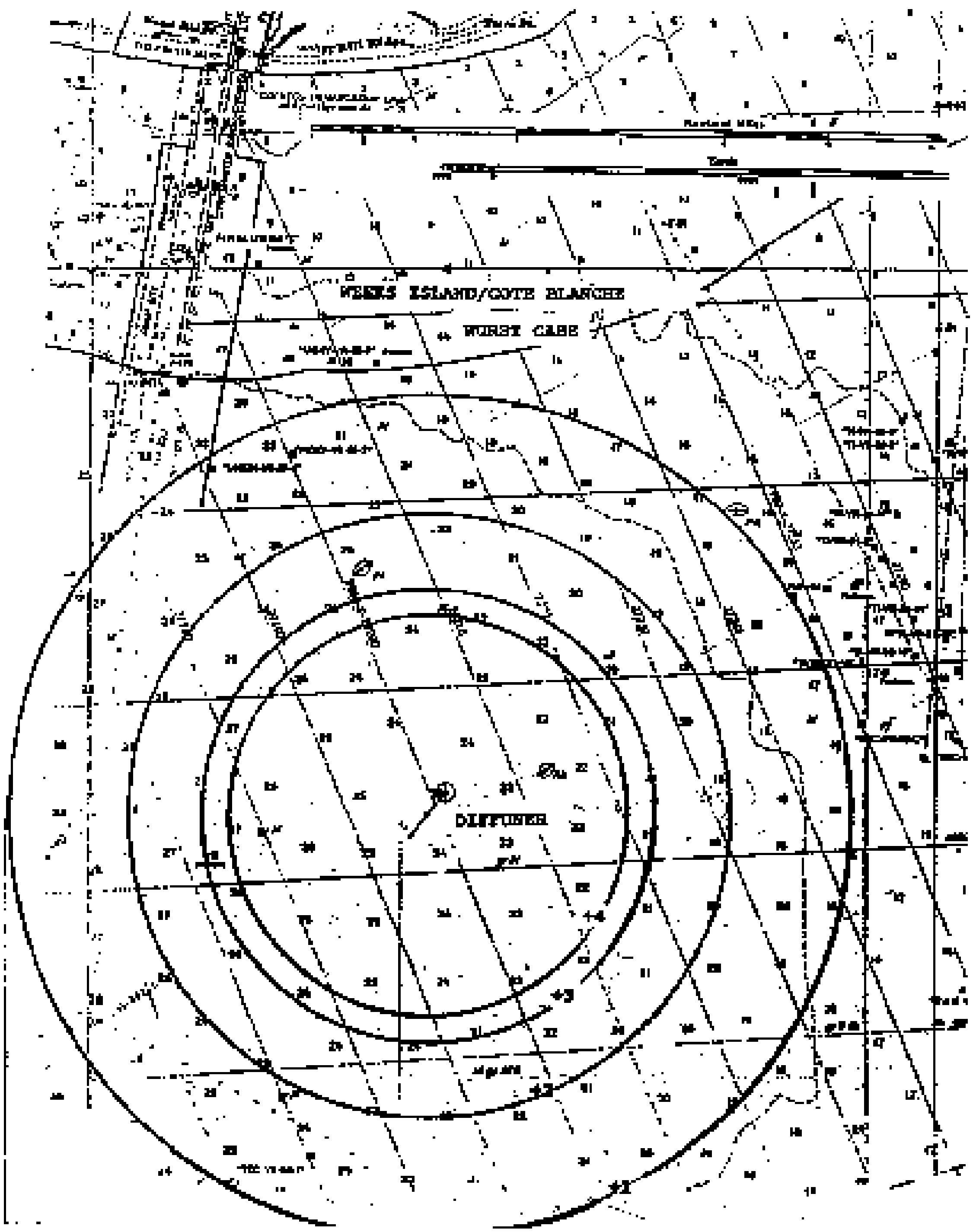


Table 16
Characteristics of Average (Typical-Case) Brine Plume at Weeks Island/Cote Blanche for 75 Open Ports

Ambient Bottom Salinity (o/oo)	28.00
Ambient Bottom Temperature (°C)	20.00
Depth (ft)	25.00
Ambient Bottom Current (m/s)	.09
Ambient Top Salinity (o/oo)	28.00
Brine Salinity (o/oo)	253.00
Brine Temperature (°C)	20.00
Number of open ports	75.00
Jet Exit Velocity (ft/s)	27.00
Port Diameter (in)	3.00
Brine discharge rate (m^3/s)	2.8
Brine discharge rate (barrel/day x 10^6)	1.5
Maximum above-ambient bottom salinity (o/oo)	3.9
Vertical extent (m)	5.5
Vertical extent (ft)	18.0

Plume Areal Extent	(km^2)	(nm^2)	(acres x 10^3)
+1o/oo contour	28.3	8.2	7.0
+2o/oo contour	15.6	4.5	3.9
+3o/oo contour	7.9	2.3	1.9

Plume Width	(km)	(nm)
+1o/oo contour	5.1	2.8
+2o/oo contour	3.8	2.1
+3o/oo contour	2.5	1.4
Plume Downstream Length	(km)	(nm)
+1o/oo contour	3.7	2.0
+2o/oo contour	2.6	1.4
+3o/oo contour	1.9	1.0
Plume Upstream Length	(km)	(nm)
+1o/oo contour	1.8	1.0
+2o/oo contour	1.3	.7
+3o/oo contour	1.0	.5

Table 17
Characteristics of Average (Typical-Case) Brine Plume at Weeks Island/Cote Blanche for 55 Open Ports

Ambient Bottom Salinity (o/oo)	28.00
Ambient Bottom Temperature (°C)	20.00
Depth (ft)	25.00
Ambient Bottom Current (m/s)	.09
Ambient Top Salinity (o/oo)	28.00
Brine Salinity (o/oo)	233.00
Brine Temperature (°C)	20.00
Number of open ports	55.00
Jet Exit Velocity (ft/s)	27.00
Port Diameter (in)	3.00
Brine discharge rate (m^3/s)	2.1
Brine discharge rate (barrel/day x 10^6)	1.1
Maximum above-ambient bottom salinity (o/oo)	3.9
Vertical extent (m)	5.5
Vertical extent (ft)	18.0

Plume Areal Extent	(km^2)	(nm^2)	(acres x 10^3)
+1o/oo contour	21.5	6.3	5.3
+2o/oo contour	11.7	3.4	2.9
+3o/oo contour	5.8	1.7	1.4

Plume Width	(km)	(nm)
+1o/oo contour	4.6	2.5
+2o/oo contour	3.4	1.9
+3o/oo contour	2.3	1.2
Plume Downstream Length	**(km)**	**(nm)**
+1o/oo contour	3.3	1.8
+2o/oo contour	2.3	1.3
+3o/oo contour	1.7	.9
Plume Upstream Length	**(km)**	**(nm)**
+1o/oo contour	1.6	.9
+2o/oo contour	1.1	.6
+3o/oo contour	.8	.4

Table 18
Characteristics of Average (Typical-Case) Brine Plume at Weeks Island/Cote Blanche for 35 Open Ports

Ambient Bottom Salinity (o/oo)	28.00
Ambient Bottom Temperature (°C)	20.00
Depth (ft)	25.00
Ambient Bottom Current (m/s)	.09
Ambient Top Salinity (o/oo)	28.00
Brine Salinity (o/oo)	233.00
Brine Temperature (°C)	20.00
Number of open ports	35.00
Jet Exit Velocity (ft/s)	27.00
Port Diameter (in)	3.00
Brine discharge rate (m^3/s)	1.3
Brine discharge rate (barrel/day x 10^6)	.7
Maximum above-ambient bottom salinity (o/oo)	3.9
Vertical extent (m)	5.5
Vertical extent (ft)	18.0

Plume Areal Extent	(km^2)	(nm^2)	(acres x 10^3)
+1o/oo contour	14.8	4.3	3.7
+2o/oo contour	7.8	2.3	1.9
+3o/oo contour	3.8	1.1	.9

Plume Width	(km)	(nm)
+1o/oo contour	4.1	2.2
+2o/oo contour	2.9	1.6
+3o/oo contour	1.9	1.0
Plume Downstream Length	(km)	(nm)
+1o/oo contour	2.8	1.5
+2o/oo contour	2.0	1.1
+3o/oo contour	1.4	.8
Plume Upstream Length	(km)	(nm)
+1o/oo contour	1.3	.7
+2o/oo contour	.9	.5
+3o/oo contour	.7	.4

Figure 10
Predicted Radial Extent of An Average (Typical-Case) Brine Plume Contours for the Weeks Island/Cote Blanche Diffuser Site

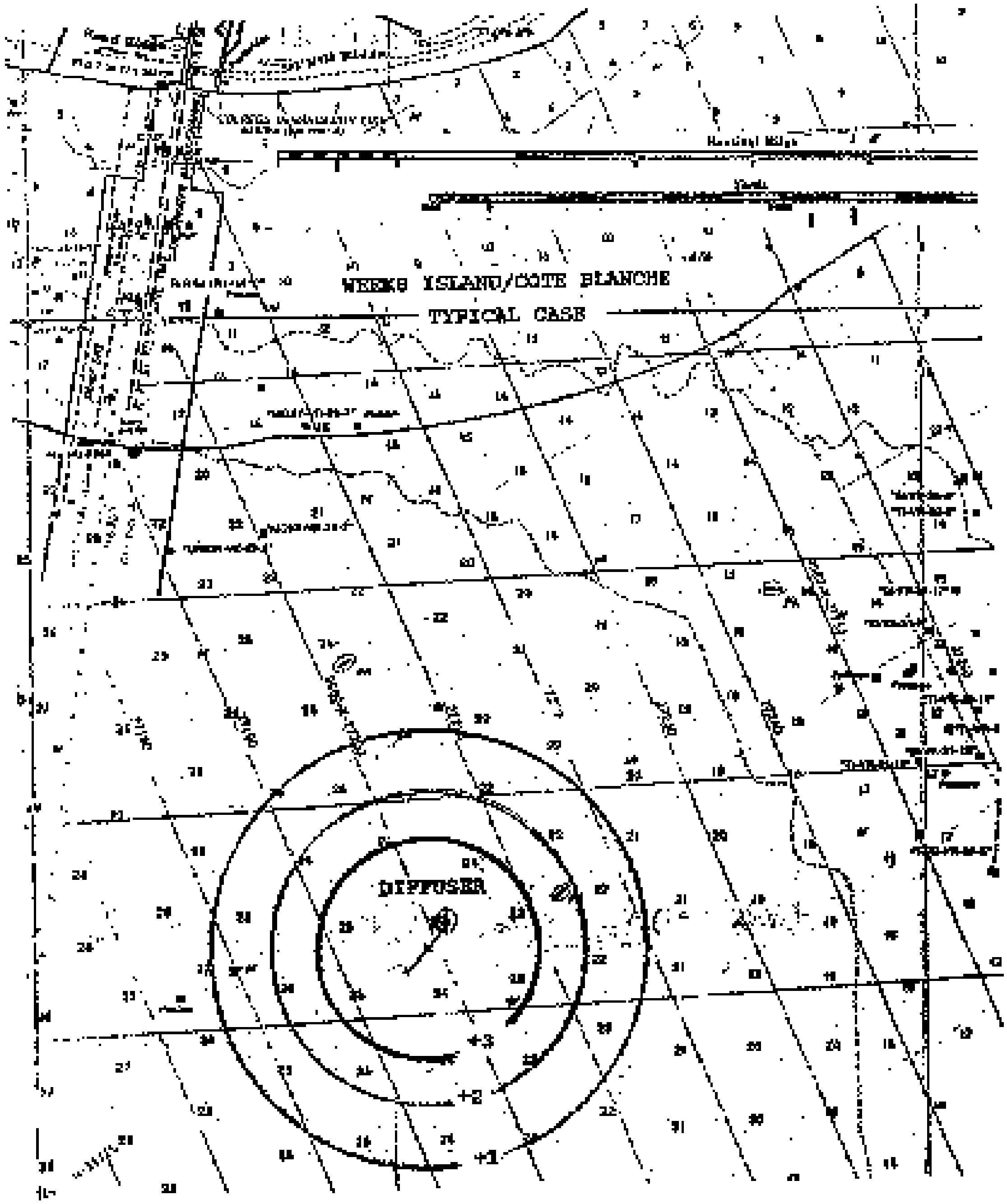


Table 19
Characteristics of a Small (Best-Case) Brine Plume at Weeks Island/Cote Blanche for 75 Open Ports

Ambient Bottom Salinity (o/oo)	35.00
Ambient Bottom Temperature (°C)	28.00
Depth (ft)	25.00
Ambient Bottom Current (m/s)	.18
Ambient Top Salinity (o/oo)	35.00
Brine Salinity (o/oo)	204.00
Brine Temperature (°C)	20.00
Number of open ports	75.00
Jet Exit Velocity (ft/s)	24.00
Port Diameter (in)	3.00
Brine discharge rate (m^3/s)	2.5
Brine discharge rate (barrel/day x 10^6)	1.3
Maximum above-ambient bottom salinity (o/oo)	3.1
Vertical extent (m)	5.4
Vertical extent (ft)	17.6

Plume Areal Extent	(km^2)	(nm^2)	(acres x 10^3)
+1o/oo contour	10.9	3.2	2.7
+2o/oo contour	5.6	1.6	1.4
+3o/oo contour	2.6	.8	.6

Plume Width	(km)	(nm)
+1o/oo contour	3.3	1.8
+2o/oo contour	2.3	1.3
+3o/oo contour	1.5	.8
Plume Downstream Length	**(km)**	**(nm)**
+1o/oo contour	2.3	1.2
+2o/oo contour	1.6	.9
+3o/oo contour	1.5	.6
Plume Upstream Length	**(km)**	**(nm)**
+1o/oo contour	.9	.5
+2o/oo contour	.6	.3
+3o/oo contour	.4	.2

Table 20
Characteristics of a Small (Best-Case) Brine Plume at Weeks Island/Cote Blanche for 55 Open Ports

Ambient Bottom Salinity (o/oo)	35.00
Ambient Bottom Temperature (°C)	28.00
Depth (ft)	25.00
Ambient Bottom Current (m/s)	.18
Ambient Top Salinity (o/oo)	35.00
Brine Salinity (o/oo)	204.00
Brine Temperature (°C)	20.00
Number of open ports	55.00
Jet Exit Velocity (ft/s)	24.00
Port Diameter (in)	3.00
Brine discharge rate (m^3/s)	1.8
Brine discharge rate (barrel/day x 10^6)	1.0
Maximum above-ambient bottom salinity (o/oo)	3.1
Vertical extent (m)	5.4
Vertical extent (ft)	17.6

Plume Areal Extent	(km^2)	(nm^2)	(acres x 10^3)
+1o/oo contour	8.8	2.6	2.2
+2o/oo contour	4.4	1.3	1.1
+3o/oo contour	2.0	.6	.5

Plume Width	(km)	(nm)
+1o/oo contour	3.1	1.7
+2o/oo contour	2.2	1.2
+3o/oo contour	1.4	.8
Plume Downstream Length	(km)	(nm)
+1o/oo contour	2.1	1.1
+2o/oo contour	1.5	.8
+3o/oo contour	1.0	.5
Plume Upstream Length	(km)	(nm)
+1o/oo contour	.7	.4
+2o/oo contour	.5	.3
+3o/oo contour	.4	.2

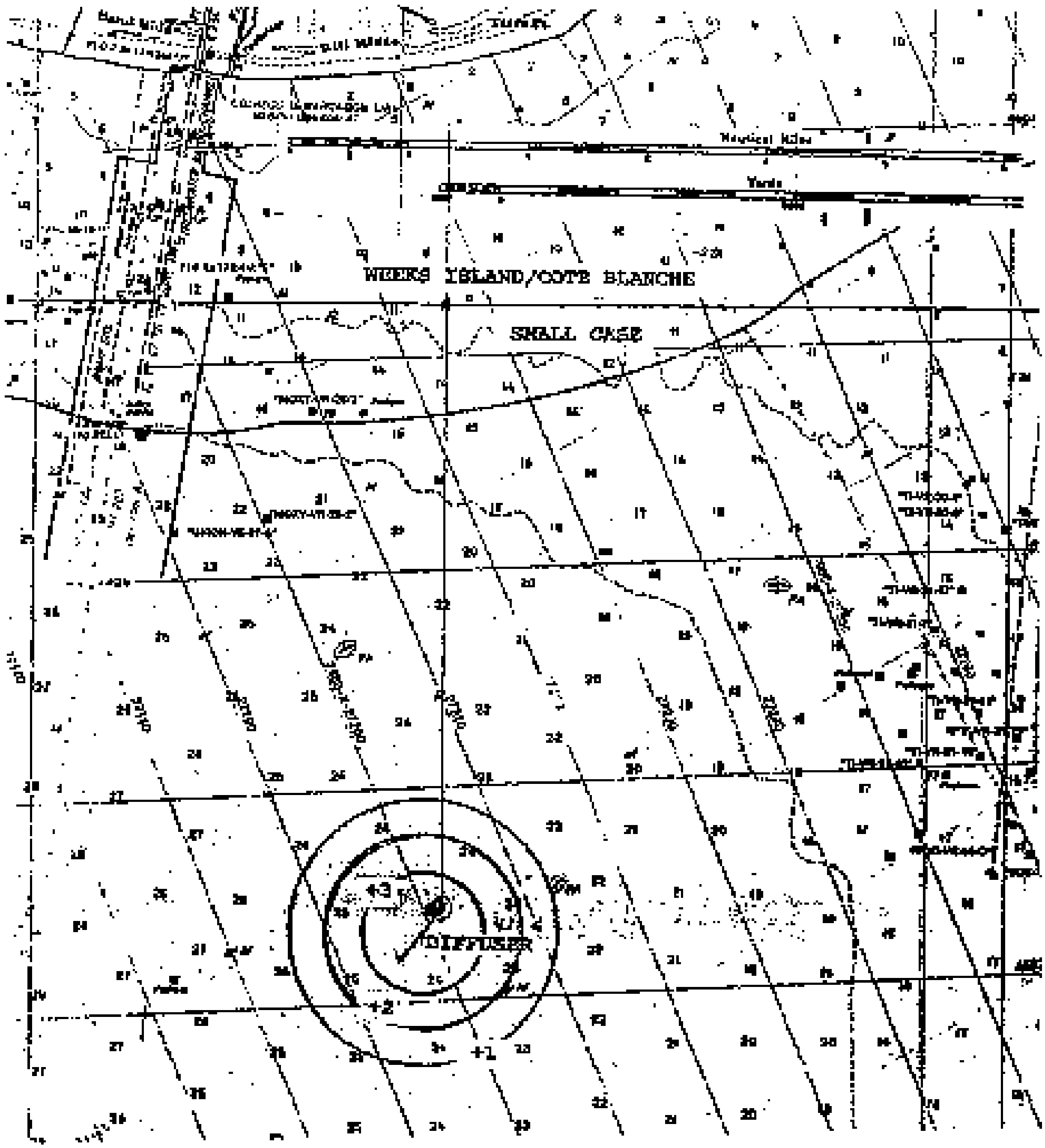
Table 21
Characteristics of a Small (Best-Case) Brine Plume at
Weeks Island/Cote Blanche for 35 Open Ports

Ambient Bottom Salinity (o/oo)	35.00
Ambient Bottom Temperature (°C)	28.00
Depth (ft)	25.00
Ambient Bottom Current (m/s)	.18
Ambient Top Salinity (o/oo)	35.00
Brine Salinity (o/oo)	204.00
Brine Temperature (°C)	20.00
Number of open ports	35.00
Jet Exit Velocity (ft/s)	24.00
Port Diameter (in)	3.00
Brine discharge rate (m^3/s)	1.2
Brine discharge rate (barrel/day x 10^6)	.6
Maximum above-ambient bottom salinity (o/oo)	3.1
Vertical extent (m)	5.4
Vertical extent (ft)	17.6

Plume Areal Extent	(km^2)	(nm^2)	(acres x 10^3)
+1o/oo contour	6.7	1.9	1.7
+2o/oo contour	3.2	.9	.8
+3o/oo contour	1.3	.4	.3

Plume Width	(km)	(nm)
+1o/oo contour	2.9	1.5
+2o/oo contour	1.9	1.0
+3o/oo contour	1.2	.7
Plume Downstream Length	(km)	(nm)
+1o/oo contour	1.9	1.0
+2o/oo contour	1.3	.7
+3o/oo contour	.9	.5
Plume Upstream Length	(km)	(nm)
+1o/oo contour	.6	.3
+2o/oo contour	.4	.2
+3o/oo contour	.3	.2

Figure 11
Predicted Radial Extent of Small (Best-Case) Brine Plume Contours for the Weeks Island/Cote Blanche Diffuser Site



RICHTON

This section summarizes the conditions and results for the worst- and typical-case scenarios at Richton. Unlike the modeling that was done for the Stratton Ridge and Weeks Island/Cote Blanche sites, the modeling for the proposed Richton site does not consider diffusion through 35 and 75 ports. Since brine diffusion through 55 diffuser ports is have been typically used in past SPR operations, 55 on open ports is considered in predicting the size of the brine plumes at the proposed Richton site.

Worst-Case Results. The worst-case (large) plume at the Richton site occurs with an ambient bottom salinity of 25 o/oo, an ambient bottom temperature of 15°C, and a bottom current of 0.03 m/s. The brine is exiting vertically through 3 in diameter ports at a velocity of 27 ft/s, at a temperature of 20°C, and saturated salinity of 263 o/oo. The worst-case results are summarized in Table 22.

The maximum above-ambient bottom salinity is predicted to be 5.3 o/oo, meaning that there are five above-ambient bottom salinity contours. The bottom areas of these contours are predicted to cover 21.5, 12.1, 6.3, 3.7, and 1.7 nm^2 for the +1 through +5 o/oo contours, respectively. The estimated maximum plume widths are 4.3, 3.4, 2.3, 1.7, and 0.9 nm for the respective contours. The +1 through +5 plumes extend 3.2, 2.3, 1.7, 1.5, and 1.2 nm downstream and 1.9, 1.3, 1.0, 0.7, and 0.6 nm upstream from the diffuser center, respectively. The vertical extent of the brine jet is predicted to be 17 ft, which is 26 ft below the water surface.

Figure 12 illustrates the worst-case elliptical shaped brine plume resulting from 55 open ports. Since the maximum above-ambient bottom salinity is 5.3 o/oo, the highest above-ambient bottom salinity contour is expected to be +5 o/oo. The ambient bottom current is 3 cm/s in the northeast direction, which is the preferred direction as determined using the data in Kjerfve and Sneed (1984). The +1 o/oo contour extends 3.2 nm from the center of the diffuser and remains as close as 0.4 nm offshore Horn Island, a barrier island offshore of Pascagoula, Mississippi, and 1.2 nm from the Horn Island Pass Channel entrance. However, the sloping bottom near Horn Island is expected to prevent the plume from actually approaching this point as the model only considers flat bottom areas. In addition, each salinity contour of the predicted brine plume covers the western portion of the designated dredged material disposal area offshore of Horn Island. The predicted plume does not enter Mississippi Sound.

As shown in baseline oceanographic data (Kjerfve and Sneed, 1984), the bottom current moves in all compass directions with some preference for the northeast direction. To account for this variability, the maximum extent of the downstream length is used as the radius of a circle with its origin at the diffuser center for each above-ambient bottom salinity contour (i.e., no preference is shown for any direction) (see Figure 13). The results show that the +1 contour just touches Horn Island. However, the plume is not expected to reach this close to Horn Island since the current is not strong enough to force the brine up the bottom slope, and as stated previously, the empirical model does not account for a sloping bottom. At its closest point, the +1 o/oo contour reaches within 0.5 nm west of the entrance to the Horn Island Pass Channel. Thus, the plume does not enter the channel or the Mississippi Sound. Again, all salinity contours enter the western portion of the dredged material disposal area.

Typical-Case Results. The average or typical brine plume characteristics occur when the ambient bottom salinity and temperature are 31 o/oo and 22 °C, respectively. The two bottom currents are 0.06 and 0.09 m/s, and the brine salinity and brine temperature are 263 o/oo and 20°C, respectively. The areal extent and plume dimensions resulting from brine diffusion through 55 open ports are shown in Table 23 for a 0.06 m/s bottom current. With a bottom current of 0.06 m/s, the maximum above-ambient bottom salinity is predicted to be +4.9 o/oo, resulting in four above-ambient salinity contours. Figure 14 illustrates the +1 through +4 elliptical shape above-ambient salinity contours covering areas of 9.1, 5.1, 2.6, and 1.5 nm^2, respectively, which are about 43 percent smaller than those predicted under worst-case conditions. The +1 o/oo contour moves as close as 1.2 nm offshore Horn Island and 1.9 nm from the Horn Island Pass Channel. Figure 15 shows the radial contours representing the downstream lengths of 2.1, 1.5, 1.1 and 0.9 nm for the +1 through 4 o/oo contours, respectively. In this case, the +1 o/oo radial contour remains 1.1 nm offshore Horn Island and 1.6 nm from the ship channel. All elliptical and radial contours enter the western half of the dredged material disposal area.

The predicted plume that occurs when the bottom current is 0.09 m/s (the ambient bottom salinity and temperature remain at 31 o/oo and 22 °C) is shown in Table 24. Figures 16 and 17 illustrate the plume's elliptically-shaped and radial contours, respectively. The +1 through +4 o/oo radii extend 1.8, 1.3, 0.9 and 0.8 nm downstream, respectively, and the predicted areal extent are 6.4, 3.5, 1.7 and 1.0 nm^2, respectively. The maximum above-ambient bottom salinity is 4.7 o/oo, and the vertical extent of the brine jet nearly reaches mid-depth, 17.1 ft above the ocean floor. The elliptically shape plume that is aligned in the preferred northeast current direction has a +1 o/oo contour which approaches as close as 1.5 nm offshore the barrier island and 2.1 nm from the ship channel. The +1 o/oo radial contour remains 1.2 and 1.8 nm from Horn Island and the ship channel, respectively. Although, each above-ambient salinity contour enters the western portion of the disposal area, these contours cover a smaller area.

Table 22
Characteristics of Large (Worst-Case) Brine Plume at Richton for 55 Open Ports

Ambient Bottom Salinity (o/oo)	25.00
Ambient Bottom Temperature (°C)	15.00
Depth (ft)	47.00
Ambient Bottom Current (m/s)	.03
Ambient Top Salinity (o/oo)	25.00
Brine Salinity (o/oo)	263.00
Brine Temperature (°C)	20.00
Number of open ports	55.00
Jet Exit Velocity (ft/s)	27.00
Port Diameter (in)	3.00
Brine discharge rate (m^3/s)	2.1
Brine discharge rate (barrel/day x 10^6)	1.1
Maximum above-ambient bottom salinity (o/oo)	5.3
Vertical extent (m)	5.2
Vertical extent (ft)	17.0

Plume Areal Extent	(km^2)	(nm^2)	(acresx10^3)
+1o/oo contour	73.3	21.3	18.1
+2o/oo contour	41.5	12.1	10.3
+3o/oo contour	21.5	6.3	5.3
+4o/oo contour	12.9	3.7	3.2
+5o/oo contour	5.7	1.7	1.4

Plume Width	(km)	(nm)
+1o/oo contour	8.0	4.3
+2o/oo contour	6.3	3.4
+3o/oo contour	4.2	2.3
+4o/oo contour	3.2	1.7
+5o/oo contour	1.7	0.9
Plume Downstream Length	**(km)**	**(nm)**
+1o/oo contour	6.0	3.2
+2o/oo contour	4.3	2.3
+3o/oo contour	3.2	1.7
+4o/oo contour	2.7	1.5
+5o/oo contour	2.2	1.2
Plume Upstream Length	**(km)**	**(nm)**
+1o/oo contour	3.5	1.9
+2o/oo contour	2.4	1.3
+3o/oo contour	1.8	1.0
+4o/oo contour	1.3	0.7
+5o/oo contour	1.1	0.6

Table 23
Characteristics of an Average (Typical-Case) Brine Plume at Richton Diffuser Site for 55 Open Ports and a 0.06 m/s Bottom Current

Ambient Bottom Salinity (o/oo)	31.00
Ambient Bottom Temperature (°C)	22.00
Depth (ft)	47.00
Ambient Bottom Current (m/s)	.06
Ambient Top Salinity (o/oo)	31.00
Brine Salinity (o/oo)	263.00
Brine Temperature (°C)	20.00
Number of open ports	55.00
Jet Exit Velocity (ft/s)	27.00
Port Diameter (in)	3.00
Brine discharge rate (m^3/s)	2.1
Brine discharge rate (barrel/day x 10^6)	1.1
Maximum above-ambient bottom salinity (o/oo)	4.9
Vertical extent (m)	5.2
Vertical extent (ft)	17.1

Plume Areal Extent	(km^2)	(nm^2)	(acres x 10^3)
+1o/oo contour	31.4	9.1	7.7
+2o/oo contour	17.4	5.1	4.3
+3o/oo contour	8.8	2.6	2.2
+4o/oo contour	5.2	1.5	1.3

Plume Width	(km)	(nm)
+1o/oo contour	5.3	2.9
+2o/oo contour	4.0	2.2
+3o/oo contour	2.7	1.4
+4o/oo contour	1.9	1.0
Plume Downstream Length	**(km)**	**(nm)**
+1o/oo contour	3.9	2.1
+2o/oo contour	2.7	1.5
+3o/oo contour	2.0	1.1
+4o/oo contour	1.7	0.9
Plume Upstream Length	**(km)**	**(nm)**
+1o/oo contour	2.0	1.1
+2o/oo contour	1.4	0.8
+3o/oo contour	1.0	0.6
+4o/oo contour	0.8	0.4

Table 24
Characteristics of an Average (Typical-Case) Brine Plume at Richton Diffuser Site for 55 Open Ports and a 0.09 m/s Bottom Current

Ambient Bottom Salinity (o/oo)	31.00
Ambient Bottom Temperature (°C)	22.00
Depth (ft)	47.00
Ambient Bottom Current (m/s)	0.09
Ambient Top Salinity (o/oo)	31.00
Brine Salinity (o/oo)	263.00
Brine Temperature (°C)	20.00
Number of open ports	55.00
Jet Exit Velocity (ft/s)	27.00
Port Diameter (in)	3.00
Brine discharge rate (m^3/s)	2.1
Brine discharge rate (barrel/day x 10^6)	1.1
Maximum above-ambient bottom salinity (o/oo)	4.7
Vertical extent (m)	5.2
Vertical extent (ft)	17.1

Plume Areal Extent	(km^2)	(nm^2)	(acres x 10^3)
+1o/oo contour	21.9	6.4	5.4
+2o/oo contour	11.9	3.5	2.9
+3o/oo contour	5.9	1.7	1.5
+4o/oo contour	3.5	1.0	0.9

Plume Width	(km)	(nm)
+1o/oo contour	4.7	2.5
+2o/oo contour	3.5	1.9
+3o/oo contour	2.3	1.2
+4o/oo contour	1.6	0.9
Plume Downstream Length	**(km)**	**(nm)**
+1o/oo contour	3.3	1.8
+2o/oo contour	2.4	1.3
+3o/oo contour	1.7	0.9
+4o/oo contour	1.4	0.8
Plume Upstream Length	**(km)**	**(nm)**
+1o/oo contour	1.6	0.9
+2o/oo contour	1.1	0.6
+3o/oo contour	0.8	0.4
+4o/oo contour	0.6	0.3

Figure 12
Predicted Large (Worst-Case) Elliptical Shape Brine Plume Contours for Richton Diffuser Site

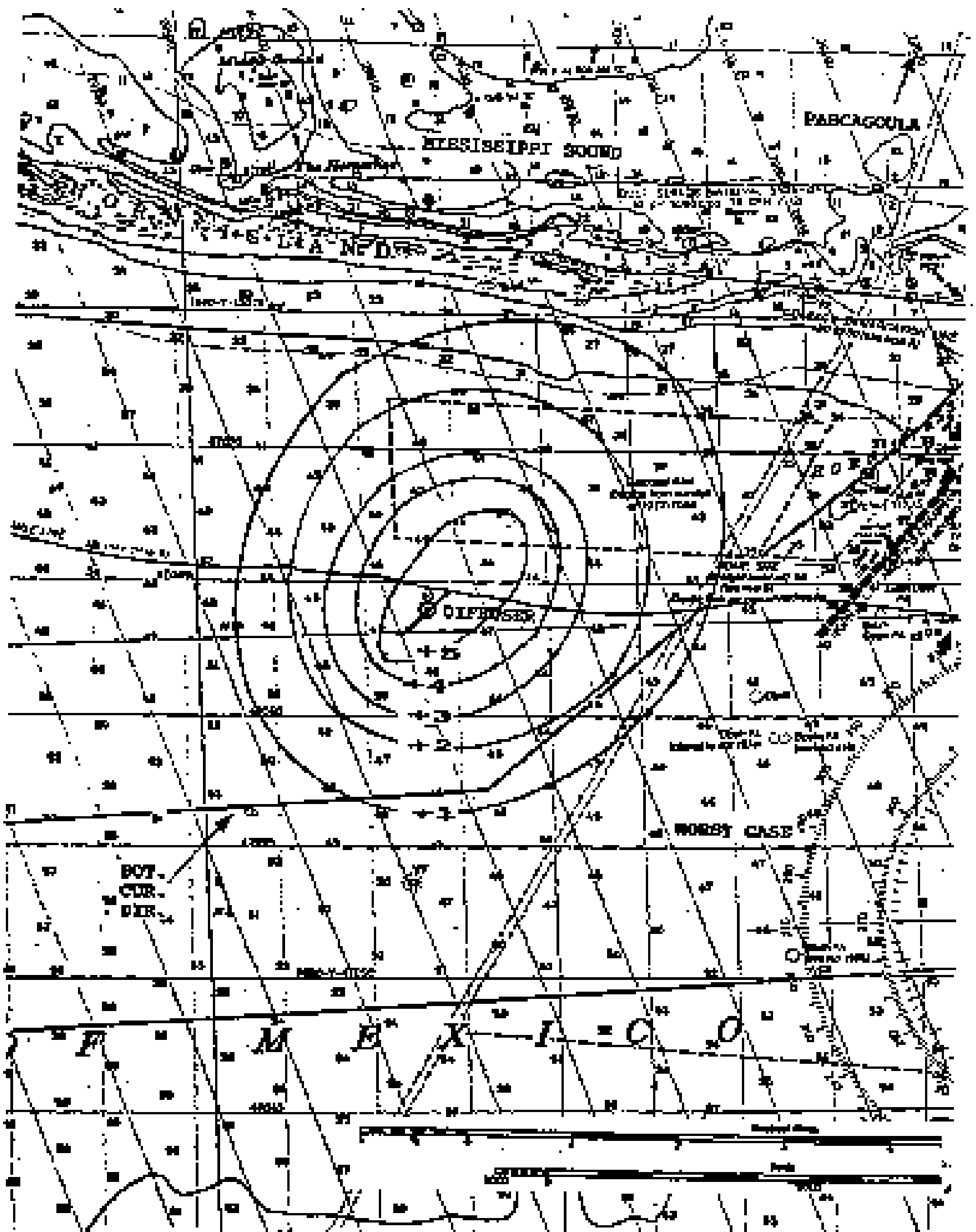


Figure 13
Predicted Radial Extent of Large (Worst-Case) Brine Plume Contours
for Richton Diffusor Site

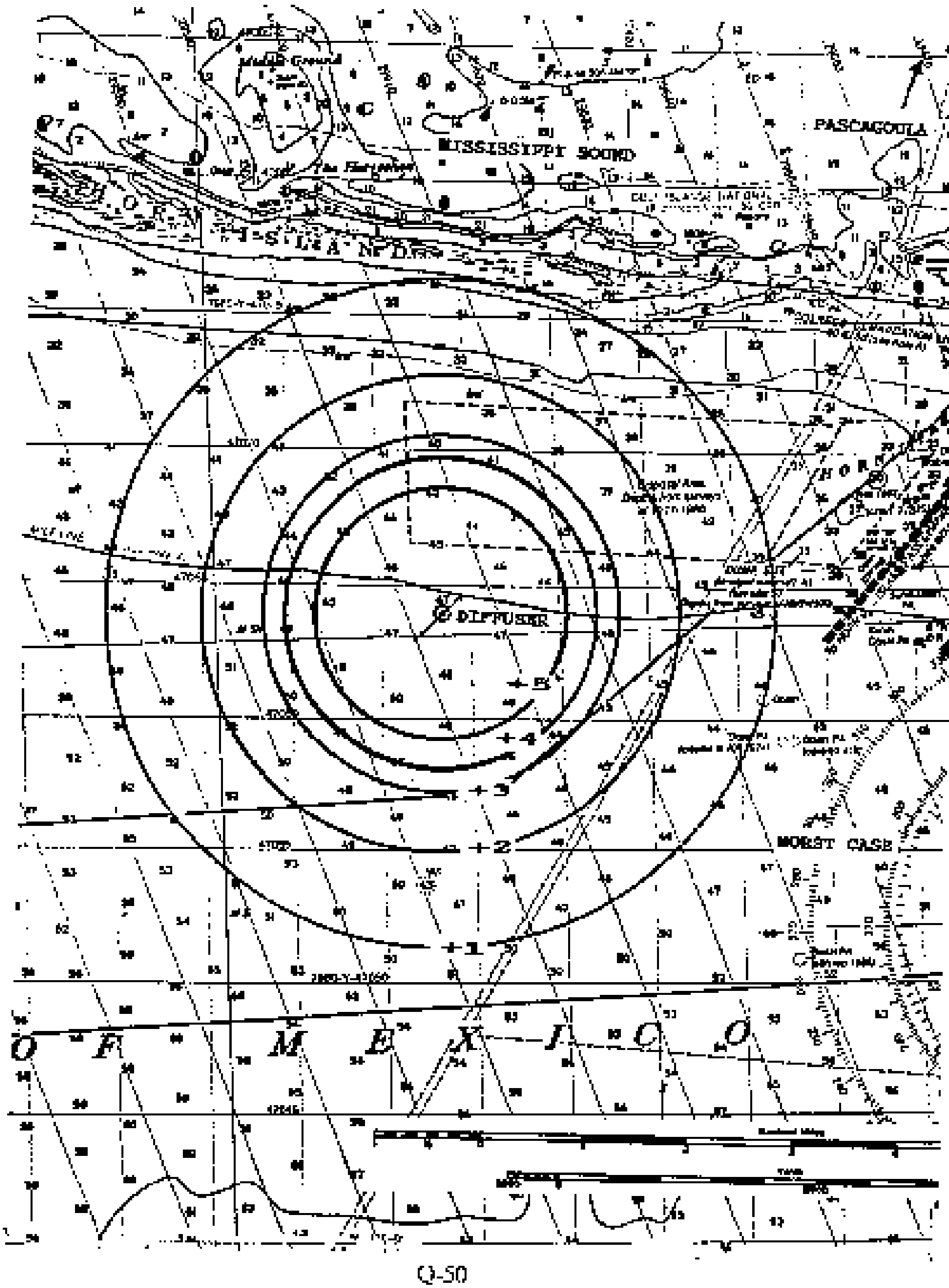


Figure 14
Predicted Average (Typical-Case) Elliptical Shape Brine Plume Contours for Richton Diffuser Site and 0.06 m/s Bottom Current

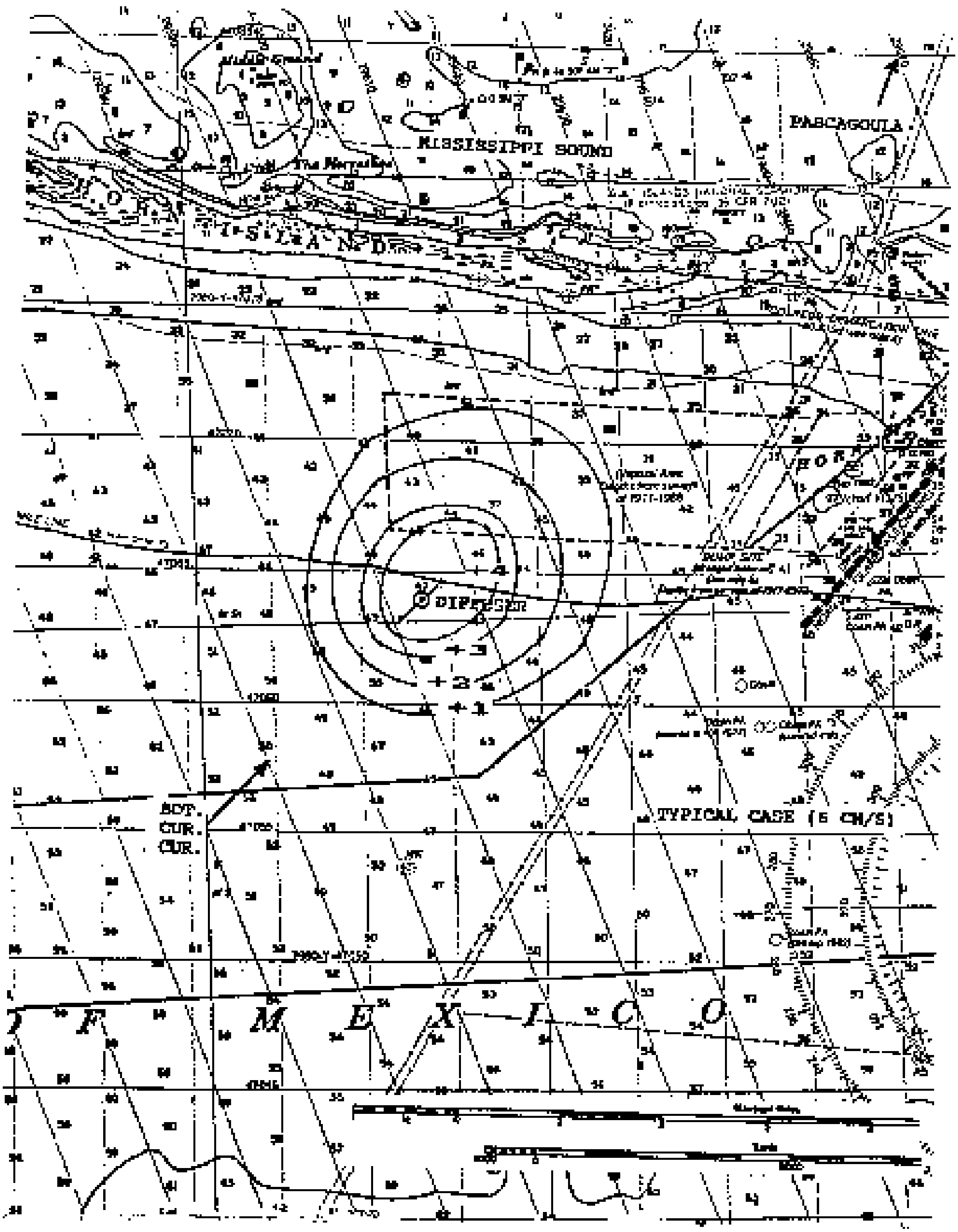


Figure 15
Predicted Radial Extent of Average (Typical-Case) Brine Plume Contours for Richton Diffuser Site and 0.06 m/s Bottom Current

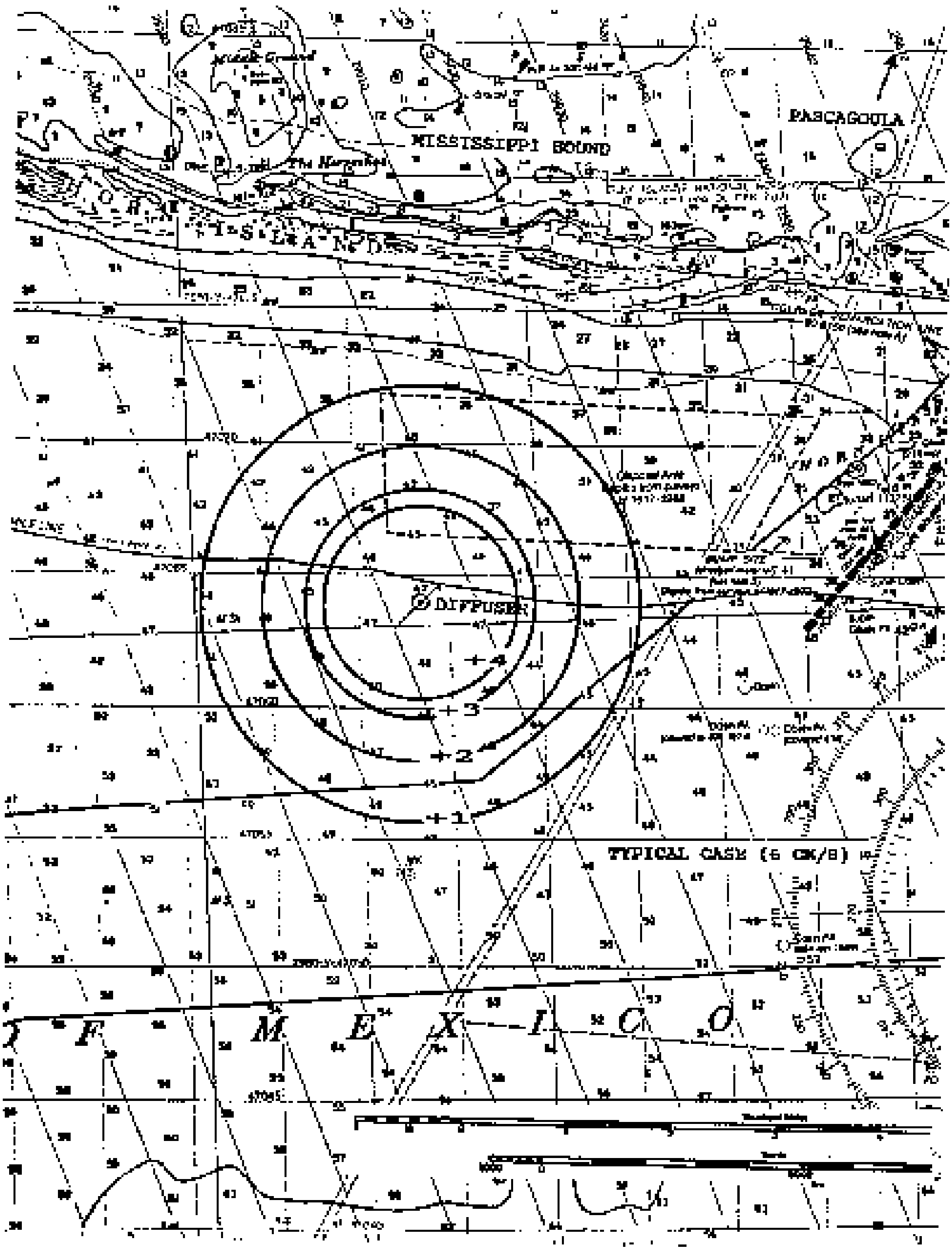


Figure 16
Predicted Average (Typical-Case) Elliptical Shape Brine Plume Contours for Richton Diffuser Site and 0.09 m/s Bottom Current

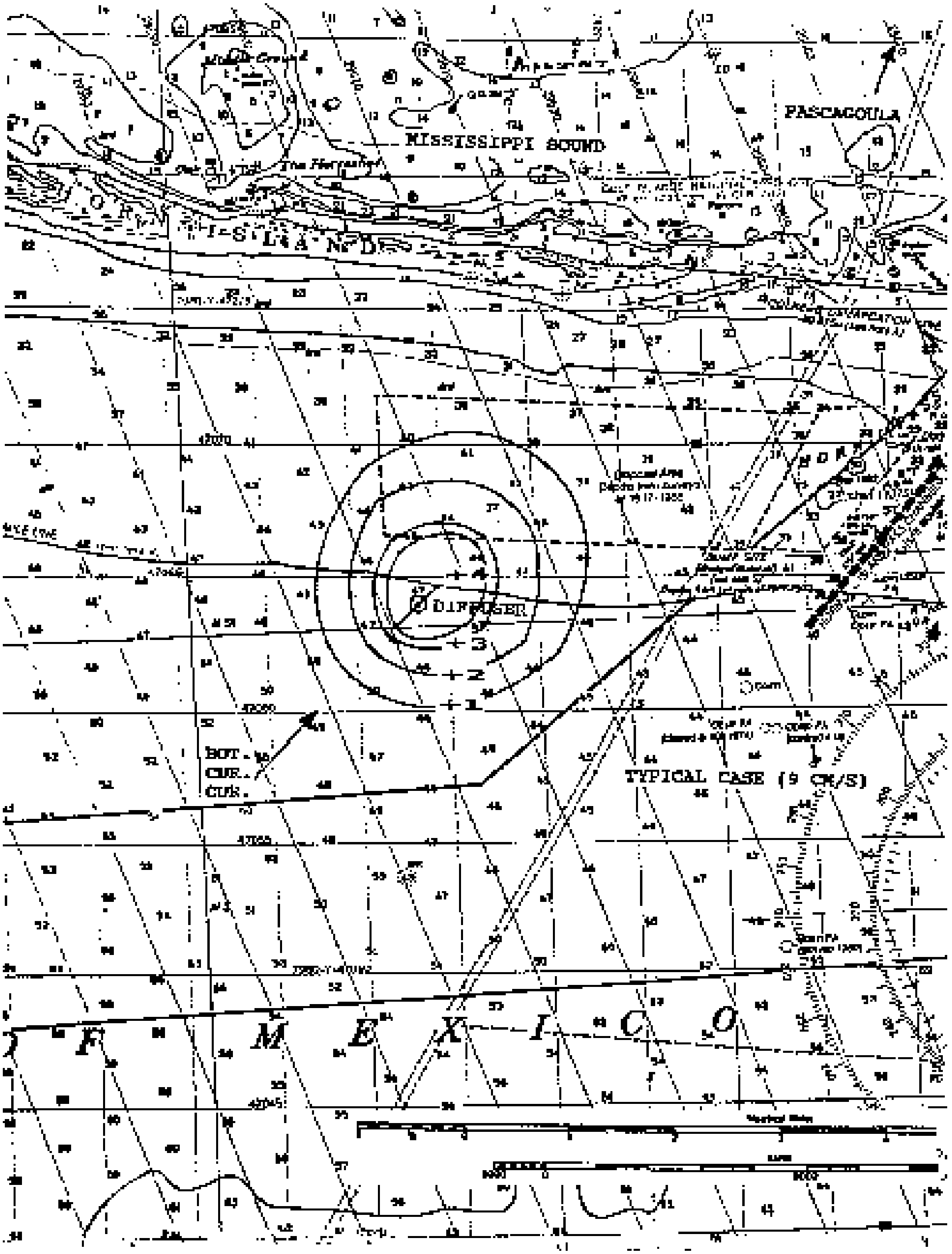
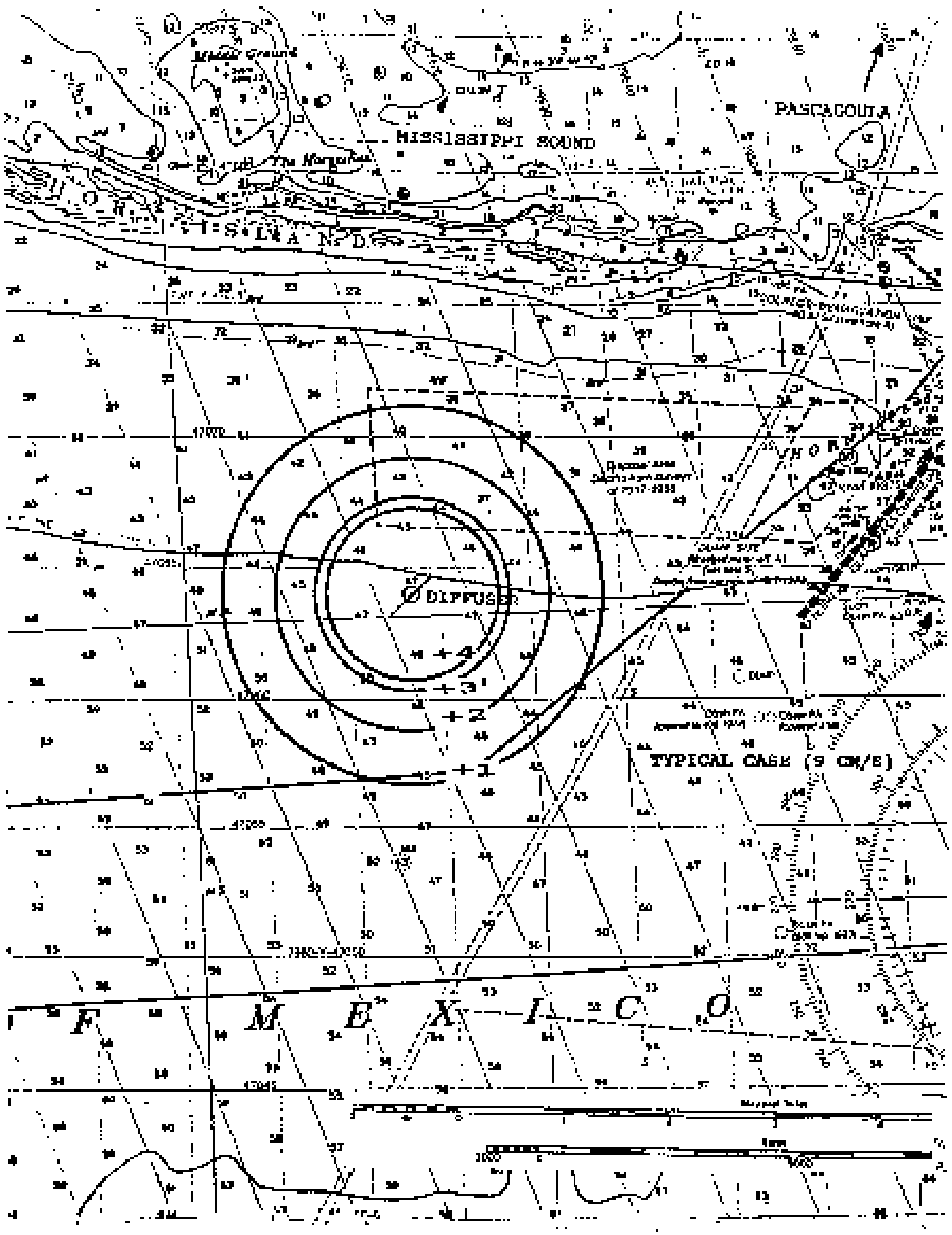


Figure 17
Predicted Radial Extent of Average (Typical-Case) Brine Plume Contours for Richton Diffuser Site and 0.09 m/s Bottom Current



FREQUENCY OF BOTTOM CURRENT MAGNITUDES AND DIRECTIONS

The worst-, typical-, and best-case conditions are estimates expected to occur at the proposed diffuser sites based on existing environmental data and historical data. One of the most critical factors affecting the plume size is the magnitude of the ambient bottom current, which is measured 2 m (6 ft) above the sea floor. The following discusses data used in the selection of the worst-, typical-, and best-case bottom currents for the Stratton Ridge and Weeks Island/Cote Blanche sites and the worst- and typical-case bottom currents for the Richton site.

Stratton Ridge and Weeks Island/Cote Blanche Sites. A Randall and Kelly (1982) report focuses on current meter data collected by Waddell and Hamilton (1981) during the period of October 1977 through October 1978 at the Big Hill Secondary site, located 3 nm east of the Big Hill diffuser site (Table 25). The bottom current is 3 cm/s or less for a small percent of the time during the winter and spring months. Its frequency of occurrence ranges from 1 percent of the time in February to 15 percent of the time in May, July, and August. Thus, the worst-case plumes are more likely to occur in the late spring and summer months. A current of 9 cm/s, which corresponds to the typical-case scenario, and its associated range (between 6 and 12 cm/s) occur between 25 and 40 percent of the time. These currents occur 40 percent of the time during March, July, and August, 36 percent of the time in June, and 25 percent of the time during the other months. A current of 18 cm/s, which correspond to the best-case scenario, and its associated range (15 to 20 cm/s) occur between 6 percent and 24 percent of the time. The average frequencies of occurrence for the worst-, typical-, and best-case plumes, based upon the average the frequencies of occurrence of the bottom currents, are 8%, 31%, and 15%, respectively. According to Randall and Kelly (1982) these bottom currents occur at West Hackberry with a similar frequency. Therefore, these frequencies are also representative of brine plumes generated at both the Stratton Ridge and Weeks Island/Cote Blanche sites.

Similar current data for the West Hackberry diffuser site (Kelly et al., 1984) were analyzed to illustrate the frequency of occurrence for selected bottom currents (see Table 26). The lowest currents (2 - 5 cm/s) normally occur in the summer months with an eighteen-month average frequency of 10.4 percent. Currents in the 5 to 10 and 10 to 15 cm/s ranges occur most often with an eighteen-month average frequency of 57.5 percent. Currents between 15 and 20 cm/s have an eighteen-month average frequency of 16.3 percent. Therefore, the worst-case plume, which corresponds to a 3 cm/s bottom current, occurs about 10.4 percent of the time and the typical- and small-case plumes occur about 57.5 and 16.3 percent of the time, respectively. Table 27 tabulates the bottom current direction for the West Hackberry site. These data show that the preferred bottom current direction is west (i.e., parallel to the coastline) 26 percent of the time.

Richton Site. The bottom current data measured offshore of Horn Island (Kjerfve and Sneed, 1984) were examined to determine the magnitude and preferred direction of the bottom currents for the Richton's worst- and typical- case plumes (Table 28). Bottom currents between 0 and 4 cm/s and 4 and 8 cm/s occur 34 percent of the time; bottom currents between 8 and 14 cm/s occur 22 percent of the time. Therefore, the worst-case plumes (with a 0.03 m/s bottom current) and the typical-case (with a 0.06 m/s bottom current) plumes occur 34 percent of the time. The bottom current occurs in all directions with a preference for the north-northeast direction 19 percent of the time and the northeast-east direction 26 percent of the time. Therefore, the NE direction is chosen as the representative bottom current direction.

These bottom current data (Kjerfve and Sneed, 1984) represent only a 4-month period of data collection. In addition, Kjerfve and Sneed (1984) indicate that the bottom current direction should be viewed with caution due to biofouling during the first two months of data collection.

The preferred northeast direction of the bottom current is nearly in line with the direction of the diffuser although it is preferred that the diffuser lie normal to the predominant current direction. At the West Hackberry and Big Hill diffuser sites, the diffusers are oriented more normally to the predominant direction of the bottom current, which is typically parallel to the coastline.

Table 25
Frequency of Occurrence for Range of Current Magnitudes Based on Current Joint Frequency Distribution of Big Hill Secondary Site Bottom Current Data for December 1977 Through August 1978, Randall and Kelly (1982)

Month/Yr	Current Magnitude (cm/s)				
	0 - 3	3 - 6	6 - 12	12 - 15	15 - 20
DEC 77	3.8	14.4	25.9	12.8	18.6
JAN 78	2.6	7.7	25.6	13.8	19.4
FEB 78	1.0	8.9	24.0	13.8	20.8
MAR 78	7.1	16.9	42.4	13.6	11.0
APR 78	4.6	10.6	25.2	15.6	23.9
MAY 78	15.3	16.7	23.3	12.0	14.9
JUN 78	10.1	18.2	36.7	13.3	12.5
JUL 78	15.1	20.8	41.5	12.4	7.9
AUG 78	14.5	22.3	42.7	7.3	6.6
AVE	8.2	15.2	31.9	12.7	15.1

Table 26
Summary of Frequency of Occurrence for Range of Current Magnitudes Based on Joint Frequency Distribution of West Hackberry Site Bottom Current Data for May 1982 Through November 1983, Kelly et al (1984)

Month/Yr	Current Magnitude (cm/s) 2 - 5	5 - 10	10 - 15	15 - 20
May 82	12.5	25.5	25.0	15.5
Jun 82	15.3	35.4	26.4	14.9
Jul 82	9.4	40.2	35.9	11.7
Aug 82	14.2	41.0	29.8	8.9
Sep 82	12.5	33.6	30.4	13.8
Oct 82	7.0	28.0	35.5	19.1
Nov 82	6.4	27.1	34.2	22.1
Dec 82	8.2	20.6	20.8	24.1
Jan 83	8.2	24.7	29.0	18.0
Feb 83	6.8	23.7	35.9	20.1
Mar 83	10.4	26.1	21.2	9.0
May 83	8.0	19.1	16.5	17.3
Jun 83	12.9	26.0	28.3	15.6
Jul 83	10.2	28.2	26.2	15.2
Aug 83	11.8	33.3	27.7	14.7
Sep 83	14.3	29.6	29.6	16.0
Oct 83	8.9	35.1	31.5	17.3
Nov 83	9.3	23.8	30.4	20.4
AVERAGE	10.4	28.9	28.6	16.3

Table 27
Frequency of Occurrence for Range of Current Directions Based on
Joint Frequency Distribution of West Hackberry Site Bottom Current Data For
May 1982 Through November 1983, Kelly et al (1984)

Frequency of Occurrence (%)									
Month/Year	N	NE	E	SE	S	SW	W	NW	CALM
May '82	8.5	9.9	11.4	9.4	11.0	13.4	23.7	9.5	3.1
June '82	8.1	19.2	24.2	15.1	6.3	7.2	5.7	9.4	4.9
July '82	4.8	20.8	35.2	10.2	5.8	5.5	11.2	4.7	1.7
August '82	7.7	13.0	16.1	9.4	5.6	6.9	29.2	7.1	5.0
September '82	3.5	3.3	5.4	7.2	5.8	12.6	43.3	15.0	3.8
October '82	5.1	7.9	8.2	3.9	3.2	7.7	47.3	16.1	0.5
November '82	8.6	8.2	7.2	3.5	6.1	11.8	39.6	13.3	1.7
December '82	4.8	10.6	7.0	6.6	6.6	13.7	30.8	18.8	1.1
January '83	12.6	19.5	8.5	4.7	5.4	16.5	21.8	8.7	2.3
February '83	10.3	27.5	17.4	7.3	5.4	6.4	20.2	4.0	1.5
March '83	5.0	16.2	14.0	2.7	5.9	14.0	34.7	4.5	3.2
May '83	6.7	6.9	4.4	5.5	8.9	14.9	38.0	12.7	2.0
June '83	8.3	10.0	13.9	12.4	6.1	13.6	19.2	12.1	4.4
July '83	21.0	12.9	7.8	9.8	9.5	12.5	12.0	9.5	5.0
August '83	11.3	16.1	15.0	8.3	7.3	17.1	14.5	8.5	3.9
September '83	7.8	7.6	6.9	7.6	5.4	14.6	29.0	14.2	6.8
October '83	6.7	18.7	14.5	10.0	4.7	10.2	19.4	12.6	3.1
November '83	7.9	17.6	2.8	3.1	5.0	9.0	39.4	11.3	3.9
AVERAGE	8.3	13.7	12.1	7.6	6.3	11.5	26.6	10.7	3.2

Table 28
Summary of Frequency of Occurrence for Range of Current Magnitudes Based on Joint Frequency Distribution of Offshore Mississippi Sound Site Bottom Current Data for November 1, 1980 to January 9, 1981 and March 21 to May 23, 1981, Kjerfve and Sneed (1984)

Current Magnitude (cm/s) Frequency of Occurrence			
0 - 4	4 - 8	8 - 14	14 - 22
34%	34%	22%	10%

Current Direction Frequency of Occurrence							
N-NE	NE-E	E-SE	SE-E	S-SW	SW-W	W-NW	NW-N
19%	26%	13%	6%	6%	7%	9%	14%

CHAPTER 4

PREDICTION OF BRINE JET VERTICAL EXTENT

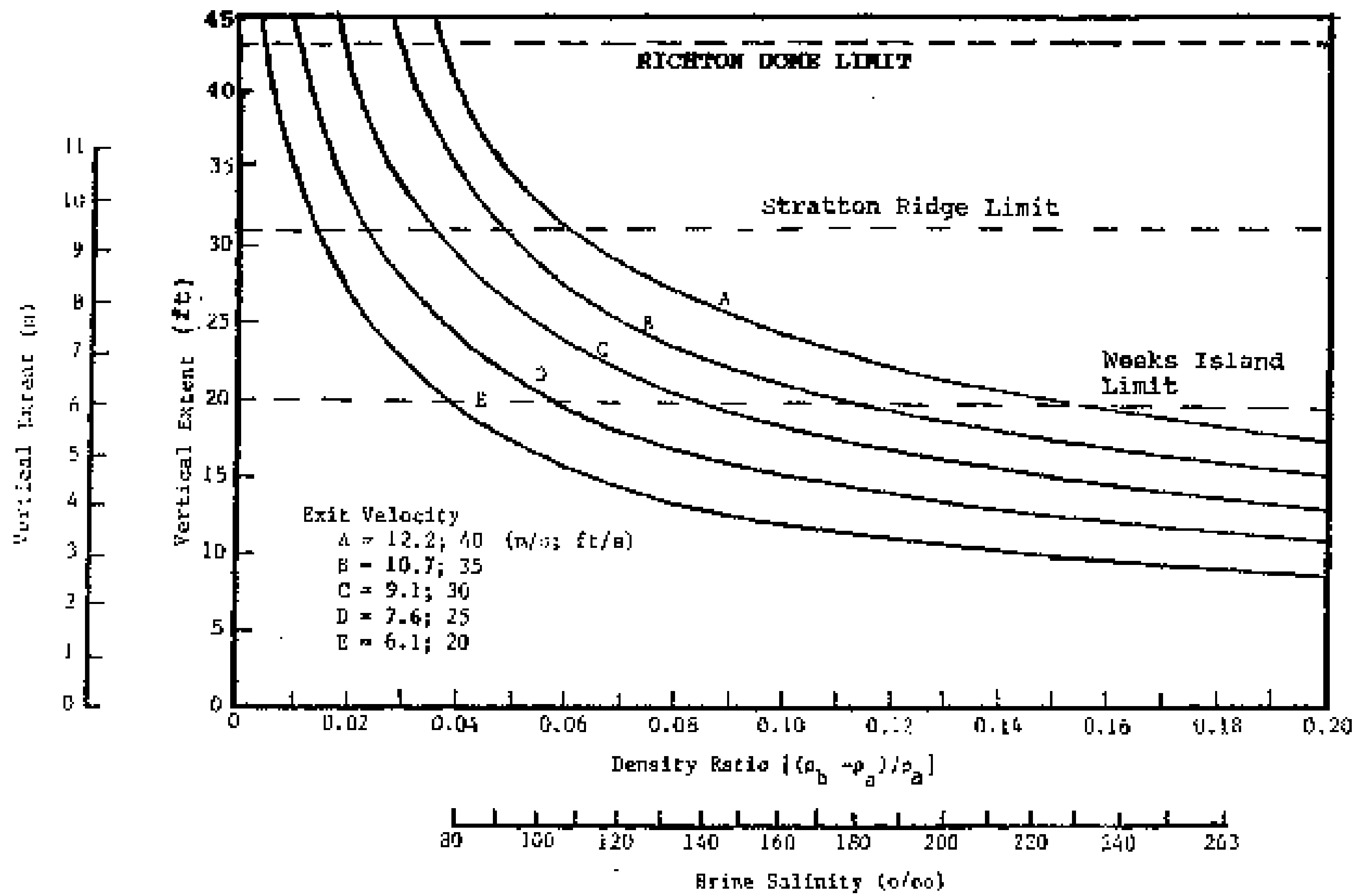
The vertical extent of the brine jets depends upon the exit velocity, port diameter, brine density, and ambient density of the receiving waters. The vertical extent of negatively buoyant jets has been investigated in laboratory experiments reported by Tong and Stolzenbach (1979), Turner (1966), and Randall and McLellan (1983). These experiments have resulted in the following equation:

$$Z/D = CV_e/[g(\rho_b-\rho_a/\rho_a)D]^{1/2} \qquad (5)$$

where Z is the maximum height of brine jet above the port, D is inside port diameter, V_e is the port exit velocity, g is the gravitational acceleration constant, ρ_b is the brine density, ρ_a is the ambient sea water density, and C is a proportional constant. Randall and McLellan (1983) derived a value of 2.2 for C.

Using the ambient conditions of 25 o/oo and 15.5 °C, the above equation was used to compute the vertical extent of the brine jet. The results are plotted in Figure 18. This graph can be used to evaluate the effect of brine salinity reduction on the vertical extent of the brine jet and to study conditions that cause the jet to reach the surface. Linear interpolation between the curves is used to obtain a value for exit velocities ranging between 20 and 30 ft/s.

Figure 18
Vertical Extent of Brine Jet for Various Discharge Conditions With the Ambient Salinity and Temperature as 25 o/oo and 15.5 °C



CHAPTER 5

SUMMARY

The U.S. DOE is proposing to locate diffusers in the Gulf of Mexico for disposing brine from several proposed expansion SPR sites: Stratton Ridge, Weeks Island, Cote Blanche, and Richton. These diffusers will be similar to those used at Bryan Mound, West Hackberry, and Big Hill. The proposed Stratton Ridge diffuser site is located approximately 4 nm offshore of Surfside, Texas in 36 ft of water. Weeks Island and Cote Blanche share the same proposed diffuser site, which is located in 25 ft of water approximately 7.5 nm offshore Sand Ridge in Louisiana. The proposed Richton diffuser site is located approximately 10.5 nm offshore of Pascagoula, Mississippi in 47 ft of water, approximately 3 nm offshore Horn Island and 3.5 nm southwest of the Horn Island Pass Channel.

An empirical brine plume prediction model developed from West Hackberry brine plume data was used to predict the plume characteristics for the proposed Stratton Ridge, Weeks Island/Cote Blanche, and Richton sites. A similar empirical model was used to estimate the same plume characteristics at the Big Hill site prior to its construction and operation. The model uses inputs based upon the characteristics of the receiving water, brine water, and diffuser. Although site-specific data for the proposed diffuser sites are not available, data are available from studies conducted at similar SPR sites. Big Hill data was used to develop scenarios for the proposed Stratton Ridge site, Weeks Island data was used to develop scenarios for the proposed Weeks Island/Cote Blanche diffuser location, and several data sets collected in the Mississippi Sound and offshore barrier islands were used to develop scenarios for Richton. Bryan Mound data were not used in this analysis since Bryan Mound is located in water (71 ft) that is significantly deeper than the proposed diffuser sites. The ambient water parameters used in this analysis should satisfactorily represent those of the proposed diffuser locations. The brine water and diffuser characteristics are the same as those found at the West Hackberry and Big Hill sites. In addition, extensive offshore environmental studies found no detrimental effects resulting from brine discharge over a 5-year period at Bryan Mound or over a 3-year period at West Hackberry.

The predicted results for the Stratton Ridge 55-port diffuser are described for worst-, typical-, and best-plume scenarios. The worst-case scenario is determined mostly by its low bottom current (0.03 m/s) and its high exit velocity (30 ft/s). For this case, the predicted plume has a maximum above-ambient bottom salinity of 4.7 o/oo and, therefore, has 4 above-ambient bottom salinity contours. The model predicts that the areas inside the elliptical contours will be 23.6, 13.4, 6.9 and 4.2 nm^2 for the +1 through 4 o/oo above-ambient salinity contours, respectively. The maximum widths of each plume contour are 4.5, 3.5, 2.4 and 1.8 nm. Similarly, the downstream lengths (in the direction of the bottom current) are 3.4, 2.4, 1.8 and 1.5 nm and the upstream lengths are 2.0, 1.4, 1.0 and 0.7 nm, respectively. If the downstream length is used as the radius of the plume's maximum extent, then the +1 contour reaches the Freeport ship channel and Surfside Beach. However, the model does not account for the effects of a bottom slope. Therefore, it is expected that the low bottom currents encountered in the worst-case scenario are not strong enough to move the negatively buoyant plume up the bottom slope and on land. A typical plume occurs when the bottom current is 0.09 m/s and the exit velocity is 27 ft/s. Under these conditions the maximum above-ambient salinity reduces to 3.8 o/oo, and therefore only 3 above-ambient salinity contours are predicted. The predicted area inside the +1 through 3 o/oo contours is 5.9, 3.2 and 1.6 nm^2. The downstream length for the +1 o/oo contour reaches 1.7 nm from the diffuser center and has a maximum width is 2.4 nm.

Similar scenarios were used for the Weeks Island/Cote Blanche site, which is located in shallower water (25 ft). For the 55-port diffuser worst-case scenario, the maximum above-ambient bottom salinity at the diffuser is 4.9 o/oo and, therefore, there are 4 above-ambient bottom salinity contours. The model predicts that the areas inside the elliptical contours are 29.3, 16.7, 8.7 and 5.2 nm^2 for the +1 through 4 o/oo above-ambient salinity contours, respectively. The maximum widths of each plume contour are 5.4, 4.3, 2.9 and 2.3 nm for the respective +1 to 4 o/oo contours. Similarly, the downstream lengths are 4.1, 2.9, 2.2 and 1.9 nm and the upstream lengths are 2.5, 1.7, 1.3 and 0.9 nm, respectively. If the downstream length is used as the radius of the plume's maximum extent, then the +1 contour for the site extends approximately 3 nm offshore without impacting the Freshwater Bayou channel near Sand Ridge in Louisiana. A typical plume occurs when the bottom current is near 0.09 m/s and the exit velocity is 27 ft/s. Under these conditions the maximum above-ambient salinity is 3.9 o/oo and, therefore, there are 3 above-ambient salinity contours. The predicted areas inside the +1 through 3 o/oo contours are 6.3, 3.4 and 1.7 nm^2. The downstream length and maximum width of the +1 o/oo contour are 1.8 nm and 2.5 nm from the diffuser center, respectively.

The predicted plumes for the Richton 55-port diffuser are described for worst- and typical-plume scenarios. The worst-case scenario is characterized by the low bottom current of 0.03 m/s. For this case, the maximum above-ambient bottom salinity at the diffuser is predicted to be +5.3 o/oo, meaning that there are five above-ambient bottom salinity contours. The model predicts the area inside each elliptically shape contour is 21.3, 12.1, 6.3, 3.7 and 1.7 nm^2 for the +1 through +5 o/oo contours, respectively. The maximum width of each plume contour is 4.3, 3.4, 2.3, 1.7 and 0.9 nm for the respective +1 to +5 o/oo contours. Similarly, the downstream length (in the direction of the bottom current) is 3.2, 2.3, 1.7, 1.5 and 1.2 nm, and the upstream length is 1.9, 1.3, 1.0, 0.7 and 0.6 nm, respectively. If the downstream length is used as a radius of the plume contours' maximum extent, the +1 contour approaches as far as Horn Island, but it does not enter Mississippi Sound or the Horn Island Pass Channel. Since the model does not account for the effects of a bottom slope, it is expected that the low bottom currents encountered in the worst case scenario are not strong enough to move the negatively buoyant plume up the bottom slope and on land. All plume contours enter the western portion of the designated dredged material disposal area offshore Horn Island.

A typical plume is expected to occur at Richton when the bottom current is near 0.06 m/s and the exit velocity is 27 ft/s. Under these conditions the maximum above-ambient salinity is +4.9 o/oo, which means that up to four above-ambient salinity contours occur. The predicted area inside the +1 through +4 o/oo contours are 9.1, 5.1, 2.6 and 1.5 nm^2. The downstream length for the +1 o/oo contour reaches 2.1 nm from the diffuser center, and the maximum width is 2.9 nm. The +1 o/oo radial contour remains 1.1 nm offshore Horn Island and 1.6 nm from the Horn Island Pass ship channel.

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APPENDIX R

CALCULATIONS TO ESTIMATE HYDRAULIC CHANGES RESULTING FROM RAW WATER WITHDRAWAL

R.1 Introduction

Chapter 7 of this DEIS includes an assessment of the hydraulic changes in water bodies that would serve as the raw water source for each of the candidate expansion sites. The proposed source of raw water for Big Hill, Stratton Ridge, Weeks Island, and Cote Blanche is the ICW, and the proposed source of raw water for the Richton site is the Leaf River. The hydraulic changes in the ICW caused by Big Hill's raw water withdrawal have been evaluated extensively in the past, both through predictive modeling completed in 1981 and 1985 prior to the initiation of operations at Big Hill and through field observation and experience over the four-year period that Big Hill withdrew water from the ICW for leaching. Chapter 7 summarizes these conclusions for Big Hill and evaluates how they continue to be applicable for the proposed Big Hill expansion. No prior modeling, however, has been completed for the other four candidate sites, and none of the other sites have any operational experience that can serve as a direct basis for evaluating the proposed raw water withdrawals. For these sites, therefore, Chapter 7 summarizes new modeling results predicting hydraulic changes that may be caused by the proposed raw water intake. This appendix documents the equations and input parameters that support those modeling results for Stratton Ridge, Weeks Island, Cote Blanche, and Richton.

R.2 Calculations

Hydrological impacts on the ICW and the Leaf River were estimated as changes in the slopes of the water surface profiles using site-specific channel characteristics, assumed flow rates, and Manning's equation:

$$V=\frac{1.49}{n}R^{2/3}S^{1/2} \tag{1}$$

where

V	=	flow velocity (ft/s),
n	=	Manning's roughness coefficient (unitless) for a dredged channel, assumed n = 0.028 based on typical values reported in the literature[1] for channel characteristics resembling the ICW,
S	=	energy slope (ft/ft), and
R	=	hydraulic radius (ft).

Although flows in the ICW and the Leaf River are nonuniform, Manning's equation is assumed to be valid outside the "local" influences of the raw water intake. This is valid if the energy slopes and channel slopes are approximately equal. Manning's equation can be rearranged to solve for the energy slope, S, which corresponds to the slope of the water surface profile:

$$S = \frac{V^2 n^2}{2.22 R^{4/3}} \tag{2}$$

At all four sites, channel geometries were assumed to be trapezoidal, and bottom slopes were assumed to be negligible in the longitudinal direction. The hydraulic radius and cross-sectional channel area, therefore, can be computed as follows:

$$R = \frac{(b + Zy)y}{b + 2y\sqrt{1 + Z^2}} \tag{3}$$

$$A = (b + zy)y \tag{4}$$

where

R	=	hydraulic radius (ft),
A	=	cross-sectional channel area (ft^2),
b	=	bottom width (ft),
y	=	water depth (ft), and
z	=	side slope, run per one unit rise (ft/ft).

The assumed bottom widths, depths, and side slopes of the ICW and Leaf River are presented in Table R.1-1 along with the calculated hydraulic radii and cross-sectional channel areas. The channel geometry assumed for the ICW corresponds to values of the top width measured from nautical charts and the bottom dimensions maintained by dredging by the Corps of Engineers. The geometry assumed for the Leaf River corresponds to values of the top width measured from USGS quadrangle maps, reported depths, and an assumed side slope.

Table R.1-1
Assumed Channel Geometries and Estimated
Hydraulic Radii and Cross-Sectional Channel Areas

Site/Water Body	Assumed Channel Geometries				Estimated Channel Characteristics	
	b (ft)	y (ft)	z (ft/ft)		R (ft)	A (ft^2)
Stratton Ridge/ICW	125	12	5.2		8.9	2,250
Weeks Island/ICW	125	12	2		10.0	1,788
Cote Blanche/ICW	125	12	2		10.0	1,788
Richton/Leaf River	200	8	2		7.3	1,728

At each site, the raw water intake will withdraw an average of 100 cfs. This intake rate was imposed on a range of flow rates of the ICW and Leaf River to evaluate potential hydraulic changes in each water body. Because data on actual flow rates in the ICW near the proposed raw water intakes at Stratton Ridge, Weeks Island, and Cote Blanche are not available, estimates of the change in energy slope were developed for a range of probable ICW flow rates before and after water withdrawal, where

$$Q = \text{flow rate (cfs)} = V \times A.$$

Data on flow rates in the Leaf River near Richton's proposed raw water intake are available from the Mississippi Department of Environmental Quality and were used to estimate the change in the energy slope in the river. These estimated changes in energy slope, in units of ft/ft, were then converted into estimates of the vertical change in water depth per mile of waterway caused by the proposed raw water withdrawals.

The flow rates used in the analysis and the estimated changes in vertical depth resulting from 100 cfs withdrawals at each site are shown in Table R.1-2. Because all calculated energy slopes are very small, they compare favorably with the assumed horizontal channel slopes, validating the use of Manning's equation.

Table R.1-2
Vertical Changes in Channel Depth at Each Site
Corresponding to 100 cfs Withdrawals and Various Flow Rates

Flow Conditions Without Withdrawal				Flow Conditions With 100 cfs Withdrawal				Vertical Change in Depth
Q_1	V_1	S_1		Q_2	V_2	S_2		(Inches per Mile)
Stratton Ridge								
1,000	0.44	3.77×10^{-6}		1,100	0.49	4.56×10^{-6}		0.05
2,000	0.89	1.51×10^{-5}		2,100	0.93	1.66×10^{-5}		0.10
5,000	2.22	9.43×10^{-5}		5,100	2.27	9.81×10^{-5}		0.24
Weeks Island								
0	0	0		100	0.056	9.18×10^{-7}		0.06
500	0.28	1.29×10^{-6}		600	0.34	1.90×10^{-6}		0.04
1,000	0.56	5.14×10^{-6}		1,100	0.62	6.30×10^{-6}		0.07
5,000	2.8	1.29×10^{-4}		5,100	2.9	1.38×10^{-4}		0.58
Cote Blanche								
1,000	0.56	5.12×10^{-6}		1,100	0.62	6.2×10^{-6}		0.07
2,000	1.12	2.05×10^{-5}		2,100	1.17	2.26×10^{-5}		0.13
5,000	2.8	1.28×10^{-4}		5,100	2.9	1.33×10^{-4}		0.36
Richton								
660	0.38	3.62×10^{-6}		735	0.43	4.49×10^{-6}		0.06
720	0.42	4.31×10^{-6}		795	0.46	5.25×10^{-6}		0.06
3,869	2.24	1.24×10^{-4}		3,944	2.28	1.29×10^{-4}		0.3
30,100	17.4	7.53×10^{-3}		30,175	17.5	7.56×10^{-3}		1.9

ENDNOTES

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APPENDIX S

SAMPLE CALCULATIONS FOR ESTIMATING AIR EMISSIONS

S.1 Surge Tanks

Surge tank emissions are a combination of rim seal losses and withdrawal losses.

Assumptions:[1]

- Two - 200,000 bbl tanks (50 ft in height, diameter = 170 ft)
- Six - 400,000 bbl tanks (50 ft in height, diameter = 240 ft)
- Tanks have external floating roofs with a primary metallic shoe and a secondary rim mounted seal
- White external surface; lightly rusted interior
- Average wind speed = 8 mph; average atmospheric pressure = 14.75 psia
- Crude Characteristics

  Reid vapor pressure = 8

  Gravity = 36.8 API

  Liquid density = 7.0 lb/gal

  Crude temperature = 74°F (standby)
74°F (fill)
100°F (drawdown)

  Average molecular weight = 50 lb/lb mole

S.1.1 Rim Seal Loss

Rim Seal Loss can be calculated as follows:

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[1] Based on EPA Report AP-42, 4th edition, 1985, "Compilation of Air Pollutant Emission Factors," Section 4.4, "Storage of Organic Liquids."

Rim Seal Loss

$L_R = K_s V^n P_* D M_v K_c$

Where:

K_s = seal factor = 0.2
V = 8 mph
n = seal-related wind exponent = 1.0
P_* = parameter related to ambient pressure and true vapor pressure

$$P_* = \frac{P/Pa}{[1+(1-P/Pa)^{0.5}]^2}$$

Pa = 14.75 psia
P = 6.6 psia (74°F)
10.0 psia (100°F)

P_* = 0.092 (74°F)
= 0.129 (100°F)

D = tank diameter (ft)
= 170 ft (200,000 bbl tank)
= 240 ft (400,000 bbl tank)
M_v = molecular weight of crude (lb/lb mole)
= 50 lb/lb mole
K_c = product factor = 0.4 for crude oil

The rim seal loss for a 200,000 bbl tanks during fill can therefore be calculated as:

$L_R = (0.2)(8)^{1.0}(0.092)(170)(50)(0.4)$

$= 500.5$ lb/yr

and the rim seal loss for a 400,000 bbl tank during fill would be:

$L_R = (0.2)(8)^{1.0}(0.092)(240)(50)(0.4)$

$= 706.6$ lb/yr

A summary of rim seal losses is provided below in Table S.1-1.

Table S.1-1
Summary of Rim Seal Losses

Summary of Rim Seal Losses (per tank)		
Tank Capacity	**Standby, Fill**	**Drawdown**[2]
200,000 bbl	500.5 lb/yr	701.8 lb/yr
400,000 bbl	706.6 lb/yr	990.7 lb/yr

S.1.2 Withdrawal Loss

Withdrawal Losses can be calculated as follows:

Withdrawal Loss

$$L_W = \frac{(0.942)QCW_L}{D}$$

Where:

L_W = withdrawal loss (lb/hr)
C = shell clingage factor = 0.006
W_L = liquid density = 7.0 lb/gal
D = tank diameter = 170 ft (200,000 bbl tank)
240 ft (400,000 bbl tank)
Q = throughput (37,000 bbl/hr peak)

Obviously, withdrawal loss emissions only occur during pumping of crude oil from the surge tanks. Since drawdown is the project stage with the most extensive transport of crude oil across the docks, it is necessary to determine the daily and peak year frequency of pumping. This can be determined for the case of four docks, two 200,000 bbl tanks and six 400,000 bbl tanks based on existing plans relative to the transport of oil through pipeline and across the docks. Table S.1-2 gives hypothetical quantities of oil transported and pumping times during the first 149 days and final 23 days of withdrawal.

[2] Drawdown emissions are higher due to higher crude temperature. Calculations made using P^* = 0.129.

Table S.1-2
Summary of Transported Oil Quantities and Pumping Durations

	First 149 days	Final 23 days
Transported across docks (4)	0.740 MMBD	0.260 MMBD
Per dock	0.185 MMBD	0.065 MMBD
Hours/day pumping	5	1.75
Total Hours	745	40

Based on the above information, the number of hours in which withdrawal emissions are occurring during drawdown is 98 per tank. Assuming that the 400,000 bbl tanks are used twice as much as the 200,000 bbl tanks, the average use during a drawdown is 112 hours for the 400,000 bbl tanks and 56 hours for the 200,000 bbl tanks.

Using the equation for withdrawal loss emissions and the information on the number of hours during drawdown and fill when emissions occur, an emissions summary (Table S.1-3) for drawdown and fill can be developed, on a per-tank basis.

Table S.1-3
Withdrawal Loss Emissions Summary

Tank Size	Short-Term Peak Per Tank (lb/hr)		Long-Term Average Per Tank (ton/year)[3]	
	Drawdown	Fill[4]	Drawdown	Fill[5]
200,000 bbl	8.62	5.77	0.24	0.15
400,000 bbl	6.1	4.09	0.34	0.21

[3] Long term emissions = Hourly emissions/tank x Hour/year/tank x # tanks x 1/2000.

[4] Assumes tank is active during 40 minutes of peak hour.

[5] Fill occurs 35 hr/year for 200,000 bbl tanks and 70 hr/year for 400,000 bbl tanks.

S.1.3 Summary

Table S.1-4 is a summary of the worst-hour and annual average surge tank emissions for the three project phases.

Table S.1-4
Summary of Worst-Hour and Annual Average Surge Tank Emissions

	DRAWDOWN		FILL		STANDBY	
Tank Size	lb/hr [6]	ton/yr [7]	lb/hr [8]	ton/yr [9]	lb/hr [10]	ton/yr
200,000 bbl:						
Rim Seal	0.16	0.70	0.11	0.48	0.11	0.48
Withdrawal	8.62	0.48	5.77	0.30	0.0	0.0
TOTAL	8.78	1.18	5.88	0.78	0.11	0.48
400,000 bbl:						
Rim Seal	0.68	2.97	0.48	2.11	0.48	2.11
Withdrawal	18.3	2.05	4.09	1.28	0.0	0.0
TOTAL	19.0	5.02	4.57	3.39	0.48	2.11

[6] Worst-hour drawdown withdrawal losses assume that one 200,000 bbl and three 400,000 bbl tanks are active at 37,000 bbl/hr during peak hour. Rim seal losses assume two 200,000 bbl and six 400,000 bbl tanks.

[7] Numbers for annual emission assume two 200,000 bbl and six 400,000 bbl tanks. Each 200,000 bbl tank is assumed to be active for 56 hours of drawdown year, and each 400,000 bbl tank is assumed to be active for 112 hours of drawdown year.

[8] Worst-hour withdrawal losses during SPR fill assume that one 200,000 bbl and one 400,000 bbl tank are active for 40 minutes of peak hour at 37,000 bbl/hr. Rim seal losses assume two 200,000 bbl and six 400,000 bbl tanks.

[9] Numbers for annual emission assume two 200,000 bbl and six 400,000 bbl tanks. Each 200,000 bbl tank is assumed to be active 35 hr/yr, and each 400,000 bbl tank is assumed to be active 70 hr/yr.

[10] RIM seal losses assume two 200,000 bbl and six 400,000 bbl tanks.

S.2 **Tanker Emissions**

S.2.1 Fill

Assumptions:[11]

- 50,000 bbl/day average
- Max. rate of unloading = 37,000 bbl/hr
- Ballasting emission factor = 0.42 lb/10^3 gal
- 72% of crude delivered in ships with non-segregated ballast tanks
- Four docks

Emissions during the Peak Hour can be calculated to be:

$$37{,}000 \text{ bbl/hr} \times 42 \text{ gal/bbl} \times 0.42 \text{ lb}/10^3 \text{ gal} = 652.68 \text{ lb/hr}$$
$$= 163.17 \text{ lb/hr/dock}$$

Annual Emissions are calculated as:

$$50{,}000 \text{ bbl/day} \times 365 \text{ day/yr} \times 42 \text{ gal/bbl} \times 0.42 \text{ lb/103 gal} \times 0.72 \times 1 \text{ ton/2000 lb} = 115.89 \text{ ton/yr}$$
$$= 28.97 \text{ ton/yr/dock}$$

[11] Based on dock logs for St. James Terminal for the period 1980 through 1982 and on assumptions used in the SPR Final EIS (DOE/EIS 0024, July 1978).

S.2.2 Drawdown

Emissions during drawdown can be calculated using the following method:

Drawdown

$C_L = C_A + C_G$ (page 4.4-8, eqn. (2); AP-42)

Where:

C_L = total loading loss (lb/10^3 gal)

C_A = arrival emission factor (lb/10_3 gal)
= 0.86 lb/10^3 gal (uncleaned)
= 0.33 lb/10^3 gal (cleaned)

Assuming 50% of the tankers are clean:

C_A = 0.60 lb/10^3 gal

C_G = emission factor generated by evaporation (lb/10^3 gal)
= 1.84(0.44P - 0.42)MG/T (page 4.4-8, eqn (3); AP-42)

Where:

P = true vapor pressure = 6.0 psia (at 100°F)
M = molecular weight of vapors = 50 lb/lb mole
G = vapor growth factor = 1.02
T = vapor temperature = 560 R

Therefore:

C_G = 1.84 [(0.44)(6.0) - 0.42](50)(1.02)/560
= 0.372 lb/gal

$C_L = C_A + C_G$
= 0.60 + 0.372
= 0.972 lb/10^3 gal

Assuming a rate of loading of:

37,000 bbl/hr/dock
740,000 bbl/day, 149 days
260,000 bbl/day, 23 days

and that the total crude shipped during drawdown = 116,240,000 bbl, Peak Hour Emissions can therefore be calculated as:

0.972 lb/10^3 gal x 37,000 bbl/hr x 42 gal/bbl = 1510 lb/hr/dock

and Annual Emissions can be calculated as:

116,240,000 bbl x 42 gal/bbl x 0.972 lb/10^3 gal x 1 ton/2000 lb = 2373 ton/yr
= 593.17 ton/yr/dock

S.3 Fugitive Emissions

Assumptions:[12]

- 10 pump seals at 0.046 lb/hr/pump
- 584 valves at 0.0005 lb/hr/valve
- 1,200 flanges at 0.00056 lb/hr/flange

Using the above information the following emissions calculations can be made.

Pump Seal Emissions = 10 pumps x 0.046 lb/hr/pump = 0.46 lb/hr
= 2.01 ton/yr

Valve Emissions = 584 valves x 0.0005 lb/hr/valve = 0.292 lb/hr
= 1.28 ton/yr

Flange Emissions = 1,200 flanges x 0.00056 lb/hr/flange = 0.672 lb/hr
= 2.94 ton/yr

S.4 Vehicle Emissions

Assumptions:

- 36 GSA, 50 personal motor vehicles
- 25 mph speed; 2 hours operation per day

From EPA's MOBILE4 emission model the following ranges of emission rates exist for 1990 model autos at 25 mph speed:

HC: 0.3 - 1.0 g/mi

CO: 3.0 - 10.0 g/mi

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[12] Based on AP-42, p. 9.1-30 for uncontrolled emissions.

NO_x: 0.6 - 0.7 g/mi

The upper end of each range is associated with high mileage vehicles.

HC Emissions

86 vehicles x 25 mi/hr x 1.0 g/mi x 1 lb/453.6 g x 1 hr = 4.74 lb/hr

Daily Emissions = 4.74 lb/hr x 2 hr = 9.48 lb/day

Annual Emissions = 1.73 ton/yr

CO Emissions

86 vehicles x 25 mi/hr x 10.0 g/mi x 1 lb/453.6 g x 1 hr = 47.4 lb/hr

Daily Emissions = 94.8 lb/day

Annual Emissions = 17.3 ton/yr

NO_x Emissions

86 vehicles x 25 mi/hr x 0.7 g/mi x 1 lb/453.6 g x 1 hr = 3.31 lb/hr

Daily Emissions = 3.31 lb.hr x 2 hr = 6.62 lb/day

Annual Emissions = 1.21 lb/day

APPENDIX T

OZONE MODELING METHODOLOGY

The primary air quality issue associated with the emission of hydrocarbons is the potential for contribution to the production of ozone. The Urban Airshed Model (UAM) was selected as the tool for assessing the potential impacts on ozone production.

T.1 Description of the Urban Airshed Model

The UAM is a three-dimensional photochemical grid model designed to calculate concentrations of inert and chemically reactive pollutants. The basis for the UAM is the atmospheric diffusion (or "species continuity") equation. This approach provides a mass balance in the model and accounts for emissions, transport, diffusion, chemical reactions, and atmospheric removal processes. The UAM is usually applied to an 8- to 72-hour period during which meteorological conditions favor the occurrence of elevated pollutant concentrations.

The major factors that affect photochemical activity in the atmosphere and subsequent ozone production include:

- the spatial and temporal distribution of emissions of nitrogen oxides (NO_x) and volatile organic compounds (VOC), both anthropogenic and biogenic;
- the composition of the emitted VOC and NO_x;
- the spatial and temporal variations in the wind fields;
- the dynamics of the atmospheric boundary layer, including stability and the level of vertical mixing;
- the chemical reactions involving VOC, NO_x and other important species;
- the diurnal variations of solar insolation and temperature;
- the loss of ozone and ozone precursors by dry deposition; and
- the ambient background concentrations of VOC, NO_x, and other species in and immediately upwind from the region of study.

The UAM simulates all of these processes. The UAM model is generally applied in a summertime meteorological setting, when photochemical activity is at a peak. The UAM employs Version IV of the Carbon Bond Mechanism for solving chemical kinetics.[1] As implemented in the model, this consists of over 80 reactions and 30 different chemical species.

The UAM model has been in use and development for over 20 years. Most of the financial support for the model development has been provided by the U.S. Environmental

Protection Agency. The UAM model has been used for air quality management purposes as well as air quality impact assessments for individual projects throughout the U.S. and in several foreign countries.

Because the UAM accounts for spatial and temporal variations as well as differences in the reactivity (speciation) of emissions, it is ideally suited for evaluating the effects of emission changes on urban air quality. This is accomplished by first replicating a historical ozone episode to establish a base case simulation. Model inputs are prepared from observed meteorological, emission, and air quality data for a particular day or days. The model is then applied with these inputs and the results are evaluated to determine its performance. Once the model results have been evaluated and determined to perform within prescribed levels, the same meteorological inputs and a projected emission inventory can be used to simulate future impacts. That is, the model will calculate hourly ozone patterns likely to occur under the same meteorological conditions as the base case. The difference in ozone patterns between the base case and the projected emission inventory represents the net impacts of the emission change.

T.2 Model Input Data and Approach

The specific application of the UAM used in this analysis is partly based on an extensive study performed for the Baton Rouge Ozone Task Force.[2] The Baton Rouge study consisted of the application of the UAM to a seven-parish area surrounding the city of Baton Rouge. The UAM application established a baseline simulation for the investigation of emission control strategy effectiveness.

T.2.1 Geographical Extent of Analysis

The UAM modeling grid used for this application was 132 by 132 kilometers covering the seven-parish ozone non-attainment area. The location of this grid is shown in Figure T.2-1. A 2 kilometer grid increment was used in order to have sufficient resolution to separate the impacts of large stationary sources. The St. James Terminal is located towards the southeastern portion of the UAM grid.

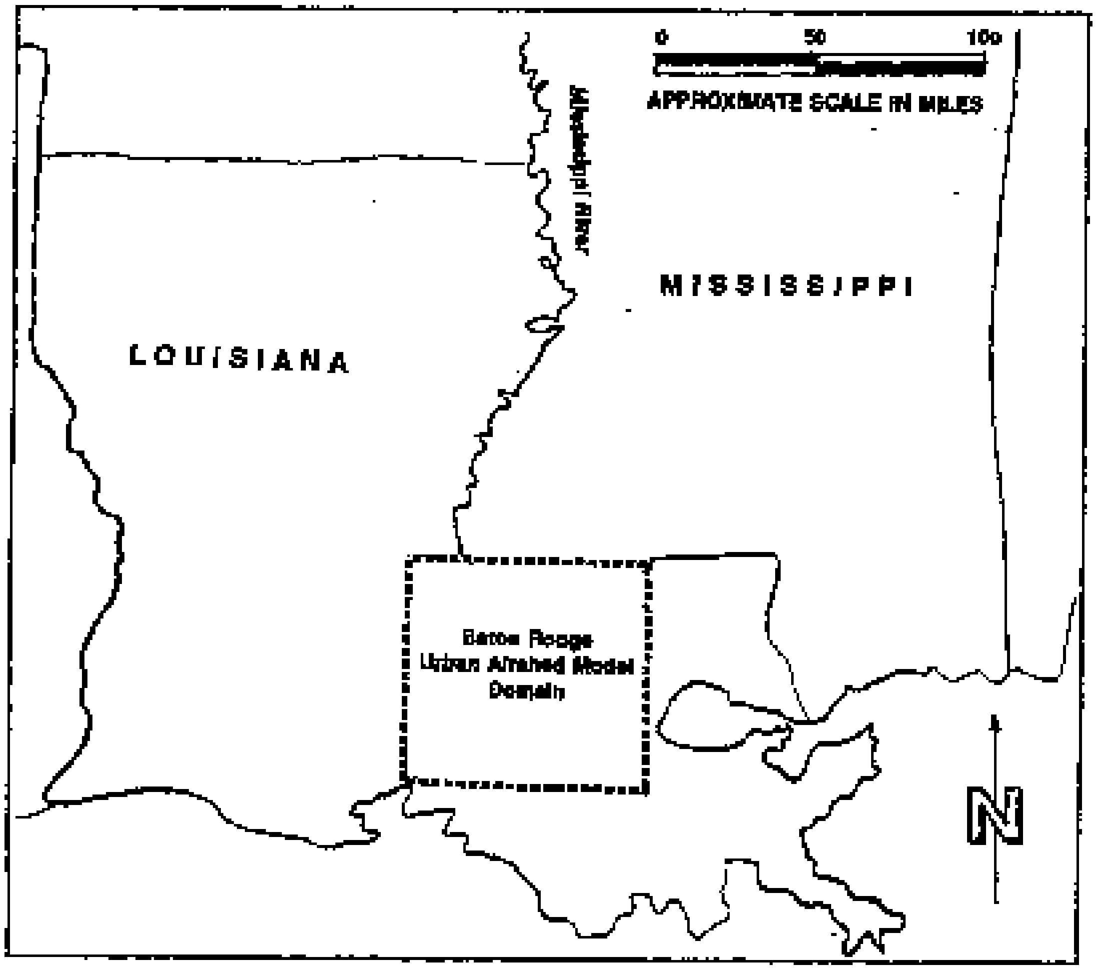
T.2.2 Meteorology

Surface weather maps for the period of May 24-25, 1990 show a high pressure system over the eastern United States. Winds in the area were light and somewhat variable, with the flow during the morning hours being generally northeast and during the afternoon hours from the southeast. Daily maximum temperatures were in the mid- to upper-eighties. On May 25, the highest ozone concentrations were observed to the northwest of the urban area, with a peak concentration of 15.2 parts per hundred million (pphm) at New Roads. The episode represents a stagnation event in which local effects dominate, with some transport of ozone from the Baton Rouge area and points south to the New Roads area.

T.2.3 Baseline Air Quality

Ambient air quality measurements were available from 14 different monitoring sites. Ambient air quality data are used by UAM to establish initial conditions for the model simulation. The hydrocarbon concentrations were speciated according to the requirements of the Carbon

Figure T.2-1
Location of Modeling Grid for Urban Airshed Model



Bond IV mechanism. Measurements of ozone, NO_x, carbon monoxide (CO), and eight hydrocarbon species were spatially interpolated throughout the model grid. Pseudo monitoring stations were placed along the northern and western boundaries of the grid and assigned background rural concentration values in order to prevent the extrapolation of concentrations measured in urban areas to the domain boundaries that are primarily in rural locations.

T.2.4 Emissions

The UAM requires an hourly, gridded inventory of emissions of NO_x, CO, and hydrocarbons reported as Carbon Bond IV species. The emission sources included stationary sources (both point and area), mobile sources, and biogenic sources. The inventory accounted for both seasonal and diurnal variations in emissions as well as the speciation of reactive hydrocarbons by source. Hourly gridded emissions were developed during the Baton Rouge Ozone Task Force study.

T.2.5 Project Emissions

Hourly emissions from the St. James Terminal are shown in Table 7.6-3 in Chapter 7. These emissions are based on the emission calculations summarized in section 7.6.4 for drawdown, the project phase producing the maximum emission rates. The assumption is made that the loading of tankers with crude oil commences at 7:00 am and proceeds until four tankers are filled. Based on the amount of crude oil projected to be shipped from the St. James Terminal, the loading of a ship at the maximum pumping rate of 37,000 bbl/hr is five hours. It is assumed that all four loading docks would be active at the same time. This maximizes the emissions during the morning and produces a worst-case scenario for the production of ozone. After the tankers are filled, emissions associated with other activities continue at the terminal. Workers are assumed to depart between 2:00 pm and 3:00 pm each day and return at 6:00 the next morning. It is obvious from Table 7.6-3 that tanker loading is the only important activity associated with hydrocarbon emissions at the St. James Terminal.

T.3 Model Results/Estimates of Site-Specific Air Quality

T.3.1 St. James Terminal - Peak Activity

The resulting impacts from the UAM simulations of air quality for the drawdown phase are summarized in Table T.3-1. This table shows the peak measured ozone concentrations for May 25, 1990 at various monitoring stations, the maximum ozone impacts for the baseline emissions case, and the maximum ozone impacts with the St. James Terminal emissions. Net impacts of the St. James Terminal could be as high as 6 pphm under these modeling assumptions. At two monitoring locations (LSU and Star-North), concentrations that are below the National Ambient Air Quality Standard of 12 pphm in the base case exceed the standard when emissions from St. James Terminal are included.

T.3.2 St. James Terminal - Fill and Standby

Because the emissions of ozone precursors during the fill and standby phases are so much smaller than emissions during the drawdown phase it can be concluded that the ozone impacts during these phases would be considerably smaller than the modeled impact.

Table T.3-1
Results of UAM Simulation of Peak Ozone in parts per hundred million for May 25, 1990 -- Base Case and Base Case with St. James Terminal

Location	Peak Observed (pphm)	UAM Base Case (pphm)	UAM with SJ Terminal (pphm)	SJ Terminal Net Impact (pphm)
Pride	8.8	8.3	8.3	0.0
Gross Tete	9.0	6.8	6.8	0.0
Bayou Sorrell	7.6	7.0	7.0	0.0
French Settlem.	9.1	9.3	9.3	0.0
New Roads	15.2	13.0	13.1	0.1
Baker	10.9	11.2	11.2	0.0
LSU	12.4	10.9	13.9	3.0
Carville	8.3	8.8	10.8	2.0
St. James	6.6	8.7	8.7	0.0
Star-North	6.9	10.1	12.8	2.7
Capitol	12.5	12.2	14.2	2.0
WLUX-Port Allen	12.1	12.4	13.0	0.6
Garyville	7.8	9.3	9.3	0.0
Region Peak	**15.2**	**15.0***	**16.0***	**6.0***

* Note that this value is the highest prediction within the modeling grid. The values for specific monitoring locations are placed in the table to show the difference between observed and predicted values. The region peak is not the highest of the predictions at the monitoring locations, but rather the highest modeled impact anywhere in the study area. Also, maximum peak concentrations do not necessarily occur during the same hour for the base case with and without the St. James Terminal.

ENDNOTES

1. Gery, M.W., G.Z. Whitten, and J.P. Killus, *Development and Testing of the Carbon-Bond IV Mechanism for Urban and Regional Modeling*, Systems Applications International Report 88/002, 1988.

2. Haney, J.L., et al., *Application of the Urban Airshed Model in the Baton Rouge Seven-Parish Study Area*, Presented at the Annual Meeting of the Air and Waste Management Association, paper 90-94.9, 1990.

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