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Final Environmental Impact Statement

(Final of Draft EIS, FEA-DES-77-10 and of
Draft Supplement to Final EIS, FEA-FES-76/77-6)

STRATEGIC PETROLEUM RESERVE

Seaway Group Salt Domes

(Bryan Mound Expansion, Allen,
Nash, Damon Mound and West Columbia)

Brazoria County, Texas

U.S. DEPARTMENT OF ENERGY

June 1978

Volume 3 of 3

Appendices C thru K

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Brazoria County, Texas

Responsible Official

James L. Liverman
Acting Assistant Secretary for Environment

U.S. DEPARTMENT OF ENERGY
Washington, DC 20545

June 1978
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ENVIRONMENTAL IMPACTS OF THE PROPOSED AND ALTERNATIVE ACTIONS

C.1 INTRODUCTION

The environmental setting of the proposed project has been described in Appendix B. This section describes the impacts which the project may have on that environment.

Risks related to storage and transportation of oil and brine for each proposed SPR storage site are summarized in Section C.2. Impacts associated with construction and operation at the proposed site (Bryan Mound) are presented in Section C.3; impacts associated with the four alternate sites are described in Sections C.4 through C.7. References cited are included as Section C.8.

C.2 SPR OIL AND BRINE SPILLS FOR THE CANDIDATE STORAGE SITES

As the possible accidental release of oil and brine during project development and operation may have impacts on many aspects of the environment, the quantities of these fluids expected to be released to the environment are summarized here. Detailed descriptions of oil and brine spill risks, including methodology of calculation, dispersal in the environment, and cleanup and prevention technology are provided in Appendix E. Evaluation of the associated environmental risks expected to accompany development of each site is provided in the site-specific descriptions of impact in Sections C.3 through C.7.

Oil spills which might accompany development of SPR storage facilities would result from marine transport between the open Gulf of Mexico and the DOE docks at Freeport, from pipeline transport between the docks and the storage sites, and from terminal operation at the storage sites and at the SEAWAY Tank Farm. The risk of cavern collapse is considered unlikely. Estimates of spill frequency and total spill volume are provided in Tables C.2-1 and C.2-2 (taken from Appendix E) during cavern fill and cavern withdrawal operations, respectively, for the Bryan Mound early storage development or for SPR expansion at each candidate site.

The greatest volume of oil spill is expected to occur during cavern fill (for each site) because of the VLCC tanker lightering operation in the Gulf (during withdrawal, oil is expected to be transported directly to other ports by 45 to 50 thousand dead weight ton (MDWT) tankers or supplied inland by the SEAWAY Pipeline. The greatest potential for large oil spills would occur with tanker transport between the Gulf and Freeport (60,000 barrels maximum credible spill; 1111 barrels average spill).

Because exposures are similar, the expected frequency and volume of oil spills is basically a function of storage capacity. Thus, a 163 MMB storage capacity at any combination of sites would produce roughly 2.6 times as much oil spillage as the Bryan Mound early storage site alone (163 MMB/63 MMB). Additional exposure would occur by developing Allen, West Columbia, Nash or Damon Mound, rather than Bryan Mound because of greater pipeline length and the additional terminal facility risks. Oil spill expectation

TABLE C.2-1 Expected crude oil spills - cavern fill operations.

Oil Handling Mode/Location	Average Spill Size (bbl)	Bryan Mound Early Storage		Bryan Mound SPR Expansion		Allen Dome SPR Expansion		West Columbia SPR Expansion		Nash Dome SPR Expansion		Damon Mound SPR Expansion		Total Program[a] Spill Risk		Maximum Credible Spill Size (bbl)
		No. Spills	Barrels	No. Spills	Barrels	No. Spills	Barrels	No. Spills	Barrels	No. Spills	Barrels	No. Spills	Barrels	No. Spills	Barrels	
Gulf																
-Transfers	12.9	14.6	189	23.2	300	23.2	300	23.2	300	23.2	300	23.2	300	37.8	489	1,000
-Vessel Casualty	1111	0.018	20	0.029	32.2	0.029	32.2	0.029	32.2	0.029	32.2	0.029	32.2	0.047	52.2	60,000
Freeport Harbor																
-Transfers	21.7	2.9	63	4.6	100	4.6	100	4.6	100	4.6	100	4.6	100	7.5	163	500
Terminals																
-Bryan Mound	500	0.0315	15.8	0.05	25	0.05	25	0.05	25	0.05	25	0.05	25	0.0815	40.8	5,000
-SEAWAY	1100	---	---	---	---	0.05	55	0.05	55	0.05	55	0.05	55	0.05	55	5,000
-Alternative Storage Site	500	---	---	---	---	0.05	25	0.05	25	0.05	25	0.05	25	0.05	25	5,000
Pipelines																
-Pumping[b]	1100	0.0005	0.6	---	---	0.0063	6.9	0.0158	17.3	0.0252	27.7	0.0252	27.7	0.0257	28.3	10,000
Total - Single Fill	---	17.6	288.4	27.9	457.2	28.0	544.1	28.0	554.5	28.0	564.9	28.0	564.9	45.6	853.3	
Total - 5 Fills	---	87.8	1442.0	139.5	2286.0	140.0	2720.5	140.0	2772.5	140.0	2824.5	140.0	2824.5	228.0	4266.5	

[a] Totals are for worst case combination of sites having 163 MMB storage capacity, i.e., Bryan Mound early storage and Nash or Damon Mound SPR expansion.

[b] No pipeline spills are allocated to Bryan Mound SPR expansion as oil would be exposed to spillage due to standby storage with early storage facility. For other SPR sites, pipeline spill exposures occur between site and Seaway Terminal.

TABLE C.2-2 Oil spill expectation model projections - cavern withdrawal operations[a] and project totals.

Oil Handling Mode/Location	Average Spill Size (bbl)	Bryan Mound Early Storage		Bryan Mound SPR Expansion		Allen Dome SPR Expansion		West Columbia SPR Expansion		Nash Dome SPR Expansion		Damon Mound SPR Expansion		Total Program[b] Spill Size		Maximum Credible Spill Risk (bbl)
		No. Spills	Barrels	No. Spills	Barrels	No. Spills	Barrels	No. Spills	Barrels	No. Spills	Barrels	No. Spills	Barrels	No. Spills	Barrels	
Gulf																
-Transfers	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---
-Vessel Casualty	1111	0.0028	3.1	0.0045	5	0.0045	5	0.0045	5	0.0045	5	0.0045	5	0.0073	8.1	60,000
Freeport Harbor																
-Transfers	42	1.2	50.4	1.9	80	1.9	80	1.9	80	1.9	80	1.9	80	3.1	130.4	500
Terminals																
-Bryan Mound	500	0.0315	15.8	0.05	25	0.02	10	0.02	10	0.02	10	0.02	10	0.0515	25.8	5,000
-SEAWAY[c]	1100	0.0189	20.8	0.03	33	0.05	55	0.05	55	0.05	55	0.05	55	0.0689	75.8	5,000
-Alternative Storage Site	---	---	---	---	---	0.05	25	0.05	25	0.05	25	0.05	25	0.05	25.0	5,000
Pipelines																
-Pumping[d]	1100	0.0008	0.9	---	---	0.0016	1.8	0.0041	4.5	0.0066	7.2	0.0066	7.2	0.0074	8.1	10,000
Total - Single Withdrawal	---	1.2	91.0	1.7	124.3	2.03	176.8	2.03	179.5	2.03	182.2	2.03	182.2	3.29	273.2	
Total - 5 Withdrawals	---	6.3	455.0	8.4	621.5	10.1	884.0	10.1	897.5	10.1	911.0	10.1	911.0	16.4	1366.0	
Project Total - 5 Cycles	---	94.1	1897.0	147.9	3001.0	150.1	3604.5	150.1	3670.0	150.1	3735.5	150.1	3735.5	244.2	5632.5	
Project Total with Oil Stored in Pipeline	---	94.1	1930	147.9	3001.0	150.2	3657.7	150.2	3803.0	150.3	3948.5	150.3	3948.5	244.4	5878.5	

[a]During withdrawal it is assumed that about 40 percent of the oil is shipped by tanker to the Gulf and about 60 percent is delivered to the SEAWAY Pipeline.

[b]Totals are for worst case combination of sites having 163 MMB storage capacity, i.e., Bryan Mound early storage and Nash or Damon SPR expansion.

[c]For worst case exposure calculations, it is assumed that all oil pumped from Allen, West Columbia, Nash, and Damon Mound sites is sub

[d]No pipeline spills are allocated to Bryan Mound SPR expansion as oil would be exposed to spillage due to standby storage with early storage facility. For other SPR sites, pipeline spill exposures occur between site and SEAWAY Terminal.

for Bryan Mound early storage and Nash dome (163 MMB combined, maximum pipeline length) is 5879 barrels; oil spill risks for Bryan Mound early storage and SPR expansion (163 MMB, minimum pipeline length) is 4539 barrels.

A summary of brine and raw water spill risk expectations for the candidate SPR sites is provided in Table C.2-3 for leaching, oil fill, oil withdrawal and standby storage. Brine spill exposures occur from pipelines during leaching, oil fill and standby storage; raw water exposures occur from pipelines during leaching, oil withdrawal, and standby storage.

Total expected spillage of brine and raw water are very dependent on site development selection because pipeline length is a principal exposure parameter. For example, if Bryan Mound is selected for SPR expansion, total spillage is calculated to be 310 barrels of brine (80 percent in the Gulf) and 120 barrels of raw water (65 percent in the Gulf). If SPR expansion occurs at either Damon Mound or Nash dome, however, the total expected spill volume is 2492 barrels of brine (10 percent in Gulf) and 3026 barrels of raw water (3 percent in Gulf).

In describing site-specific impacts to water quality, ecology, and other aspects of the environment, in Section C.3, reference will be made to the spill expectations given in Tables C.2-1 through C.2-3.

TABLE C.2-3 Brine and raw water spill[a] expectation model projections during project lifetime.

Storage Facility		Leaching Brine Gulf	Leaching Brine Onshore	Leaching Raw Water Gulf	Leaching Raw Water Onshore	Cavern Fill Brine Gulf	Cavern Fill Brine Onshore	Cavern Fill Raw Water Gulf	Cavern Fill Raw Water Onshore	Standby Storage Brine Gulf	Standby Storage Brine Onshore	Standby Storage Raw Water Gulf	Standby Storage Raw Water Onshore	Oil Withdrawal Brine Gulf	Oil Withdrawal Brine Onshore	Oil Withdrawal Raw Water Gulf	Oil Withdrawal Raw Water Onshore	Project Lifetime Brine Gulf	Project Lifetime Brine Onshore	Project Lifetime Raw Water Gulf	Project Lifetime Raw Water Onshore
Bryan Mound	No. Spills	-	-	-	-	0.0125	0.0025	-	-	0.0035	0.0016	0.0078	.0035	-	-	-	0.0005	0.0160	0.0041	0.0155	0.0076
Early Storage	Barrels	-	-	-	-	62.5	12.5	-	-	18	8	39	17	-	-	-	2.5	80.5	20.5	78	37.5
Bryan Mound	No. Spills	0.01	0.002	-	0.001	0.0195	0.0040	-	-	0.0043	0.0019	b	b	-	-	-	b	0.0338	0.0079	b	0.001
SPR Expansion	Barrels	50	10	-	5	97.5	20.1	-	-	21	9	b	b	-	-	-	b	168.5	39.1	b	5
Allen Dome	No. Spills	0.01	0.024	-	0.023	0.0195	0.047	-	-	b	0.0717	b	0.0707	-	-	-	0.0115	0.0295	0.143	b	0.178
SPR Expansion	Barrels	50	120	-	120	97.5	235	-	-	b	359	b	359	-	-	-	57.5	147.5	714	b	895
West Columbia	No. Spills	0.01	0.048	-	0.047	0.0195	0.091	-	-	b	0.15	b	0.15	-	-	-	0.0235	0.0295	0.289	b	0.371
SPR Expansion	Barrels	50	240	-	235	97.5	455	-	-	b	750	b	750	-	-	-	117.5			b	1853
Nash Dome	No. Spills	0.01	0.072	-	0.071	0.0195	0.142	-	-	b	0.237	b	0.237	-	-	-	0.036	0.0295	0.451	b	0.582
SPR Expansion	Barrels	50	360	-	355	97.5	710	-	-	b	1142	b	1142	-	-	-	180	147.5	2212	b	2910
Damon Mound	No. Spills	0.01	0.072	-	0.071	0.0195	0.142	-	-	b	0.237	b	0.237	-	-	-	0.036	0.0295	0.451	b	0.582
SPR Expansion	Barrels	50	360	-	355	97.5	710	-	-	b	1142	b	1142	-	-	-	180	147.5	2212	b	2910
Total ram	No. Spills	0.01	0.072	-	0.071	0.032	0.1445	-	-	0.0078	0.2410	0.0078	0.2410	-	-	-	0.0365	0.0498	0.458	0.0155	0.5896
Spill Risk[c]	Barrels	50	360	-	355	160	723	-	-	39	1160	39	1160	-	-	-	183	249	2243	78	2948

[a] Average spill from brine pipelines taken to be 5000 barrels; maximum credible spill taken to be 30,000 barrels; computed for five cavern fill/withdrawal operations.

[b] Losses from these SPR operations would occur in any case as a result of Bryan Mound early storage and are attributed to these facilities.

[c] Program totals are for worst case combination of sites having 163 MMB storage capacity, i.e., Bryan Mound early storage and Nash or Damon Mound SPR expansion.

C.3 PROPOSED SITE FOR SPR EXPANSION - BRYAN MOUND

The candidate site proposed for expansion of storage capacity in the Seaway Group is Bryan Mound. As explained in Section 2.3, Bryan Mound has previously been selected for early storage development of 63 MMB of existing cavern space. The following facilities are required for early storage development and therefore would be available for site expansion (Figure A.2-3): a pump station and control house; 100,000 barrel brine settling pond; a blanket oil system; four 200,000 barrel oil surge tanks; a 30-inch diameter oil pipeline connecting the storage site with the SEAWAY Docks 3 miles to the east and with the SEAWAY Tank Farm 4 miles to the northwest; a raw water intake system with desander at the Brazos River Diversion Channel; and 5 backup brine disposal wells located along the pipeline corridor to the northeast. The environmental impacts of construction and operation of these facilities, including storage of 63 MMB of oil in four existing salt dome cavities, have been addressed in FES 76/77-6 and its supplement.

New facilities required for SPR site expansion include the following: up to 12 leached storage cavities having a total capacity of 100 MMB (for a site total of 163 MMB); roadways and sections of oil, brine, and raw water pipelines to connect the new cavities with the central pump and control house; a 30-inch diameter brine disposal pipeline and diffuser to the Gulf; two tanker docks to be constructed, one adjacent to the SEAWAY Docks and the other at Brazos Harbor. The present report considers impacts associated with construction and operation of these new facilities and with expanded use of the early storage development facilities. Where impacts are increased by development of both storage facilities (such as oil spills or hydrocarbon emissions), total impacts of the entire facility are considered.

System alternatives which are considered include: 17 additional brine injection wells for disposal into deep subsurface aquifers; brine supply to the Dow Chemical Company plant in Freeport; use of a brine diffuser system 12.5 miles into the Gulf, construction of a deepwater monobuoy in the Gulf for oil fill and withdrawal; use of Phillips Petroleum

Company docks, as available; use of SEAWAY Docks instead of constructing new docks (applicable only if SEADOCK is constructed); withdrawal of ground water for leaching and oil displacement, supply of raw water from Dow Chemical Company's Harris and Brazoria Reservoirs; and onsite gas turbine power generation. Impacts of development and use of these alternatives are also considered in the following subsections.

C.3.1 Impacts of Site Preparation and Construction

C.3.1.1 Land Features

Proposed Facilities

Grading and excavation at the 240 acre Bryan Mound storage site would be confined to about 36 acres (Table A.3-1), most of which would occur in areas already disturbed. Excavation of about 30,000 cubic yards would be required. Before revegetation of disturbed areas is complete, some erosion of the soil may occur.

Construction of the new tanker docks would require an estimated 1,050,000 cubic yards (cy) of dredging from the harbors and about 14 acres of dock site grading. As these facilities would be constructed on disturbed industrial land, the environmental impacts would not be significant. Suitable locations for spoil disposal are available nearby.

About 6000 cy of material would be temporarily displaced during installation of a pipeline between the DOE early storage phase oil distribution pipeline and the Brazos Harbor dock (Figure A.3-1). This activity would temporarily disrupt soil on about 4 acres of marsh and 4 acres of cleared land.

Construction of the brine disposal system to the Gulf diffuser 5.8 miles offshore would effect 21 acres of coastal prairie, marshland and beaches and 142 acres of Gulf bottom. About 38,490 cy of soil would be displaced during onshore construction, and the excavated materials would be temporarily stored on the pipeline right-of-way for refilling the trenches. Offshore, 158,792 cy of bottom sediments would be displaced during construction, with the majority resettling in the pipeline right-of-way. These activities would have a significant but temporary impact on land effected by construction. Careful recontouring and revegetation of the beach sands crossings would be necessary to maintain long term stability and prevent permanent alteration of the environment.

Leaching of 10 storage cavities in the Bryan Mound salt dome would involve removal of 100 MMB of salt by leaching for disposal in the Gulf of Mexico. This is equivalent to 20.8×10^6 cy of salt.

The alteration of land features, in addition to disturbance of 36 acres at the storage site required for site expansion, would be 10 acres along pipeline rights-of-way, and 14 acres at the DOE Tanker Docks. Accompanying quantities of earth excavation would be approximately 6000 cy.

Alternative Facilities

The alternative brine disposal system into deep aquifers would require disturbance of 61 acres offsite and possibly up to 61,000 cy of fill to construct the drill pads for 19 additional brine injection wells. About 57,000 cy of material would temporarily be excavated for pipeline installation.

The alternative brine diffuser 12.5 miles offshore in the Gulf of Mexico would temporarily disrupt 326 acres of land, all but 21 of which would be offshore. The construction would require 97,300 cy of excavation offshore beyond that excavated for the 5.0 mile pipeline which would resettle to the same general area after pipeline completion.

Alternative raw water supply from Dow Chemical Company would require temporary excavation of about 32,000 cy of material in a 37 acre right-of-way along existing pipeline rights-of-way to install an additional pipeline. Alternative brine disposal to Dow would require no new pipelines or earth excavation. Development of a well field to tap the Evangeline aquifer would require 69 acres and 57,000 cy of excavation.

Onsite power generation would require no additional land disturbance.

Use of the Phillips docks for oil distribution would require construction of a short pipeline, requiring excavation of an estimated 2500 cy of material on 6 acres of land. Conversion of SEAWAY Dock capacity would require minimal amounts of site grading adjacent to the Docks.

Construction of a monobuoy for tanker offloading and loading in the Gulf of Mexico would require a 30 mile pipeline to 100 foot water depth. An estimated 369,000 cy of material would be excavated on 727 acres of right-of-way in the Gulf.

C.3.1.2 Water Resources

Site preparation and construction of the proposed facilities at Bryan Mound may impact the water resources of several water bodies, including: the onsite lakes, the Intracoastal Waterway, the Brazos River Diversion Channel, Freeport and Brazos Harbors, the Gulf of Mexico and groundwater aquifers. Potential impacts are treated according to specific aspects of facility development.

Raw Water Withdrawal

Water for leaching the caverns would be obtained from the early storage phase intake on the Brazos River Diversion Channel. Withdrawal of a maximum of 534,000 B/D (35 cfs) would be required. This is less than 0.5 percent of the average daily flow of the Brazos River. Normal river flow ranges from about 400 cfs to 20,000 cfs, and salinity is frequently greater than 20 ppt. Under extreme low flow conditions (40 cfs), tidal dynamics in the Brazos River Estuary would still assure a more than adequate supply of water, as the 10 foot channel promotes inshore flow of Gulf water. During periods of low flow, a significant natural increase in the salinity of the lower Brazos River is produced by intrusion of sea water from the Gulf of Mexico. The additional impact of withdrawal on water quality is expected to be undetectable.

Brine Disposal

Construction of the brine diffuser pipeline to the proposed diffuser site would require the dredging of a submarine trench 5.8 miles into the Gulf. This construction would cause a major increase in turbidity near construction activities. Other anticipated effects would include increased suspended nutrients in the water column, reduced dissolved oxygen concentration, increased concentrations of trace metals in the water column, and increased organic pollutants such as hydrocarbons and organic pesticides. These effects are expected to be minor due to the limited duration of construction activities, the mitigating effects of dispersion, and the small areal extent of the impacts relative to the regional resource.

During cavern leaching, a maximum discharge of approximately 684,000 B/D of brine (∿270 ppt) would be released to the Gulf of Mexico over 50 to 60 months through a pipeline and diffuser. Brine would be discharged in 50 feet of water (ambient salinity of 30 to 35 ppt) 5.8 miles south of Bryan Beach. In order to gain a quantitative indication of the possible impacts of brine disposal on water quality in the Gulf of Mexico, computer simulation analyses were performed using a time-dependent model (NOAA, 1977). Model input included estimated current fields that closely approximate actual conditions and observed current patterns obtained from baseline monitoring at the Gulf diffuser site. A summary of the study results is provided in Appendix G.

For the case of the most active current conditions, the predicted maximum salinity concentration at the ocean floor was 3.5 ppt greater than ambient (∿10 percent) in the immediate vicinity of the diffuser. The 1.0 ppt salinity excess contour at the bottom covered about 500 acres; the 0.5 ppt contour covered approximately 2000 acres. The salinity excess values at mid-water depths did not generally exceed 0.1 ppt.

For the case of stagnant currents, the predicted maximum salinity excess was greater than 5 ppt in the 25 acres immediately around the diffuser. The 1.0 ppt salinity excess contour covered about 2000 acres after 8 days of stagnation. However, the area affected by the smaller concentration excesses (less than about 0.5 ppt) were often smallest for the case with stagnation.

The results of the analyses show that the current sequence has only a moderate effect on the maximum predicted concentration in the far field, but it has a substantial influence on the shape of the calculated concentration distribution. Periods of strong ambient current produce long, narrow plumes. Concentrations near the diffuser are relatively low due to the strong dependence of near field dilution on current speed. During periods of stagnation, the plumes remain closer to the diffuser. Concentrations near the diffuser are generally higher during stagnant conditions than for the strong net current cases due to salinity concentration build-up. The expected average concentration of oil in the displaced brine during cavern refills is 6 ppm (see Appendix D). Disposal would occur for a 2.3-year period during each refill operation.

Discharge of the brine would effect water quality in the area in several ways. The ion ratios of bulk constituents relative to "normal" seawater are shown in Table G.3-4. Only sodium exceeds normal concentrations while other ions, most importantly magnesium, are well below existing conditions. Of greater importance is the distortion of the Ca/Mg and K/Na ratios in the brine relative to seawater which have been shown to be an important ecological factor in the physiological function of several aquatic organisms. This imbalance may be as signigicant a concern as increased osmotic stress due to excess salinity. Increases in the concentrations of dissolved and precipitated chemical components would parallel increased salinity. Having an affinity for the surface of existing particles, the possible settling of these components could influence sessile marine life in the disposal area.

Some trace metals are found in higher than normal seawater concentrations in the raw water from the Brazos River. Concentrations in the leaching water could exceed EPA recommended guidelines during low river flow or flooding conditions. When the raw water is retained in the caverns for a sustained period of time such as during withdrawal and refill, sedimentation of most heavy metals out of the brine would occur.

The oil in brine analysis and experience gained during several years of operation of a similar facility in Manasque, France has shown that concentrat of oil in the discharged brine should be well below the EPA recommended guide line (see Appendix D).
Maximum oil concentrations at the diffuser are expected to be less than 15 ppm and average 6 ppm over the project, and are not expected to have adverse impacts. Depressed dissolved oxygen concentrations resulting from elevated salinity and temperature are expected to be minor and temporary.

The 5-well backup brine disposal system would inject brine into deep salt water bearing sands. These sands are relatively permeable; thus, it is expected that the dense brine would flow downdip with a relatively slow movement that would not induce extensive mixing with the formation water. The high permeability of the sands would minimize the likelihood of migration of brine or saline water displaced up along faults or improperly cased wells. No impact to water supply is anticipated.

Dock Construction

Dredging at the DOE dock sites adjacent to the SEAWAY Docks on the Old Brazos River and in Brazos Harbor (1,050,000 cy) would result in temporary increases in turbidity, and possible releases of toxic sulfides, heavy metals, arsenic, pesticides, or other toxic materials trapped within the bottom sediments. If the bottom sediments are polluted the release of these pollutants cannot be avoided. Most researchers have concluded that modern (hydraulic) dredging techniques have little effect on the water directly overlying the sediments (Slotte, 1974; Windom, 1972 and 1975; May, 1973; Seila, 1971; and Macklin, 1962). These investigations report that dredging activities may increase water turbidity and other parameters to a very minor degree up to a mile from the dredge site under certain conditions. Significant increases in any parameter have been reported only within 200 feet of the dredge.

The amount of dredging required for the DOE docks is comparable to ongoing maintenance dredging (over 1 million cy annually) and proposed deepening of the harbor channel (100 million cy). In 1975, the Corps of Engineers measured water quality in Freeport Harbor and the Intracoastal Waterway before, during, and after dredging (Appendix B). Increased values of nitrogen and chemical oxygen demand were indicated during dredging activity, but most parameters showed no significant change in concentration as a result of dredging. Due to the present low quality of water in Freeport Harbor and the liklihood that little change in overall water quality would occur from dredging activities, the construction of the DOE docks should have a negligible impact.

Construction of Surface Facilities

Sediment represents the major non-point source of water pollution from surface construction sites. Sediment includes solid and organic materials detached from the ground surface by erosion and carried into the drainage system. Large volumes of sediment may ultimately reduce the storage capacity of waterways, thereby increasing flooding hazards, fouling and destroying aquatic habitats, and diminishing recreational and property values. While the sediment is suspended in the water, it may enhance the transport of pollutants such as human and animal sanitary wastes, pesticides, and petrochemicals.

Site preparation and construction activities at Bryan Mound and along the connector oil pipelines would require displacement of approximately 31,300 cy of soil from 36 acres of land. The site soils are highly erodable, presenting a potential impact to the onsite lakes and the nearby Intracoastal Waterway. These impacts may include increased sedimentation, and introduction of chemicals released from the soil or from construction activities. Construction would include the building of a storm-water runoff collection and treatment system to minimize future impacts.

Numerous solid and liquid products, both organic and inorganic, used in construction are a source of water pollution. They may be broadly grouped under the following headings:

- Petroleum products
- Herbicides and pesticides
- Fertilizers
- Metals
- Soil additives
- Construction chemicals
- Miscellaneous wastes

Of these, petroleum products, herbicides and pesticides, and fertilizers are the best known and the best documented sources of chemical pollution. Pollution from petroleum products generally occurs from improper disposal of waste materials such as crankcase oil and cleaning solvents; leakage of fuels and oil from storage facilities, and damaged or improperly maintained vehicles; fuel spills during equipment refueling; and the use of oils for dust control on roadways. Herbicides and pesticides are used on construction sites to control undesirable vegetation, insects, and rodents. Fertilizers are extensively utilized in the revegetation of areas affected by grading. The primary cause of pollution from their use is the improper use, handling, and disposal of waste materials. Volumes of pollutants from these sources would be small and, except in the case of chronic releases, would have a small effect on water quality.

The biological pollutants which generally enter receiving streams and other water bodies as a result of construction activities are bacteria, fungi, worms, viruses, and other less common organisms. Portable sanitary facilities would be provided at the construction sites according to Occupational Safety and Health Administration standards.

Accidental Brine Release

The estimated quantity of brine spilled during leaching of Bryan Mound expansion cavities is 50 barrels into Gulf of Mexico waters and 10 barrels onto land and water bodies between Bryan Beach and the storage site (Table C.2-3). In addition, an estimated 5 barrels of salt water would be lost from the raw water supply system. Maximum credible spills of up to 30,000 barrels are considered possible, though highly unlikely.

A brine spill at the site or along the disposal pipeline could locally impact the water quality in the upper unit of the Chicot aquifer, however. The brine would tend to migrate downward within the formation and downdip along the formation due to density differences. A massive spill, although highly unlikely, could possibly impact the quality of municipal water supplies pumped from aquifers in the Brazosport area by causing increased salinities in those aquifers. As local recharge of near surface aquifers has been found to be minimal, potential seepage from the membrane-lined brine pit or minor pipeline spills are likely to have negligible impact on water quality.

Hurricane surge studies conducted by the U.S. Army Corps of Engineers indicate that the 100-year flood elevation, excluding wave runup, at Bryan Mound is +12.0 feet MSL (Trahan, personal communication). As the brine pond would be protected by an existing levee of elevation +19 feet MSL, there is little likelihood of a catastrophic failure that would result in the release of the contents of the pond. Should a storm surge of sufficient magnitude occur to breach the levee, impacts caused by loss of the brine would not be distinguishable from storm wave and saltwater damages.

Construction and Use of Alternative Facilities

Alternative systems to provide raw water for cavern leaching and oil displacement include supply from Dow Chemical Company's existing reservoirs and withdrawal of saline ground water from the Evangeline aquifer. Use of Dow's reservoirs would have negligible environmental impact, as sufficient storage capacity is available at the reservoirs so that withdrawal for this project would be insignificant. (The ultimate source for this water remains the Brazos River.) Development of a suitable well field to supply 534,000 B/D for cavern leaching is feasible, based on aquifer characteristics provided in Section B.2.2.2. The problem of surface subsidence remains, however. Development of a well field with negligible potential for subsidence may require hundreds of acres. Final design of the well field would depend on analysis of test well results (Appendix A).

Impacts that might result from withdrawal of such large quantities of water include lowering of the piezometric level in the pumped zone, land subsidence, and intrusion of the pumped zone by waters of different salinities. Land subsidence and saltwater intrusion result directly from drawdown or reduction of the piezometric level in the aquifer. This, in turn, depends upon such factors as pumping rate, well spacing and completion, and aquifer thickness. With due consideration to well spacing and completion methods and given the great thickness and high permeability of sands containing moderately saline water in the site vicinity, it should be possible to provide the required quantities of water with less than 100 feet of drawdown in the vicinity of the well field. Data provided in publications by Pettit and Windslow (1957), Hammond (1969) and Sandeen and Wesselman (1973) indicate that about one foot of subsidence results from 100 feet of drawdown in the Texas coastal area. Subsidence on the order of 1.6 feet in Freeport and 2.7 feet in Texas City had already occurred by 1959 from much smaller ground water withdrawals than those that would be needed for operation of the Bryan Mound oil storage facility. However, most of that pumping was restricted to the freshwater zones of the upper Chicot aquifer, about 150 feet thick. The lower unit of the Chicot aquifer and the Evangeline aquifer provide a total of over 1500 feet of sand containing moderately saline water.

Alternative brine disposal systems include providing all or part of Dow's feedstock demand, construction of a brine diffuser system 12.5 miles offshore, and deep well injection into Miocene sands. Delivery of brine to Dow would have few environmental impacts as the pipeline is presently in place. Brine spillage of the order of tens of barrels could be expected. This alternative appears impractical at this time since Dow has been unwilling to accept brine at the rates and volumes necessary. The nature of the impacts associated with the 12.5 mile diffuser system would be similar to those discussed for the proposed diffuser system. Brine diffusion may occur at a slightly slower rate at this site during some seasons, due to stronger vertical stratification of the water column. A complete description is provided in Appendix G. Deep well injection of brine into saline water bearing sands would not affect potable water supplies unless confining beds above the sands should be fractured, resulting in upward displacement of saline water, or unless migration up improperly plugged wells is initiated. Brine injection to deep salt water bearing sands can impact water supplies in various ways including increasing the salinity of the water in the sand formation, displacement of moderately saline water from one portion of the sand formation into portions containing fresh water, or inducing migration of brine or moderately saline water from the sand into a fresh water aquifer via such avenues as faults or abandoned wells. In certain geologic provinces where the rock is under stress it may be possible to generate earthquakes or activate faults by high pressure injection of waste water.

The proposed receiving formations for injection of brine at Bryan Mound range in depth from 3000 to 8000 feet, well below any aquifer containing fresh or slightly saline water. The increase in salinity, therefore, would be restricted to water that would not be economically competitive for desalination due to the large quantities of slightly saline water available in the region. Generally the only wells extending to the depth of the injection zone are oil wells which are generally concentrated near the dome. Injection zone formations are not in a state of stress and are relatively permeable, thus providing a path of least resistance in preference to faults. Standard operating procedures and routine monitoring of injection pressures should preclude hydrofracturing. In addition, the extremely dense brine would tend to move downdip in the receiving formation and the relatively slow movement would not induce mixing with the formation fluids. No adverse impact on water supplies is foreseen should injection be selected for brine disposal.

Another potential problem associated with deep well injection of brine concerns migration of oil and gas resources due to displacement or pressurization. This problem is discussed in Appendix H.

Should this deep well injection alternative be selected, all deep wells in the disposal area would be investigated for potential migration of oil and gas. Also, an extensive program to monitor pressure in the receiving formation, would be initiated prior to and during brine injection.

Alternative methods of transporting oil include use of Phillips or SEAWAY Docks in place of new DOE docks and construction of a marine pipeline and monobuoy. As no dredging would be required to use the industry docks, water quality impacts would be limited to minor quantities of erosion and release of construction wastes at the dock sites. Construction of the offshore terminal facilities would produce significant local, but temporary, suspension of bottom sediments and trapped chemicals along the 6-mile pipeline right-of-way to single anchor leg mooring. These impacts would be similar to those discussed for dredging in Freeport Harbor.

Onsite electric power generation would have relatively minor impacts on water resources. Cooling water in quantities much less than needed for leaching would be taken from the Brazos River raw water supply system and could be discharged through the brine disposal pipeline to the Gulf.

C.3.1.3 Air Quality

The quality of the air in the vicinity of Bryan Mound would be slightly affected during site preparation and construction; impacts would be short term and confined to a relatively small area. The principal pollutant of concern would be hydrocarbon emissions since data presented in Section B.2.3.3 indicate that hydrocarbon concentrations in the vicinity of Bryan Mound frequently exceed the NAAQS.

Sources of Emissions

The quality of the air at the Bryan Mound site during construction would be affected by the following pollution sources:

- general construction vehicles
- drilling rig engines
- fugitive dust

During the site preparation phase, there would be clearing operations, landfill, and road construction. This phase would last approximately seven months. A number of machines and heavy vehicles would be used. The diesel and gasoline engines would emit hydrocarbons (HC), SO_2, CO, NO_2, and particulates.

Accurate prediction of quantities of pollutants emitted during construction is difficult because emissions depend upon many factors, including type, number and model year of vehicles, duty cycle, speed, cold operation fraction, and ambient temperature. Vehicular emission rates given in Table C.3-1 were calculated using emission factors from U.S. EPA publication AP-42 (1976) and estimates of the projected use of construction equipment. The onsite vehicle sources are assumed to be 10 heavy-duty gasoline vehicles and 10 heavy-duty diesel vehicles, with a conservative duty factor of 2000 hours/year and maximum speed of 10 miles per hour.

Drill rig equipment typically includes three large engines, and other smaller engines. These engines would be assumed to total 4000 horsepower and, as a worst case, to be heavy-duty diesels. The drill rig equipment is assumed to operate at 50 percent load for about 7000 hours/ year. Estimated emission rates are given in Table C.3-1. Except for CO, the estimated drill rig equipment emissions are much larger than vehicular emissions.

TABLE C.3-1 Onsite emission rate during construction.

Pollutant	Vehicles[a] (g/sec)	Drill Rig[b] (g/sec)
CO	1.37	1.306
Hydrocarbons	.117	0.482
NO_2	.212	6.86
SO_2	.020	0.432
Particulates	.015	0.418

[a] 10 heavy duty gasoline vehicles plus 10 heavy duty diesel vehicles at a conservative duty factor of 2000 hr/yr, each.

[b] Assuming 2 heavy-duty diesel drill rigs, 4000 total horsepower operating at 50 percent load, 20 hours per day.

Source: Compilation of Air Pollutant Emission Factors, Second Edition, U. S. Environmental Protection Agency, February 1976.

Dust emissions would result from construction activities at the site. The dust would be associated with land clearing, excavation, cut and fill operation, and other activities. The amount of dust would vary from day to day depending on the activity and the weather. A large portion of the dust would be due to equipment traffic over temporary roads. Field measurements at apartment and shopping center construction sites yield an estimate of 1.2 tons of dust per acre of construction per month of activity (EPA, 1976). This estimate is high for the Bryan Mound site because the estimate is for a semiarid climate. Dust emissions are often inversely proportional to the square of ground moisture. Since ground moisture at Bryan Mound is 1.66 times the semiarid level (EPA, 1976), the dust emissions during construction are estimated to be 0.5 tons of dust per acre of construction per month of activity.

No additional crude oil storage tanks would be constructed for expansion at Bryan Mound. Paint solvent emissions (and impacts) resulting from painting the four 400,000 barrel storage tanks were described in FES 76/77-6. The size of these tanks have been reduced to 200,000 barrels capacity each. The air quality impacts due to paint solvent emissions would thus be substantially reduced.

Impacts on Air Quality

The impact of the atmospheric emissions due to site construction is dependent on the ambient air quality and the dispersal characteristics of the atmosphere, both of which have been discussed in Section 3.2.2. Downwind concentrations were calculated using methods recommended by the Environmental Protection Agency (Turner, 1969) and averaged over appropriate time intervals.

Pollutant concentrations at one kilometer (km) downwind from construction vehicles and drill rig equipment are shown in Table C.3-2. The concentrations were calculated using the emission rates given in Table C.3-1 and projected "worst case" meteorological conditions (Appendix I, Part 1). Downwind concentrations from the construction vehicles were calculated assuming an area source model with a construction area having dimensions of 250 meters on a side. An insignificant addition of pollutants

TABLE C.3-2 Estimated pollutant concentrations at 1.0 kilometer downwind of construction activities.

	National and State Standards		Downwind Concentrations ($\mu g/m^3$)[a]	
Pollutant	Averaging Period	Limit ($\mu g/m^3$)	Constuction Vehicles[b]	Drill Rig
Particulates	1 yr.	75	0	1
	24 hr.	260	0	10
	5 hr.	100	0	20
	3 hr.	200	0	22
	1 hr.	400	0	27
SO_2	1 yr.	80	0	1
	24 hr.	365	0	11
	30 min.	730	1	31
CO	8 hr.	10,000	22	58
	1 hr.	40,000	31	83
HC	3 hr.	160[c]	2	25
NO_2	1 yr.	100	0	15

[a]Exclusive of background levels

[b]Based on area source model for a construction area of 250 x 250 meters.

[c]Non-methane hydrocarbons only; concentrations are for total hydrocarbons.

would result from brine diffuser pipeline construction onshore and offshore.

The amount of dust-producing construction is relatively small for the proposed project because most of the onsite and access roads are paved. Most of the dust would settle within the site boundaries except that associated with offsite pipelines. The fugitive dust escaping the site will not seriously impact the environment.

Downwind concentrations given in Table C.3-2 are quite small when compared to the state and national air quality standards. However, since background HC levels often exceed the 3-hour standard (160 $\mu g/m^3$) in the Brazosport area, infrequent additional exceedances may be expected during site and associated facility construction. Since existing levels of particulates (TSP), SO_2, CO, and NO_2 in the area are generally very low (Section B.2.3.3) and maximum expected concentrations during construction are quite small, no other exceedances of the state and national air quality standards are expected (The SO_2 30-minute and TSP 1-, 3-, and 5-hour standards are Texas Single Source Standards). All impacts during construction would be short-term in nature and confined to relatively small areas at the storage site along pipeline rights-of-way. Because all pollutants released during construction are assumed to be ground-release, concentrations would decrease with increasing distance.

Alternatives

Alternative sources of raw water would have some effect on construction emissions. Use of water from the Dow reservoirs would involve no construction. However, development of a ground water well field would result in drilling emissions similar to those given in Table C.3-1. Since these emissions would occur a mile or two from the dome site, little interaction would occur and air quality impacts would be essentially as described above.

Development of alternate brine disposal systems would increase construction emissions. A pipeline would be required to deliver brine to Dow Chemical Company and both a pipeline and a well field would be required for deep well injection. These emissions would be relatively small, short-term and confined to a small area with little impact on ambient air quality. The extension of the brine diffuser to 12.5 miles to the Gulf would increase emissions locally for a brief period of time.

Of the alternative methods of delivering oil to and from the storage site, only construction of a marine terminal would affect air quality. However, most construction would be several miles offshore and associated concentrations should be no higher than for the storage site (Table C.3-2). Effects on air quality in the Freeport area should be negligible.

C.3.1.4 Noise

Noise levels associated with the major construction equipment are specified in Table C.3-3. Using hemispherical sound radiation assumptions, the noise levels are extrapolated to nearby locations off the site to determine the effect on ambient sound levels.

Conventional oil well drilling rigs would be used for drilling the new cavern wells. It is estimated that two, sometimes three, large drills may be operating simultaneously on the site. The equivalent sound level, L_{eq}, contribution of this activity is estimated to the 67 decibels (dB) at 500 feet. Assuming that drilling activity is continuous throughout a day, the daytime and nighttime equivalent sound level, L_d and L_n, contributions are both estimated to be 67 dB at 500 feet.

The noise sources associated with leaching are pumps. These pumps would be housed in a sheet metal pumphouse. Sound levels within the pumphouse would be between 90 and 100 dB(A). Outdoor pump sound levels add negligibly to the ambient sound at 500 feet, due to attenuation by the pumphouse walls.

Most facilities at the Bryan Mound site would be completed as part of the early storage phase of the project.

Pipelines connecting the site to the existing SEAWAY Docks and proposed DOE docks in Freeport and the existing SEAWAY Tank Farm at Jones Creek would be constructed as part of the early storage phase. A pipeline, approximately one-half mile in length, connecting the Brazos River Harbor with the main oil distribution pipeline would be constructed for SPR expansion. A pipeline 5.8 miles into the Gulf for the brine diffuser

TABLE C.3-3 Equipment sound levels for construction at Bryan Mound site (proposed site for Seaway SPR development)

Equipment	# of Units	A Weighted Sound Level at 50 feet (dB)	A Weighted Sound Level at 500 feet (dB)	Usage Factor[b]
Storage Tank Construction				
Concrete Mixer	1	85	65	.4
Crane,	2	83	63	.08
Generator	2	78	58	.4
Truck	2	88	68	.26
Dozer	2	87	67	.4
Backhoe	1	85	65	.16
		Leq = 70 dB at 500 feet		
Pipeline Construction - Conventional Lay				
Truck	2	88	68	0.16
Backhoe	1	85	65	0.4
Concrete mixer	1	85	65	0.16
Welding machine	1	83[c]	63	0.5[c]
Scraper	1	88	68	0.08
Crane	3	83	63	0.16
		Leq = 68 dB at 500 feet		
Pipeline Construction - Push-Ditch Method				
Backhoe	1	85	65	0.4
Dragline	1	80	60	1.0
Dozer	2	87	67	0.4
Diesel Winch	1	83	63	0.4
Marsh Buggy	1	78	58	0.5
Welding Machine	1	83	63	0.5[c]
		Leq = 69 dB at 500 feet		
Road Construction				
Truck	2	88	68	0.4
Buldozer	1	87	67	0.4
		Leq = 68 dB at 500 feet		
Dock Construction				
Pile driver	2	101	81	0.04
Trucks	2	88	68	0.16

[a] "Background Document for Proposed Portable Air Compressor Noise Emission Regulations," U.S. Environmental Protection Agency, EPA 550/90/9-74-016 (October, 1974).

[b] Fraction of time equipment is in its noisiest mode.

[c] Estimated.

would also be constructed. The two basic pipeline construction methods are described in Section A.2. Since it is not known which method would be employed for specific sections of the pipe run, a conservative estimate would be an L_{eq} of 69 dB at 500 feet and an L_d of 67 dB at 500 feet for pipeline construction.

Roadways would be constructed along the pipeline rights-of-way. Crushed rock or shells would be used as fill on the existing marsh vegetation; it is assumed that two dump trucks and one bulldozer would be used for this road construction. The L_{eq} is estimated to be 68.1 dB at 500 feet; the daytime equivalent sound level, L_d, during construction would be 67 dB at 500 feet.

The major noise producing equipment used for construction of docks is expected to be one or two pile drivers and trucks. The sound level data for this equipment are presented in Table C.3-3. Assuming construction activity occurs 10 hours a day in the daytime, the equivalent sound level, L_{eq}, and daytime equivalent sound level, L_d, contributions are estimated to be 71 dB and 68 dB at 500 feet, respectively.

Sound levels from construction activities presented above are summarized in Table C.3-4.

Noise levels are extrapolated assuming hemispherical sound radiation to determine distances at which the construction activity would contribute significantly to ambient noise levels, assuming a baseline day/night sound level of 54 dB adjacent to the site. Within a circle defined by this radius (Table C.3-4), average day/night sound levels would be increased by at least 3 decibels, a discernable amount. These impact zones are shown in Figure C.3-1.

The assumption of hemispherical sound radiation does not include attenuation due to foliage, air, or ground effects, and is therefore conservatively high. The area affected by construction activity at the storage site is mostly uninhabited marshlands. Dock construction would raise noise levels at areas along the uninhabited Intracoastal Waterway and at the Dow Chemical Company plant. These are commercial and industrial zones, where prefacility day/night sound levels are expected to be

TABLE C.3-4 Summary of construction activity noise levels at 500 feet and associated impact zone radius.

	L_{eq} (dB)	L_d (dB)	L_n (dB)	Impact Zone Radius (ft)[a]
Drilling Wells	67	67	67	4500
Pipe Laying	69	67	--	1800
Access Road Construction	68	66	--	1400
Dock Construction	71	68	--	2200

[a] This is the distance within which prefacility sound levels are raised by at least 3 dB by activity described. A baseline ambient sound level of 54 dB is assumed for the calculation.

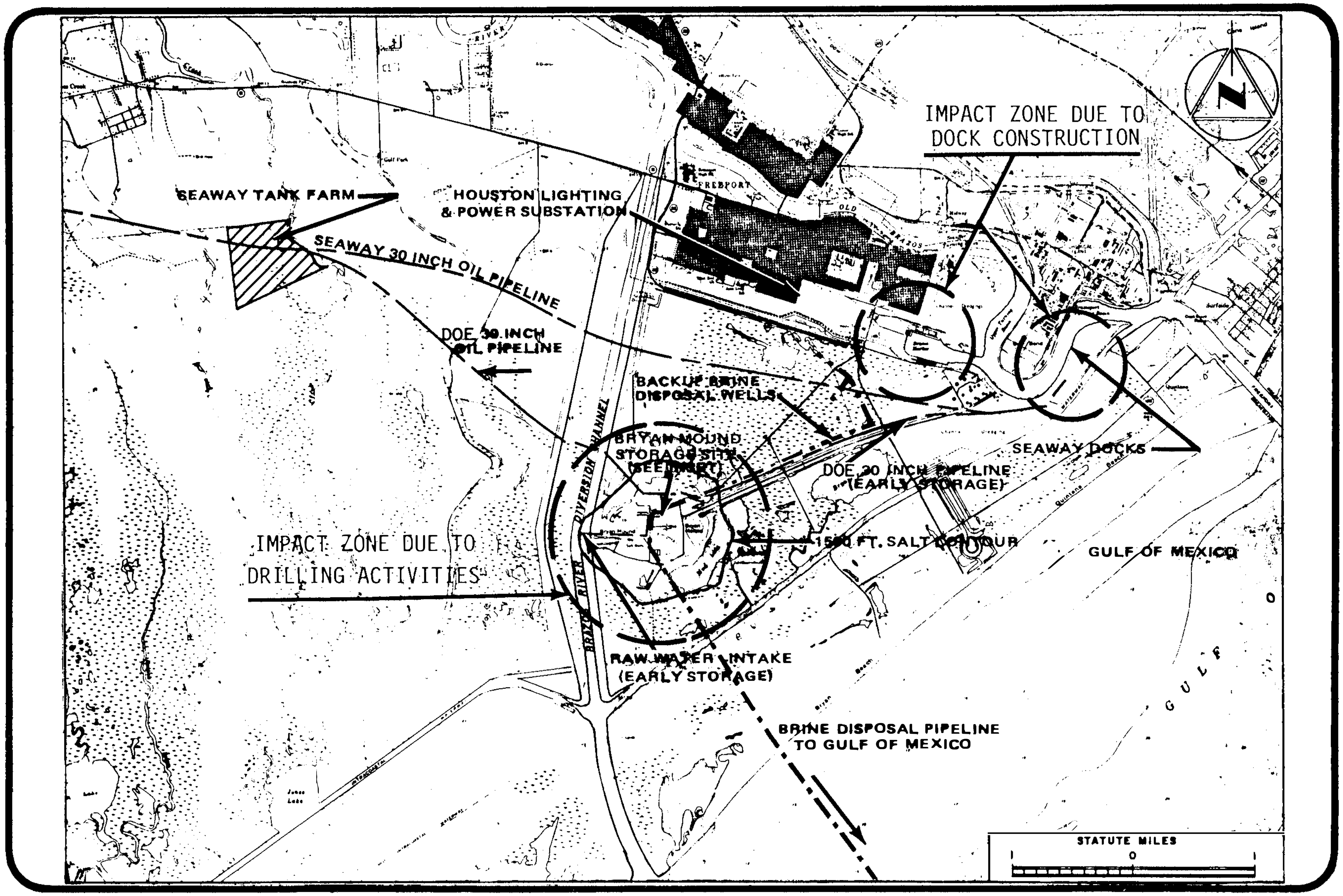

FIGURE C.3-1 Noise impact zones - Bryan Mound dome (proposed site for Seaway SPR development) higher than 54 dB. Some residences in the city of Freeport may be affected during construction, but the present industrial uses in the area and the short duration of construction would mollify the degree of this impact. Therefore, impacts due to dock construction would be negligible. Pipe laying and access road construction would impact areas for only a short duration. Since most of the pipeline runs through uninhabited marshlands, the impact would be negligible.

The Federal Environmental Protection Agency has identified levels for limits of L_{dn} requisite for the protection of public health and welfare with an adequate margin of safety for both activity interference and hearing loss. Within the areas indicated on Figure C.3-1, the L_d and L_n would be above 55 dB during construction activity. Since there are very few residences within these zones of noise impacts, workers on the site would be the most likely receptors of the noise. The short total duration of the construction of facilities at Bryan Mound would minimize undesirable noise impact. Offshore pipeline construction would only temporarily affect noise levels in any sensitive areas.

<u>Alternatives</u>

An alternative brine disposal method would require the construction of a total of 16,000 feet of pipe from the wells to the northeast where the brine would be injected into deep subsurface saline water bearing sands. Similarly, a ground water well field could be developed to supply leach water. A pipeline might be built to receive raw water from Dow Chemical Company. The same techniques and equipment as those described above would be used. The impacts of construction of any of these would be similar to the other construction activity noise levels discussed above.

Construction of a marine pipeline and offshore monobuoy would not affect noise levels at any sensitive areas. Conversion of SEAWAY or Phillips Docks would involve less noise than construction of new DOE docks.

C.3.1.5 Species and Ecosystems

Site preparation and construction of the proposed facilities for SPR expansion at Bryan Mound may affect both terrestrial and aquatic biotic resources in the area. Terrestrial habitats potentially affected include cleared industrial land, coastal prairie, brackish marsh and beach/ dune communities. Aquatic habitats include the Brazos River Diversion Channel, ICW, several lakes and ponds adjacent to the storage site, the Old Brazos River harbor, and the nearshore Gulf of Mexico. Figure C.3-2 shows the major habitats in relation to proposed and alternative SPR facilities.

Most areas to be affected by proposed facility construction have already been cleared for previous industrial use. Also, the proposed early storage development at Bryan Mound would be either in progress or recently completed when the SPR site expansion construction is begun. In many cases the SPR expansion would not create new impacts but would add small additional impacts to those of the early storage development or the existing industrial brining operations.

In the following subsections, potential impacts on biological resources are treated according to specific aspects of facility development.

Raw Water Withdrawal

Withdrawal of 700 million barrels of raw water from the Brazos River Diversion Channel at a rate of 534,000 barrels per day (B/D) for leaching the storage cavities would have a major effect on both the plankton and nekton in the Brazos River Diversion Channel. It can be assumed that 100 percent of all of the organisms taken into the raw water pipeline would be destroyed since these organisms would be pumped into the solution cavities where the salt concentration (salinity) of the water would be increased to about 280 parts per thousand (98 percent saturation). The aquatic organisms destroyed would include such phytoplankton as diatoms, dinoflagellates and blue-green algae, zooplankton, especially shrimp and ichthyoplankton (larval forms of invertebrates and fish), and small fish such as menhaden, silversides, minnows and anchovy. Adult forms of many larger fish would not be directly affected by water

FIGURE C.3-2 Air photo - Bryan Mound (proposed site for Seaway SPR development) withdrawal since the intake system would be designed for a maximum velocity of 0.5 ft/sec and thus these mobile organisms should be able to avoid entrainment of this low velocity. Of major importance would be the impact of the water intake (entrainment) on the ichthyoplankton.

The water quality of the lower Brazos River has been reported to be poor and the ichthyoplankton would be expected to be very scarce (since these forms are very sensitive to changes in water quality). However, withdrawal of water required to solution mine the cavities could possibly kill a large number of aquatic organisms if they were entrained in the intake water. Depending upon the season of the year, the numbers of aquatic organisms entrained in the raw source water would vary markedly. Generally during the spring the numbers of all organisms present would be expected to be high; the numbers of aquatic organisms (especially ichthyoplankton) would generally decrease with the approach of warm summer temperatures and would reach a minimum during the winter.

In the absence of natural mortality rates for egg and larval stages by unit volume, impact estimates cannot be quantified but are expected to be small. There are no known species of fish or shellfish which are particularly dependent on the Brazos and which might be sensitive to seasonal depletions of juvenile populations.

Brine Disposal

Construction of the brine diffuser pipeline would have a minimal impact on marine biota in the region as a whole but would significantly effect some organisms within the proposed right-of-way. The physical and chemical impacts of construction on water quality have been described in Section C.3.1.2. Dredging activities would drastically alter, and cause a temporary loss of benthic habitat within the pipeline corridor. Benthic organisms may be smothered by localized sedimentation from dredging with recovery occurring slowly. Loss of benthos may temporarily reduce local nekton productivity and siltation may affect respiration. Increased turbidity would reduce plankton productivity. Some increased uptake of resuspended trace metals by the plankton may also occur. These effects would occur in a concentrated area along the right-of-way and would last for only a brief period in any one location.

Since the brine solution would be discharged into the Gulf of Mexico, it may impact the marine biota in and around the point of discharge. The distribution of the brine plume and its impacts, as analyzed by NOAA (1977), are described in Section C.3.1.2 and in Appendix G. Temperature, and to a lesser extent salinity, regulate the temporal and spatial distribution of marine organisms. Organisms found in the coastal region of Texas are generally tolerant of the variable temperatures and salinities found there although responses vary with different life cycle stages. The impacts on these organisms would depend on their proximity to the relatively small area of extreme temperature and salinity increases near the diffuser.

The high temperature-salinity sector for the proposed diffuser site would be anticipated to have salinity values of approximately 5 to 264 ppt, temperatures of about $1^{o}F$ to $130^{o}F$, and to have an areal extent of approximately 25 acres. This sector would also contain excess turbulance, particulates and dissolved hydrocarbons, as well as low dissolved oxygen levels and atypical chemical constituents. Plankton, while entrained in this part of the plume would experience severe stress, retardation of community growth, or death. Assuming total mortality, a yearly average of 4.1×10^{5} cells would be destroyed in each liter of water so affected, however recovery of some stressed organisms is anticipated after currents carry them away from the high salinity-temperature area. Benthic organisms in this area would be destroyed at the average rate of 1.3×10^{8} per acre most of the year assuming total mortality, but this value could increase in summer when maximum biomass occurs. The mature nekton would be minimally effected due to their ability to avoid this area, but developmental stages (eggs and larvae) in the immediate area may experience adverse impacts on metabolic functions and development. Operation of the proposed brine diffuser is not expected to effect a significant portion of the marine biota in the region.

Beyond the high temperature-salinity area, the plume would continue to cause smaller increases in temperature, salinity and other parameters which would have minimal effects. Some effects on productivity and development of benthic organisms may result from physiological stress. Decreases in local productivity of nekton may result from reduced benthic community productivity. Operation of the proposed diffuser system is not expected to adversely impact any unique habitats or endangered species. A more detailed discussion of the impacts of brine diffusion on local marine biota is presented in Appendix G.

Dock Construction

Construction of the dock and pier facilities in Brazos Harbor and adjacent to the SEAWAY Docks may affect approximately 14 acres of manmade land, which has been filled and graded at each site. Vegetation is limited to a few grass and weed species which are sparsely distributed over the site.

The dock areas are utilized by a limited number of wildlife species. A small number of birds including herons, egrets, gulls, terns, shorebirds and a few species of passerine birds, may be temporarily affected by dock construction. Mammals likely to be disturbed as a result of construction and related activities include only small rodents and rabbits. Frogs and a few species of snakes are the only herpetofauna species expected to be affected by construction.

An estimated 1,050,000 cubic yards of material would be dredged for each dock, thereby destroying some benthic organisms. However, since Freeport and Brazos Harbors are normally dredged every two years, the existing benthic community is very poor in both abundance and species. The increased dredging activity associated with the proposed SPR expansion at Bryan Mound is not expected to have a significant impact on the harbor biota. Furthermore, any increased turbidity and sedimentation of harbor waters would be of short duration.

Construction of Surface Facilities

Grading and filling of the site for well pads, and dikes would disturb a maximum of about 40 acres of cleared land (coastal prairie habitat); this would cause a temporary problem with erosion which would, in turn, increase the turbidity and concentration of suspended solids in the nearby small lakes and ponds. When these cleared areas are revegetated, soil erosion would be reduced.

The 40 acres of coastal prairie removed from biological productivity would reduce the annual primary production of the prairie land by about 4.0×10^8K cal (7.2×10^4 lbs of organic carbon), assuming that onsite total coastal prairie primary production is 2.5×10^3K cal/m^2/hr (1.8×10^3 lbs. of organic carbon per acre per year) (U.S. Dept. of Interior, 1974). This would be an insignificant reduction in primary productivity in coastal Brazoria County.

Grading of these 40 acres of prairie would destroy many small invertebrates. In addition, wildlife habitat for small birds and mammals would be removed from the ecosystem. The most common wildlife to be directly affected would include small rodents, amphibians, reptiles and birds.

Also affected by onsite construction are 4 acres of marsh excavated for pipeline installation and roadways. Temporary impacts would be similar to those described above for drill pads and dikes. However, some of this land would recover a portion of its original productivity after backfilling and revegetation.

Indirect effects of site preparation and construction include forced emigration of wildlife due to loss of habitat and increased noise from construction activities. The total impact of this migration would be dependent upon the extent and availability of space, cover, food and other resources in nearby similar habitats. This forced migration could be of major local importance if construction occurred during the late winter and early springtime when the carrying capacity of the land was at its highest. Indirect impacts would also be important during the winter period when large migratory bird populations inhabit the area.

The wildife species most likely to be indirectly affected by construction activities would include birds, such as hawks, egrets, herons and waterfowl, and mammals, such as small mice, rats and rabbits. The gulf salt marsh snake and western diamondback rattlesnake could also be affected to a small degree. Some of these mobile animals may experience difficulty in locating replacement habitat. However, because of the extensive prairie and marshland areas available adjacent to Bryan Mound, the potential for relocation is considered good.

Although no specific primary production data are available for the onsite lakes, productivity estimates for algal flats and salt marshes in the area indicate that net productivity may amount to 600 pounds of organic carbon/acre/year. It is doubtful that the primary productivity of Unnamed Lake reaches this high level.

The effect of construction on primary production (photosynthesis and growth of phytoplankton, emergent and submergent aquatic macrophytes, and periphyton) in the site lakes could be both negative (due to increased turbidity) and positive (due to slight increases in nutrient levels). These changes would occur at the marsh/lake margins following heavy rains, but the impacts would be very temporary and localized. The enhancement or retardation of aquatic vegetation growth would be reflected in similar changes in productivity of zooplankton, benthic invertebrates, and small filter-feeding fish in the aquatic ecosystem. Detritus washed in from the cleared areas may also enhance the growth of benthic invertebrates. Because of the existing high levels of turbidity, this small incremental increase in suspended material is not expected to cause a major impact. Most of the large mobile invertebrates and fish would be able to avoid the temporary turbidity levels, but populations of organisms such as small clams and mussels may be reduced in number.

It is not expected that surface construction at the site would greatly impact the water quality in either the Brazos River or the Intracoastal Waterway. Also, there are no known important breeding or nesting areas on Bryan Mound which would be impacted by construction activities. No threatened, endangered or otherwise unique or important terrestrial or aquatic species are expected to inhabit the site.

Accidental Brine Release

The expected quantities of brine accidentally spilled from the retention pond onsite or from the brine disposal line to the Gulf are very small. These spills would not be anticipated to have adverse impacts on more than an acre or two of terrestrial or aquatic habitat. A maximum credible spill of up to 30,000 barrels of brine could have significant local impacts on both the vegetation and animals in the spill area; however, the probability of such a spill occurring is extremely small.

The most likely location for a major brine spill would be in offshore Gulf waters along the pipeline. It may be expected that a release of 30,000 barrels of brine in nearshore waters would destroy mostly bottom organisms, and possibly other organisms in the upper water column. This biological impact would be locally significant but recolonization would begin almost immediately after the spill had mixed with the coastal water.

Should a maximum credible brine spill occur on the salt dome or between the dome and the beach area, the brine could spread across the coastal prairie, the brackish marsh, into Mud Lake or into the ICW. Impacts on vegetation and on animal life which could not avoid the brine in these areas would be locally devastating; particularly in the terrestrial habitat or in Mud Lake. Tens of acres of habitat could be destroyed and the resulting concentration in the soil could remain above levels required for growth of new vegetation for several years. However, it must be emphasized that such a spill is statistically very unlikely to occur, especially from so short a section of pipeline.

Alternative Facilities

Conversion of Phillips and SEAWAY Docks for SPR oil distribution and delivery of brine to Dow Chemical Company would have essentially no impacts on biota resources as essentially no new land would be cleared. Withdrawal of raw water from Dow Chemical Company reservoirs would impact several acres of coastal prairie and marshland for pipeline installation.

Construction of the alternative deep well brine disposal system would take place along an existing access road which runs across the marshland to the northeast from Bryan Mound. A total of 19 acres of marshland would be required for the well pads, and an additional 42 acres of marshland would be disturbed along the pipeline right-of-way. After construction, impacts on the habitat needed for pipeline construction would be minor, since the pipeline would be buried. Disturbance to this area would be of short duration, and the land would revert back to a wetland environment. The construction of the injection wells would have a long term impact on the marshland biota, since the 19 acres required to develop the drill pads would be filled. Because of this higher elevation the filled areas would eventually support a coastal prairie habitat. Biota impacts of similar value would occur if a well field were developed to supply ground water for cavern leaching. For either alternative, there would be additional marsh exposure to possible brine or raw water spills.

The significance of these changes is difficult to quantify since they would depend upon the use and suitability of the adjacent and replacement habitat to the existing wildlife population. Reduction of marshland habitat and alteration of existing drainage patterns could significantly affect the resident herptofauna and also the bird species which utilize the marshland area. Large numbers of waterfowl and other bird species nest and feed in the Bryan Mound marsh during the winter migration period. Loss of these wetlands would produce some crowding in adjacent marshes. The "new" coastal prairie lands would provide additional habitat for species which prefer this community.

Construction of a marine pipeline and monobuoy for offloading tankers in the Gulf would require temporary disturbance of nearshore and offshore bottom material over a 30 mile pipeline corridor. Benthic organisms would be directly destroyed by jetting of the pipeline trench and by siltation. Effects are generally expected to be of minor, local significance and of short term duration. It is expected that the oil line would be placed in a corridor which parallels the planned brine disposal line, which would minimize onshore impacts in particular.

Construction and operation of the 12.5 mile brine diffuser system would have impacts similar to those described for the proposed diffuser site. Construction would occur over a larger area of the Gulf. Brine diffuison would not be expected to impact as productive a commercial fishing area at the alternative site as at the proposed site. A complete description of this alternative and its impacts is presented in Appendix G.

C.3.1.6 Natural and Scenic Resources

There would be no significant impact on recreational activities or natural and scenic resources resulting from project construction. All major recreational facilities are at a sufficient distance so that they would not be affected. Impacts on waterfowl habitats near the site are expected to be minor, as the site is in an industrially developed area; any increase in noise, dust, and traffic would be temporary. Hunting or birdwatching would be temporarily disturbed near the construction.

Construction would have a negative aesthetic impact on the project area. Although, noise, fumes, dust, vibration and traffic would result from construction activities, the site is located in an area currently in industrial use. The proximity of the site and some pipeline construction areas to Bryan Beach and water fowl areas to the west may result in some offsite adverse impacts that could be perceived by recreational enthusiasts and hunters.

Alternatives

Construction of pipeline and well fields for brine disposal or raw water supply would impact waterfowl areas in the marsh to the north of Bryan Mound. Construction of a marine terminal would require crossing Bryan Beach adjacent to the proposed brine disposal pipeline. Other alternatives should have no significant aesthetic or recreational impacts.

C.3.1.7 Archaeological, Historical and Cultural Resources

A comparison of the location of sites listed on the National Register of Historic Places and those sites identified by the Historic Preservation Office for Texas and the location of the SPR facilities has been made. Based on this comparison there are no known sites of historic significance that would be affected, however, in compliance with Section 2(a) of

Executive Order 11593, "Protection and Enhancement of the Cultural Environment" (May 13, 1971), a survey will be carried out to locate, inventory and nominate eligible historic, architectural and archeological properties to the National Register of Historic Places that may occur on lands affected by the chosen development alternative. The results of this survey will insure the proposed undertaking will not result in the transfer, sale, demolition or substantial alteration of eligible National Register Properties. As the project progresses, additional surveys will be carried out to determine that no additional eligible properties have been uncovered.

In compliance with Section 1(3) of Executive Order 11593 it wll be determined that the proposed project will not result in the destruction or deterioration of non-federally owned districts, sites, buildings, structures or objects of historical, architectural or archeological significance.

C.3.1.8 Socioeconomic Environment

Land Use

Land use impacts resulting from the development of 100 MMB of newly leached storage capacity at Bryan Mound are not significant because all permanent development would be on or adjacent to previously developed industrial land. SPR facilities would be enclosed on 390 acres of land (including a 150 acre area previously required during the early storage phase of the program). About 36 acres, or 15 percent of the 240 acre expansion area would be cleared and used for surface facilities such as roads and drill pads. Development of the brine diffuser system to the Gulf would disrupt 21 acres of coastal areas. The impacts of construction in these areas would be significant but would be temporary with land returning to its previous use within a few months or less in most cases. In areas where waterways are crossed, temporary disruption of shipping or recreational uses would occur.

Construction of offshore pipelines and the diffuser would occur in a very limited area. This area would be temporarily unavailable to commercial or recreational vessels, but in the context of the large area available in the Gulf construction would pose only a minor inconvenience. Laying the pipeline a minimum of several feet below the surrounding terrain would virtually eliminate the potential for navigational or trawling hazards after construction. The diffuser area and construction vessels would be carefully marked with approved navigational devices, ususally including lights and radar reflectors. Anti-snag diffuser ports would be utilized to avoid damage to fishing gear.

Alternative development plans would have some additional land use impacts. If brine disposal is accomplished through the use of injection wells, an additional 61 acres of land may be needed for project construction. This land would be used for a pipeline access roads and drill pads for the injection wells. As the planned right-ofway parallels an existing road, land use impacts would be minimal. The drill pads would be built on land which is predominantly marshland.

Development of a ground water supply system would impact an estimated 69 additional acres for pipelines, access roads, and wellheads.

Use of water from Dow reservoirs for leaching would require 37 acres of land for pipeline construction right-of-way. Delivery of brine to Dow's Freeport plant would have no land use impact because an existing pipeline would be used.

Conversion of SEAWAY or Philips Docks would not alter land use. Development of a marine terminal would involve land only along approximately one mile of coastal prairie, marsh and wetlands for the onshore pipeline right-of-way. A small dredge spoil area maintained by the Army Corps of Engineers would be crossed with no significant impacts.

Land use and planned development would comply with local regulations to help minimize adverse impacts. All construction in navigable waters would occur in accordance with required permits.

Transportation

The two roads connecting the Bryan Mound site to the Freeport area would be sufficient to handle the increase in traffic resulting from the construction activities onsite (Figure B.3-3). The major highways to which these roads connect already experience congestion during peak hours in the morning and evening. Assuming a peak load equal to 10 percent of the total daily volume in 1975, Route 288, the major connector to the Houston area, carried about 1871 cars during an average rush hour in 1975 at the Freeport city limits (State Department of Highways and Transportation, 1975). Route 36 carried 814 cars at the city limits and Route 523, north of the junction with Route 1495, carried about 876 cars during average peak hours over the same period. Worst case conditions would occur if each of the estimated 293 workers employed during the heaviest construction activity (Table C.3-5) commuted to the site in their own vehicles; then, significant traffic increases would occur on these roads. This worst case condition would be unlikely because of several project characteristics. First, the project would employ some workers in night shifts, as the leaching operations continue over a full 24-hour workday. Second, some of the construction workers would work shifts that begin earlier and continue later than the normal commuting hours. Third, some carpooling is expected. Finally, the construction work would be heaviest during a six month period, from the second to the seventh month. After the seventh month, total employment on all shifts would be 132 workers or less. These workers would contribute to the current congestion on some streets in the Freeport area and would cause adverse impacts if road capacities are exceeded.

If the SEADOCK project is under construction at the same time as Bryan Mound SPR expansion, traffic could be more seriously congested in the Freeport area than it would if the projects are undertaken separately.

The SPR project may have a minimal impact on waterborne transportation in Freeport Harbor due to the increase in oil tanker traffic. Total traffic in this harbor, in 1976, amounted to 436 vessels (Brazos River Navigation District). The worst case increase in tanker traffic during the initial fill of the 100 MMB storage capacity would average about one tanker every day. This assumes a tanker capacity of 32,000 DWT, or 254,000 barrels of oil. If SEADOCK is constructed, overall traffic, particularly tankers, in Freeport harbor will be significantly reduced. The increase in traffic from the SPR program, under this assumption, would not cause appreciable additional congestion.

TABLE C.3-5 Estimated construction employment and wages by month - Bryan Mound (proposed site for Seaway SPR development)

Month	Monthly Employment	Monthly Wages
0-1	105	$183,750
1-2	176	308,000
2-3	293	512,750
3-4	231	404,250
4-5	197	344,750
5-6	172	301,000
6-7	172	301,000
7-8	132	231,000
8-9	132	231,000
9-10	132	231,000
10-11	132	231,000
11-12	132	231,000
12-13	109	190,750
13-14	109	190,750
14-15	109	190,750
15-16	109	190,750
16-17	109	190,750
17-18	109	190,750
19-46	55	96,250
Construction Total		$7,350,000

The brine diffuser pipeline construction would cross the Intracoastal Waterway and 5.8 miles of the Gulf and would result in short-term disruption to its use. Shipping and other boat traffic would experience minor adverse effects should some areas be temporarily unavailable for their normal use.

Alternative project facilities, particularly development of a ground water supply system, a brine injection field, or a marine terminal, could significantly worsen traffic congestion problems because of large numbers of additional workers and movement of materials.

Population and Housing

Construction of the SPR facilities at Bryan Mound is unlikely to have a significant impact on the population in the local area. Many workers are expected to come from the Houston and Galveston-Texas City areas, which are within commuting distance of the project site. The major construction effort would be of relatively short duration, making relocation of entire families less likely. Those workers who do relocate near the project area would cause little incremental stress on the community, in comparison to existing stresses from rapid population growth.

Simultaneous construction of SEADOCK would potentially bring large numbers of temporary employees to the Freeport area. As housing is generally not available, the likely result would be that most would commute from Houston, Galveston or Texas City. However, contractors may set up temporary mobile home communities near Freeport.

No significant impact on housing or population is expected to occur should any of the alternative facilities be developed.

Economy

A large number of industries that provide goods and services for the petrochemical and chemical industries are established in the Freeport area. They appear to be capable of supplying the SPR program with most materials required to construct facilities. It is expected that local contractors, supplemented by contractors in the nearby Houston labor market, would be capable of supplying the required labor. It is anticipated that few, if any, new businesses would be established as a result of the project. The major beneficial impacts of the project would be employment and income brought to the Brazosport area.

Employment levels would vary significantly over the life of the project as shown in Table C.3-5. Brazosport currently has a low level of unemployment relative to surrounding areas, thus many of the construction workers are expected to come from the Galveston-Texas City and Houston areas. These cities have a large pool of workers skilled in the petroleum and construction industries and are within a reasonable commuting distance of the project locale.

Local availability of labor required for project construction would depend upon the level of other major industrial construction activity at the time (e.g., SEADOCK). If project construction occurs at a time when demand for manpower is high, it may be necessary to hire more contractors and workers from a greater distance. Should this induce in-migration the impact on population and public services in Brazosport could increase.

Development of the Bryan Mound site could increase local income through employment of labor and purchases of goods and services. It is impossible at this time to determine the proportion of the purchases and employment that would occur in any portion of the areas. Local petrochemical fabricating, repair, and maintenance industries would derive income by supplying materials and services to the project.

Total income resulting from construction employment has been estimated using the projected employment for each month at an average income figure of $1750 per month for each worker. The resulting income, shown on Table C.3-5, would be highest in the second through fourth months of construction and would total approximately $7.35 million over a four-year period. These expenditures for labor would have a multiplier effect on the local and regional economy, in which direct income accruing to households would be spent in other sectors of the economy. Some of these expenditures would, in turn, be realized as direct income to other households. In, Texas, the relationship of direct income from the industrial construction sector to all other sectors of the economy has been estimated to be a ratio of 2.51 (Office of the Governor). This relationship expresses the direct, indirect, and induced income paid to households per dollar direct income paid to the industrial construction sector, or more simply stated, for every dollar spent to construct the SPR facilities, $2.51 would be generated as income within the region. Thus, the $7.35 million of direct income from the four-year construction period would result in $18.45 million in direct, indirect, and induced income to households in the region. The geographic distribution of this income would be determined by the workers' places of residence and the location of retail facilities. Income received by Brazosport and Brazoria County workers would tend to be spent in the project area.

Development of the alternative facilities would have some effect on the project impact on the local economy, depending on the labor and materials required. Development of ground water supply or injection fields, construction of a 12.5 mile offshore diffuser pipeline and construction of an offshore terminal would have the greatest impact.

Government

Construction of the SPR facilities or alternatives, at Bryan Mound is expected to have a minimal effect on public services provided by the community. Security forces supplied by the project would coordinate with local law enforcement officials to protect personnel, equipment, and supplies. The project would have some fire-fighting equipment onsite, thereby reducing reliance on local fire protection services.

The area provides an adequate level of health services for the existing populace, and is not expected to be significantly affected by construction activities. Similarly, the impact on local schools is expected to be minimal, as few workers would relocate to the area. There is sufficient excess capacity in some nearby schools, due to stable or declining enrollments, to accommodate those workers who do relocate.

Construction of the Bryan Mound facility would involve the removal of 240 additional acres from the tax rolls of Brazoria County. The tax rate in the County is $1.44 per hundred dollars applied to 20 percent of the fair market value of the property. (Brazoria County Tax Office). This rate does not include special district taxes, such as school or water district taxes, which may be applied to the rate. Assuming a fair market valuation of $1000 per acre at the Bryan Mound site, the tax loss to the County from the removal of the property from the tax rolls would be $690 per year for the life of the project (assuming no increase in valuation). Sales taxes of four percent are applied against retail purchases. If 50 percent of the total income described above were spent on such taxable purchases, the revenue realized would be over $350,000 during the construction phase.

C.3.2 Impacts from Operation and Standby Storage

Should an oil supply interruption occur while oil is stored at Bryan Mound, a total of 163 MMB would be available for distribution, either by tanker or by the SEAWAY Pipeline. Oil would be pumped from both the early and expanded SPR storage caverns, using virtually the same facilities and operating procedures, oil would also be injected into the storage cavities via the same facilities. Unitl an oil supply interruption occurs these facilities would be maintained in readiness by monitoring storage cavity systems, checking pipelines for leaks, activating valves, and other standard procedures.

Thus, the SPR expansion at Bryan Mound would not introduce any new or unique operational impacts but would require extended use of systems to accommodate a capacity increased from 63 MMB to 163 MMB (159 percent increase). Principal impacts are associated with hydrocarbon emissions and oil or brine spills. Both the impacts expected to accompany early storage facility operation and expanded SPR facility operation are given, where appropriate, to provide a perspective on the significance of site expansion impacts.

C.3.2.1 Land Features and Geologic Impacts

Effects of operation and standby of the Bryan Mound storage site on land features are expected to be minimal. No significant disturbance of stie soils is expected after construction is completed. Soils will stabilize soon after they are revegetated.

Bryan Mound is located in an area identified as Seismic Zone 0, that is with no reasonable expectancy of earthquake damage (Figure B.2-7).

It is conceivable, though extremely unlikely, that the salt roof over one of the caverns could collapse. Appendix F considers the possible mechanism by which such an event could occur. A possible result would be formation of a deep surface depression, probably resulting in a lake over the dome. Should such an event take place, significant quantities of oil or brine could be released to the surface or to shallow ground water aquifers. Impacts on surface storage equipment, including oil surge tank, would be potentially disastrous. The entire concept of underground oil storage is dependent on monitoring the structural integrity of the storage cavities and every measure would be taken to preserve this integrity (Appendix F).

Alternatives

Use of alternative raw water, brine, or oil transportation systems would have no impact on land features during project operation and standby storage.

C.3.2.2 Water Resources

Impacts to water resources during facility operation may occur as a result of raw water withdrawal for oil displacement, brine disposal during oil filling, maintenance dredging at the dock sites, and possible oil or brine spills.

Raw Water Withdrawal

Water for displacing oil from the storage caverns during an oil supply interruption would be taken from the same location on the Brazos River Diversion Channel as for cavern leaching. The water withdrawal rate (including early storage capacity) would be 1,000,000 B/D (65 cfs). This is a 87 percent greater rate than during leaching but is still less than 1 percent of the normal daily discharge of the Brazos. Even during low flow in the river, withdrawal should not induce any measurable increase in saltwater flow up the river.

Therefore it is concluded that water quality and quantity in the Brazos River should not be measurably affected by raw water withdrawal during the oil withdrawal cycle.

Brine Disposal

When oil is pumped into the storage caverns, brine would be displaced intermittently to the Gulf of Mexico through the diffuser at an average rate of 240,000 B/D. During operations, brine would temporarily be stored in on-site brine pits, and discharged intermittently through the brine diffuser. This would insure design exit velocities were adequate for mixing of the brine with the Gulf water. Maximum oil concentrations at the diffuser are expected to be less than 15 ppm and to average 6 ppm over the life of the project, based on the theoretical oil in brine analysis and the experience of operation of a similar facility in France (see Appendix D)

Disposal would occur for a 2 year period during each cavern fill operation (163 MMB).

DOE is currently developing a monitoring plan to be implemented during disposal which will be designed to verify the MIT transient plume dispersion model, and to detect impacts to biologic populations and degradation of water and sediment quality attributable to the brine discharge. Predisposal laboratory and field studies are currently under way to investigate brine tolerance of selected sensitive species and to characterize existing sediments, biologic populations, water quality, and coastal dynamics in the immediate area of the proposed diffuser site. An initial report on the results of the predisposal studies is presented in Appendix G, and is summarized in Section C.3.1.2.

Disposal of brine into deep salt water bearing sands through the 5-well backup system northeast of the dome would offer less potential for adverse impact than that described for leaching, because disposal rates or quantities would likely be significantly lower. These wells would be used when the brine diffuser system is not in operation.

Maintenance Dredging

The water quality impact to Freeport and Brazos Harbors due to dredging during construction of the docks is described in Section C.3.1.2. Similar impacts from increased turbidity and release of pollutants trapped within the bottom sediments may occur during maintenance dredging, but to smaller scale than during construction. In comparison with the present maintenance dredging currently required in the Freeport Harbor of over 1 million cubic yards every two years, the incremental impact of maintenance dredging at the FEA facilities is insignificant.

Oil Spills

During project operation, oil spills could occur in the Gulf of Mexico, in the Old Brazos River, from pipelines connecting the storage site with the tanker docks, and from the well heads and oil surge tanks at Bryan Mound (Releases from the underground storage caverns are not quantified, see Appendix E). A thorough description of possible modes of spills, methodologies of spill calculations, quantification of expected spill volumes and frequencies, spill dispersion characteristics, and spill prevention and control measures is provided in Appendix E. A summary of oil spill expectations is also given in Section C.2 and in Tables C.2-1, C.2-2, and C.2-3. Possible effects of oil spills on water resources are considered in this section.

In the watershed east of the Brazos River Diversion Channel, oil spills from the Bryan Mound site and connecting pipelines between the SEAWAY Tank Farm and the docks on Bryan Mound would tend to enter a low area of swampy land and shallow lakes (Figure A.3-1). The area is bounded to the south by a storm levee, and to the west by the Brazos River levee. Drainage from the area would most likely enter the Old Brazos River Channel. Oil spills from transfer at the docks would also enter this waterway. The flushing of this channel is by sluggish tidal action which would not aid actual cleaning processes but would be well suited for containment of the floating oil by booms.

Flow of any spilled oil from the south face of the Bryan Mound site should generally be contained by dikes and berms. Any minor flows which were not contained by the diking would generally be contained between the storm wave levee and the irregular ridge of spoils alongside the ICW. It is possible that some spilled oil could enter the ICW near the confluence with the Brazos Diversion Channel and spread into the Gulf, but this is unlikely for the size spills projected as reasonable for the storage site.

Drainage from accidental pipeline ruptures near the SEAWAY Tank Farms would enter into the Jones Creek and Brazos River watersheds. The Tank Farm itself is expected to be well diked, both with respect to release of spilled oil and against storm and river flood.

Oil spills as a result of a direct release from oil tankers would reach the Gulf of Mexico.

Quantities of oil expected to be released from the early storage and SPR expansion facilities at Bryan Mound are listed by source and location in Tables C.2-1 and C.2-2. Total oil spillage for five fill/withdrawal cycles is projected to be 1930 barrels for the early storage facility and an additional 2609 barrels for the SPR expansion facilties. Of the total, 76 percent is projected to occur during fill operations, 24 percent during withdrawal, and less than 1 percent (33 barrels) during standby storage. The distribution of spills is projected to be 2526 barrels (56 percent) in the Gulf of Mexico (principally at the VLCC tanker transfer location), 1350 barrels (30 percent) at the tanker docks, 633 barrels (14 percent) at the Bryan Mound and SEAWAY Terminals, and less than 40 barrels from the connecting pipelines. The maximum credible spill events are estimated to be 60,000 barrels resulting from a tanker collision, 10,000 barrels from a pipeline rupture, 5000 barrels from storage terminals and 500 barrels from transfer operations.

An "average" crude oil has 30 percent paraffin hydrocarbons (alkanes), 50 percent napthene hydrocarbons (cycloalkanes), 15 percent aromatic hydrocarbons, and 5 percent nitrogen, sulfur, and oxygencontaining compounds. As soon as oil is released to the water environment, weathering begins. The major weathering processes are evaporation, dissolution, emulsification, sedimentation, biological degradation, and chemical oxidation.

Low molecular-weight hydrocarbons and aromatics are the most immediately toxic components of crude oil. Evaporation results in selective loss of low molecularweight hydrocarbons and aromatics, thus tending to reduce concentrations of the most toxic portions of the crude oil. Also, evaporation causes a surface residue, which has a higher concentration of sulfur and organics and may develop a specific gravity greater than water, especially if salt, clay, or organic particles are suspended in the water and available for attachment. As a result, this portion of crude oil will sink and may physically and chemically affect bottom organisms.

Dissolution in the water column is selective for low molecular-weight hydrocarbons and aromatics as well as some of the nonhydrocarbon components that are more polar. Most of the soluble materials go into solution in a relatively short time, but additional soluble material is produced later from biological and chemical oxidation. The solubility of the normal alkanes ranges from 40 ppm for C_6 molecules to 0.01 ppm for C_{12} molecules. For aromatics, solubility ranges from 1800 ppm for C_6 (benzene) to 0.075 ppm for C_{14} (amtracene). The proportion of various fractions of crude oil likely to go into solution in sea water are presented in Appendix D.

Emulsions, which are crude oil globules in water columns, are dispersed easily by currents and eventually dissolve or sink to the sediments after contact with suspended solids.

Sedimentation of oil is enhanced by evaporation and dissolution of the lighter weight fractions and by contact with suspended sediments and organic material. Close to shore, contact with suspended solids is likely during periods of high runoff or stormy weather, which disturbs bottom sediments. Sedimentation also can occur as a result of bacterial masses in the oil slick.

Bacterial degradation can occur in almost all crude oil fractions. But normal alkanes are attacked preferentially, and aromatics are least preferred. A supply of nitrogen, phosphorus, and oxygen is needed. In areas where oxygen concentrations are low, biodegradation is a slow, longterm process.

Oil spilled on the water surface would initially spread under gravitational, viscosity, and surfacetension forces. The rate of spreading because of these forces would be a function of the initial chemical characteristics of the oil and the physical characteristics of the slick, e.g., viscosity, specific gravity, slick thickness, and so forth. The rate would also vary with time as weathering or degradative processes act on the spilled oil. In addition, surface currents and surface winds would transport the slick away from its point of origin.

A spill occurring near shore may find its way into local circulation patterns, contact the shoreline in a short period of time and be carried over large areas of beach or marshland on a rising tide; containment and cleanup would be difficult under such conditions.

The relatively confined location of possible spill sites creates a fairly narrow range of oil spill situations, many of which may be mitigated by oil spill response efforts.

Two potentially significant impacts of oil spills on water resources would be the potential for buildup of toxic fractions and depletion of oxygen levels in shallow, poorly flushed water bodies. The location of such impacts would be in coastal bays and marshes southwest of Freeport (including the vicinity of San Bernard National Wildlife Refuge) and, to a lesser extent, in Mud Lake or Unnamed Lake on Bryan Mound. Because of the 25mile distance from the VLCC transfer point to shore, the diking around tanks at the site, and the very unlikely occurrence of expected pipeline spills, such impacts are not expected.

Oil spills reaching the Brazos River, Freeport or Brazos Harbors, the ICW, or the open Gulf should not have significant impacts on water quality because of the potential for dilution and for oil recovery. Oil which sinks to the bottom or is deposited on the shoreline may provide a local source of petroleum hydrocarbons to the water column for several weeks or even months.

There should be no impact on domestic or other potable surface water supplies as waters in the vicinity of project operations are too saline for consumption.

The top of the ground water aquifer is at an elevation of about 40 feet below sea level at the site with a steep gradient toward the Brazosport area. However, data present by Sandeen and Wesselman (1973) indicate that there is little or no recharge to the upper unit of the Chicot aquifer from the Brazos River Diversion Channel. This suggests that the near surface materials are relatively impermeable and would tend to prevent oil from surface spills from reaching potable water supplies.

Should a subsurface spill occur, either from a defective well casing or collapse of a storage cavity, then oil would tend to collect at the water table and migrate laterally along the water surface. Crude oil migrates very slowly through subsurface formations, and then only under pressure. However, some components of the oil, particularly the lighter aromatic hydrocarbons might be sufficiently soluble to impart an objectionable taste and odor to the water. This taste and odor could potentially reach users in the Brazosport area due to the steep hydraulic gradient in that direction.

Thus, although the potential exists for a very large crude oil spill, calculations of spill probability and the nature of local water bodies, indicates that significant impacts on local water resources should not occur.

Brine Spills

During project operation, brine spills could occur from the brine disposal pipeline and from the brine reservoir; saline water could be spilled from the raw water supply line and from the brine disposal line (during standby storage). A thorough description of possible mode of spills, methodologies of spill calculations, quantification of expected spill volumes and frequencies, spill dispersion characteristics, and spill prevention and control measures is provided in Appendix E. A summary of brine spill expectations is also given in Section C.2 and in Table C.2-3. Possible effects on water resources are considered in this section.

Quantities of brine expected to be released from the early storage and SPR expansion facilities at Bryan Mound are listed by source and location in Table C.2-3. Brine and raw water spills are expected to occur only from the piping system. Total spillage is estimated to be 75 barrels of brine and 115 barrels of saltwater from early storage operation, and 163 barrels of brine and 5 barrels of saltwater from SPR expansion facilities. Of the total, 198 barrels of brine and 78 barrels of saltwater would spill into the Gulf of Mexico, 40 barrels of brine and 43 barrels of saltwater would spill onto coastal prairie and marshland inshore of Bryan Beach (Table C.2-3). The maximum credible spill event is estimated to be 30,000 barrels; excluding possible release of up to 100,000 barrels of brine due to hurricane breaching of the storm levee and brine reservoir.

Spills of brine or saline water have less potential for adverse effects on water quality at the Bryan Mound site than do oil spills. Except for a very large brine spill, normal flushing of local water bodies (e.g., the ICW, Brazos Diversion Channel, Brazos and Freeport Harbors, Gulf of Mexico) would quickly dilute salt concentrations to normal levels, resulting in very temporary water quality degradation. Flushing is not as effective in Mud Lake, Unnamed Lake and other water bodies at Bryan Mound, however; salinity excesses would continue for several days or weeks.

Thus, although the potential exists for a very large brine spill, calculations of spill probability and the nature of local water bodies indicate that significant impacts on local water resources should not occur.

Hazards Due to Flooding

Surface facilities at Bryan Mound would be subject to potential flooding caused by hurricanes or tropical storms. Surface elevations over the dome vary from 5 to 16 feet, MSL. Elevations in the marsh adjacent to the dome are less than +5 feet MSL and at the proposed dock sites are about +4 feet MSL. A storm levee has been constructed across the southern edge of the dome to a height of +17 feet MSL. Levees are also built along the Brazos River Diversion Channel and the Old Brazos River to heights of about +19 feet MSL. Data supplied by the U.S. Army Corps of Engineers indicates that the 100 year flood level at Bryan Mound is +12 feet MSL, excluding the effects of wave runup.

Most planned SPR facilities at Bryan Mound would be located behind the protective storm levee (Figure A.3-1), including the brine pond, pump station, control house, most well pads, and most surface piping. Up to 6 well pads would be seaward of the levee.

Storm floods greater than the 100 year event could occur and could damage surface facilities. If surface piping is ruptured, a few barrels of oil could escape but would be retained within the storage area. Damage to well head piping could result in loss of few barrels from the cavern. Brine from the settling pond would be quickly diluted by sea water.

As only limited quantities of oil could be releasea in the event of a damaging storm flood, environmental effects due to the flood waters and winds are expected to be much greater than due to loss of oil or brine.

<u>Alternative Facilities</u>

Use of water supplied from the Dow Reservoirs would have no environmental impact. Withdrawal of up to 1,000,000 B/D from ground waters would further lower the water table and probably result in additional subsidence each time oil must be withdrawn from storage (see Section C.3.1.2).

Disposal of brine to Dow Chemical Company would result in approximately the same exposure to pipeline spills as disposal to the Gulf; no other adverse impacts on water resources are expected. Deep well injection of brine during oil fill would occur at rates one fourth those required during leaching; consequently, the potential for aquifer fracturing or migration of oil and gas resources would be much lower. Disposal of the brine through a diffuser 12.5 miles offshore would have operational impacts similar to the proposed system.

Use of Phillips or SEAWAY Docks would not affect expected oil spill volumes. However, use of an offshore monobouy terminal would reduce expected oil spill volumes by more than 50 percent and would particularly limit the volume of oil spilled nearshore and in the harbors.

C.3.2.3 Air Quality

Strategic petroleum reserves are planned to minimize the effects of oil supply interruption. For worst case analysis, it has been assumed that five fill/withdrawal cycles would occur over the life of the project. However, it is unlikely that multiple cycles would occur and, therefore, the intermittent and infrequent withdrawal would result in substantially less air quality impact than as presented in the following sections. Variations in the oil movement assumptions with regards to terminal usage would result in changes in the emissions totals that would be within the accuracy of the emission factors used.

The largest potential effects on air quality associated with the operation of the SPR system would result from hydrocarbon emissions during fill and withdrawal cycles. Data presented in Section B.2.3.1 indicate that non-methane hydrocarbon concentrations in the area frequently exceed the national and state standard of 160 $\mu g/m^3$ (3-hour average, 6-9 a.m.). Hydrogen sulfide emissions are expected to be minimal, since most of the crude oil that would be stored in the SPR caverns would have weathered sufficiently during overseas transit to essentially eliminate the H_2S component.

Both average and maximum hydrocarbon emission rates (except for minor sources) are presented in this section. During withdrawal operations, the crude oil is assumed to have an elevated temperature of 120^oF. Elevated crude oil temperatures are expected to result from long-term storage in salt domes at temperatures of up to 150^oF. Appendix J describes how the crude oil temperature will change as it moves to the storage tanks. Average emissions are used to determine the total emissions expected over the assumed 22-year period of operation, while maximum emissions are used to evaluate the worst case impact upon air quality.

Sources of Emissions

For the Bryan Mound storage site, the quality of air during operation would be affected by the following pollution sources:

- Fugitive Dust
- Valves, Seals, and Gauges
- Crude Oil Storage Tanks
- Tankers and Tanker Operations
- Brine Ponds

Most fugitive dust emissions during facility operation would be due to general service vehicle travel over unpaved roads. Assuming an average vehicle speed of 40 miles per hour and a road surface silt content of 30 percent, the estimated dust emission is 0.24 pounds per mile of unpaved road traveled (U.S. EPA, 1976).

There would be a wide variety of valves, seals, and gauges associated with the pumping of crude oil through the pipelines between the dock facility and the storage cavities at Bryan Mound where some small leakage would occur. Data presented in Section 3.3.2 of FES 76/77-6 concluded that only about 20 pounds/day (.106 grams per second) of hydrocarbons would enter the atmosphere. This rate is not expected to change significantly for the expansion to 163 MMB.

Standing storage tank vapor losses may be estimated using the empirical equation developed in API publication 2517 (API, 1962) and recently revised for the U.S. EPA (August, 1976). However, recent studies performed by Chicago Bridge & Iron (CBI, 1976) indicate that the API methodology overestimates standing storage losses for crude oil by approximately 90 percent for modern tanks that have double seals installed. Since the CBI tests may not be applicable to all modern tanks and since other minor losses may occur (such as vapor losses due to clinage of the oil to the tank side as oil is withdrawn from the tanks), actual losses may be 75 to 80 percent less than the standing storage losses, predicted by API 2517 methodology. Conservatively, 75 percent reduction was assumed in this report. It was assumed that four 200,000-barrel capacity modern double-seal tanks would be located at Bryan Mound. These tanks were assumed to be 32 feet high and 212 feet in diameter. Estimated hydrocarbon losses over an assumed 22-year period of operation (1979-2000) is 574 tons based on average crude oil properties (Reid vapor pressure of 4 psia and molecular weight of 70 for fugitive losses). This tonnage is included in Table C.3-6 under the early storage phase for Bryan Mound (i.e., these emissions would occur with or without expansion to 163 MMB at Bryan Mound). The average annual emission rate would be approximately 23 tons/year during years when standby or fill occur but would increase to 36 tons/year if withdrawal occurs during a given year (due to elevated crude oil temperature).

TABLE C.3-6 Estimated hydrocarbon emissions[a] (tons) during life of the project.

Location	Fills (5)	Withdrawals (5)	Brine Pond	100 MMB Expansion Total	Early Storage Total[b]
25 miles offshore (Transfer to 45 MDWT tankers)	7,560	0	0	7,560	(4,763)
Gulf of Mexico (Tanker transit)	245	140	0	385	(242)
SEAWAY and Brazos Harbor (Load and offload 45 MDWT tankers)	4,410	3,067	0	7,477	(4,760)
Storage Site	0	0	251	251	(732)[b]
Total	12,215	3,207	251	15,673	(10,497)

Note: The emissions presented in this table are for 163 MMB expansion at any site; the early storage emissions at Bryan Mound are given in brackets for comparison.

[a] Average conditions assuming Reid vapor pressure of 4 psia.

[b] Includes 574 tons due to storage tank emissions and 158 tons due to brine pond emissions. All storage tank emissions were attributed to Early Storage operation.

Estimated hydrocarbon emissions resulting from tanker loading and unloading operations including transit to and from the DOE docks are presented in Table C.3-6. These data represent the total emissions expected over an assumed 22-year period of operation (5 fills and 5 withdrawals) based on average crude oil properties (Reid vapor pressure of 4 psia and a density of 4.5 lbs/gal for fugitive losses). The minimal losses from ship's boilers have been neglected in these estimates.

Tanker and barge hydrocarbon emissions in Table C.3-6 are based upon the following activities: 1) transfer of oil from the very large crude carriers (VLCC) to 45 MDWT tankers 40 km (25 miles) offshore (emission factor of 0.72 lb/1000 gal); 2) "breathing" losses in transit by tankers (emission factor of 0.0067 lb/hr/1000 gal during fill and 0.01674 lb/hr/1000 gal during withdrawal; 3) offloading 45 MDWT tankers at the DOE docks (emission factor of 0.42 lb/1000 gal); and 4) loading 45 MDWT tankers at the DOE docks (emission factor of 0.73 lb/1000 gal). Derivation of the emission factors given above is provided in Appendix I, Part II.

During each fill cycle, delivery to Bryan Mound would be 163 million barrels (MMB) in 1086 days or an average of 150,000 barrels per day (B/D). Over each 163-day withdrawal period, the total withdrawal rate would be 1 MMB per day. However, 60 percent of this amount or 600,000 B/D are scheduled for delivery to the SEAWAY Tank Farm for pipeline transport to the north; no tanker losses would occur. Emissions from the remaining 400,000 B/D are calculated for tanker loading and transit to the 12-mile territorial limit.

It should be noted that only 100 MMB of the 163 MMB total crude oil storage capacity at Bryan Mound are related to SPR expansion. The remaining 63 MMB are part of the early storage program described in FES 76/77-6. Therefore, the total emissions from the Bryan Mound expansion given in Table C.3-6 (15,673 tons) represent only 60 percent of the total emissions expected. The 40 percent related to the early storage phase of the SPR program are given in brackets in Table C.3-6.

Emissions are substantially larger for oil fill than for withdrawal. Two factors are responsible; first, the substantial emissions accompanying VLCC-tanker transfer operations are only expected to occur during fill; second, delivery of 600,000 B/D to the SEAWAY Pipeline substantially reduces emissions due to tanker loading and transit. These factors more than offset the increased emissions due to elevated crude oil temperature during withdrawal.

Another source of hydrocarbon (HC) emissions would be the dissolved oil present in the brine removed during each fill and passed through the brine pond. Assuming a dissolved oil content of 10 parts per million (ppm), an average weight of 250 pounds per barrel (basically light ends) and that 50 percent remains dissolved in the brine, a maximum emission rate of 219 pounds per day could occur. Using this rate, the total emissions for four refills are presented in Table C.3-6. Only 251 tons of the brine pond emissions are due to the Bryan Mound expansion. An additional 158 tons would be emitted due to the early storage oil.

In section B.2.3.3, the 1970 hydrocarbon emission total in Brazoria County was estimated to be 150,690 tons. During withdrawal operations for the Bryan Mound salt dome (SPR expansion + early storage capacity) assuming complete withdrawal occurs during the year, annual HC emissions are estimated to be 1036 tons per year, or an increase of only 0.7 percent in Brazoria County. During fill operations, annual HC emissions are estimated to average only 679 tons per year, an increase of 0.5 percent in Brazoria County.

Because the national ambient air quality standard (guideline) for non-methane hydrocarbons (NMHC) is a 3-hour value (160 $\mu g/m^3$, 6-9 a.m.), worst case emissions were calculated for an evaluation of the impacts on air quality.

Worst case hydrocarbon emissions due to oil transfer were calculated assuming maximum transfer rates and emission factors based on conservative Reid vapor pressure of 5 psia (See Appendix I). During fill, the maximum emission rate is 6258 pounds per hour (P/H) assuming VLCC transfer to two 45 MDWT tankers in the gulf simultaneously at a rate of 100,000 barrels per hour (B/H) (emission factor of 1.49 lb/1000 gal). During withdrawal, the maximum emission rate is 2434 P/H assuming two 45 MDWT tankers simultaneously at the DOE docks at a rate of 30,000 B/H (emission factor of 1.05 lb/1000 gal).

Maximum transit emissions were not calculated since they are non-point sources and occur over a large area. Worst case standing storage tank emission rates were calculated using the previously described methodology and tank characteristics, but using a conservative Reid vapor pressure of 5 psia and a crude oil temperature of 120^{o}F.

Impacts on Air Quality

The environmental impact of the computed emissions is dependent on the ambient air quality and the dispersal characteristics of the atmosphere (see Section B.2.3). Downwind centerline groundlevel hydrocarbon (HC) concentrations were calculated using the model described in Appendix I, Part I. Estimates were made using maximum emission rates and atmospheric conditions corresponding to worst case conditions ("D" stability and a wind speed of 1.5 meters per second (mps) except 2 mps in the Gulf). These estimates apply to both the SPR exapnsion and the early storage phase. Expansion to 163 MMB, in most cases, increases the likely frequency and duration of obtaining these emissions rates.

Fugitive dust raised by general service vehicles over unpaved roads would cause less impact than during the construction phase where it was estimated to be small (Section C.3.1.3).

The minimal HC losses from crude oil pipelines (valves, seals and gauges) are assumed to be continuous during the project lifetime since the pipelines would be kept filled and pressurized at all times. Since this leakage occurs over a large area and would be tightly controlled, it would cause little impact on ambient air quality.

HC concentrations from storage tank emissions are based on the assumption that four 200,000 barrel tanks would be in use at all times as a part of the early storage program. Since these emissions occur over an area of approximately 30,000 square meters, an area source correction was made as described in Appendix I, Part I. The release was assumed to be elevated (32 feet) with no plume rise. "Worst case" hydrocarbon concentrations, corrected to a 3-hour average (Turner, 1969), at 2, 5, and 10 kilometers (km) downwind are as follows:

Location	Maximum Emission Rate (g/s)	HC Concentrations ($\mu g/m^3$) 2 km	5 km	10 km
Bryan Mound	2.08	24	7	3

These values are all well below the 3-hour standard of 160 $\mu g/m^3$. However, since the 3-hour HC standard is often exceeded in the Brazosport area, emissions from the storage tanks may cause infrequent additional exceedances.

Although vapor emissions from ship loading and unloading activities are not regulated, downwind hydrocarbon concentrations were calculated to provide an indication of the periodically high levels that may occur. Calculations of HC concentrations from maximum tanker operations (VLCC transfer to two tankers in the Gulf at 100,000 B/H during fill and loading two tankers simultaneously at the DOE docks at 30,000 B/H during construction were made using the conservative assumption that the emissions at each location are point source releases at groundlevel. Estimated maximum downwind distances over which the hydrocarbon concentrations would exceed 160 are $\mu g/m^3$ as follows:

Location	Maximum Emission Rate (g/s)	Maximum Downwind Distance (km) 3-Hour Concentration Exceeds 160 $\mu g/m^3$
Gulf of Mexico (40 km offshore)	789	34
DOE Docks	167	13

Although concentrations from peak VLCC transfer operations during fill may exceed 160 $\mu g/m^3$ (3-hour average) to a distance of 34 km (21 miles), values onshore would be less than 160 $\mu g/m^3$. However, under unfavorable conditions, undesirable hydrocarbon concentrations can be expected within about 13 km (8 miles) of the DOE docks during peak withdrawal operations. This distance is conservatively high since the calculation is based on the assumption that the wind direction is parallel (in line) to tanker berths, with no credit taken for tanker separation. In addition, as previously noted, multiple cycles are unlikely to occur and vapor emissions from ship loading and unloading activities are not regulated at this time.

Hydrocarbon concentrations from brine pond emissions are based on an area source model assuming a oneacre brine pond. Estimated "worst case" hydrocarbon concentrations, corrected to a 3hour average (Turner, 1969), at 2, 5, and 10 kilometers (km) downwind are as follows:

Location	Maximum Emission Rate (g/s)	HC Concentrations ($\mu g/m^3$) 2 km	5 km	10 km
Bryan Mound	1.15	16	4	2

Thus, even though the 3-hour HC standard is often exceeded in the area, the low levels expected from the brine pond during each refill cycle would have very little impact on ambient air quality. This would be true even if it is conservatively assumed that 100 percent of the oil dissolved in the brine is evaporated (the basis of the above calculations is 50 percent), essentially doubling emissions and resulting concentrations.

Interaction Among Sources at Bryan Mound

In the preceeding paragraphs, tanker transfer, brine pond, and storage tank HC emissions were considered as if each were a separate source impact. Actually, each would contribute to a cumulative effect on existing background HC concentrations. However, since the relative magnitude of the worst case emission rates from the DOE docks would be much higher than from either brine pond or storage tank emissions, combined downwind concentrations were not calculated. The maximum emissions rates at the SEAWAY Docks were based on two tankers loading simultaneously assuming a point source release, whereas the two tankers may actually be separated by as much as one mile or more. Thus, the maximum 3hour downwind HC concentration from all sources would not be expected to exceed the 3hour standard beyond the distance given for the DOE docks (13 km).

Alternatives

The only alternative facilities which would alter air quality impacts from those described previously are the use of a marine terminal for oil transport and generation of electric power onsite.

Use of a marine terminal for fill and withdrawal of oil at Bryan Mound would substantially reduce hydrocarbon emissions. Referring to Table C.3-6, the following approximate reductions would be achieved: (1) At the VLCC transfer point, the emission factor would be reduced from 0.72 lb/1000 gal to 0.42 lb/1000 gal (for total estimated emissions reduction from 12,323 tons to 7188 tons); (2) essentially complete elimination of tanker transit emissions (reduction of 627 tons); (3) complete elimination of transfer emissions at the docks (reduction of 12,237 tons). Total hydrocarbon emissions due to oil handling and transport during the project lifetime would thus be reduced from 26,170 tons to 8171 tons. Furthermore, the source of most serious hydrocarbon concentrations, oil transfer at Brazos and Freeport Harbors, would be eliminated so that only very infrequent standards exceedance might result due to tank emissions and high background levels.

Onsite power generation, based on a 45,000 HP (approximately 34 MW) capacity and using emission factors given by EPA (1976) for oilfired turbines, emissions rates (g/s) would be as follows:

Hydrocarbons	NO_x	CO	SO_2	Particulates
3.4	41.1	9.3	2.1	3.0

The hydrocarbon emissions would add approximately 2600 tons to the emission inventory shown in Table C.3-6 over an assumed 22year period of operation.

Estimated "worst case" pollutant concentrations at several distances downwind of the power plant are given in Table C.37. It was conservatively assumed that the power plant would vent from a 100-foot stack with no plume rise. Results indicate that all National and State air quality standards would easily be met. However, since the 3-hour HC standard is often exceeded in the Brazosport area, HC emissions from the power plant (especially when combined with tank and brine pond emission) may cause additional infrequent exceedances near Bryan Mound.

C.3.2.4 Noise

Principal sound sources during the operation of the storage facility would be material handling equipment, such as electric motor driven pumps for filling and emptying the storage facility.

TABLE C.3-7 Estimated pollutant concentrations (μg/m^3) downwind of onsite power plant.[a]

Pollutant	National and State Standards: Averaging Period	National and State Standards: Limit (μg/m^3)	Distance (km): 1	Distance (km): 2	Distance (km): 5
Particulates	1 yr.	75	4	2	0
	24 hr.	260	49	20	5
	5 hr.	100	94	39	11
	3 hr.	200	102	43	12
	1 hr.	400	124	52	14
SO_2	1 yr.	80	3	1	0
	24 hr.	365	34	14	4
	30 min.	730	98	41	11
CO	8 hr.	10,000	271	114	30
	1 hr.	40,000	385	162	43
HC	3 hr.	160[b]	116	49	13
NO_2	1 yr.	100	58	24	6

[a] Assumed 100-foot release with no credit for plume rise for combustion turbines using No. 2 fuel oil.

[b] Non-methane hydrocarbons only; concentration estimates are for total hydrocarbons.

Operation sound levels from the facilities described above were estimated from measurements at a liquified propane gas storage plant in New York State with similar material handling and processing equipment. The major difference between the facilities is that the pumps at the New York State facility are located outdoors; compressors and dehydrators are used; and the produce is shipped by truck.

From these measurements, it is estimated that the pumps at Bryan Mound would produce sound levels of 75dB(A) at 50 feet. Typical wall attenuation for a corrugated steel building is 20-25dB. Therefore the equivalent sound level contribution to the ambient sound level from the proposed facility at Bryan Mound is estimated to be 30-35dB at 500 feet. This contribution is negligible compared to existing ambient sound levels of 54dB in undeveloped areas near the site and 61dB at existing industrial sites.

During fill and withdrawal cycles, oil would arrive at the DOE docks in tankers. The noise produced by the tanker's approach will be of short duration, low frequency and low intensity. No noise impact is expected due to this activity.

Alternatives

An alternative power supply to commercial generation is an onsite 45,000 horsepower gas turbine generating station. This would create a source of noise during the storage fill and withdrawal periods. Gas turbines are designed to meet specific noise criteria established by the National Electrical Manufacturer Association (NEMA). It is unlikely that the turbine would produce sound levels greater than 52 dBA at approximately 400 feet. Therefore, the contribution to noise levels offsite would be negligible.

Other alternative facilities would have no significant effect on ambient noise levels at the site or in nearby inhabited areas.

C.3.2.5 Species and Ecosystems

Operational impacts of the proposed SPR facilities on biological resources in the area are principally related to the potential for oil or brine spills. Also, raw water would be withdrawn from the Brazos River Diversion Channel to displace oil from the caverns and brine would be discharged to the Gulf during oil filling, with consequent local effects on aquatic resources. Normal surface activities at the storage site and in the vicinity of the tanker docks would exclude wildlife from the immediate project vicinity but this does not represent a new or significantly adverse impact because of the existing industrial nature of the project area.

Raw Water Withdrawal

Withdrawal of brackish water from the Brazos River Diversion Channel would be required for approximately 163 days during each oil supply interruption. To displace the entire 163 MMB of storage capacity, water would be withdrawn at a rate of 1 MMB per day (42 percent of this rate would be required to displace the 63 MMB early storage oil capacity). This is a 87 percent greater withdrawal rate than is required for cavern leaching. Entrainment of aquatic organisms as described in Section C.3.1.5 would result in their destruction. Because average concentrations are used in calculation of kills, it may be assumed that the percentage of organisms present which would be killed would be equal to the percentage of water withdrawn, which is less than 1 percent of the normal river flow rate and a much lower percent of the normal daily tidal flow. No significant impacts to marine resources are expected to result.

Brine Disposal

The brine disposal rate required during oil fill is discussed in Section C.3.2.2. Discharge would occur for approximately 2.3 years following each oil withdrawal. Impacts should be considerably less than those which occur during construction (Section C.3.2.5).

Additional impacts related to brine disposal during operations may be caused by dissolved oil in the brine being displaced during refill of the cavities. Concentrations of oil in the brine effluent are expected to range from 5 to 10 ppm.

Based on a literature review conducted by LOOP, Inc., (1975), it was concluded that, in general, concentrations of petroleum hydrocarbons below 1 ppm should have very little adverse impact on marine organisms. Continuous concentrations of 5 to 10 ppm may cause heavy mortalities.

Discharge of oil contaminated brine from the diffuser is expected to provide dilution of the effluent by a factor of 50 to 100 almost immediately (from an excess salinity of about 280 ppt to about 3 ppt, Appendix G). Existing water quality for ambient oil and grease levels near the discharge area is high (less than 1 mg/l). Concentrations of hydrocarbons should not be distinguishable from ambient conditions beyond a few hundred feet from the diffuser, even under stagnant current conditions. It is possible that very near the point of discharge, chronic pollution problems could exist and low productivity and a low species diversity of many marine organisms could result. However, the effects should not be significant, even locally, to marine resources.

Tanker Transport

Marine transport operations could affect the marine life in Freeport Harbor, since ship passages may cause increased turbidity and shoreline erosion. Passage of a barge or tanker can re-suspend sediments which require at least 2.5 hours to settle (U.S. Army Corps of Engineers, 1975). High turbidity may clog or abrade gills of fish and macrobenthos, or suffocate mollusks. It can also reduce plankton productivity, thus reducing the amount of food available to filter-feeding fish and mollusks. The State of Texas classifies Freeport Harbor as only suitable for non-contact recreation because the harbor has poor water quality. Light penetration in the water column at the proposed dock area is presently only 1.3 to 4.8 feet, and this may be intermittently reduced by ship passage. Therefore, impacts directly attributable to the tankers connected with the Bryan Mound oil storage operations would be minor in comparison to the total impact from all ship traffic and dredging within the harbor.

Accidental Oil Release

The potential for oil spills during project operation is described in Appendix E; expected annual spill volumes by mode of operation and by geographical location are summarized in Section C.2, particularly Tables C.2-1 and C.2-2. In the event of an oil spill, the expected movement from various spill locations, the weathering processes likely to occur, and the potential for water quality degradation are described in Section C.3.2.2. The section treats some of the biological effects which can occur as a result. The information on frequency and volume of expected oil spills for Bryan Mound is summarized in Section C.3.2.2.

Frequencies of oil spills are also given in the summary tables. Except for transfer spills, all modes of spills are expected to be very infrequent. For example, a single fill of 100 MMB for Bryan Mound site expansion is estimated to result in about 28 oil spills, 23 of which would occur at the VLCC-tanker transfer location. A single withdrawal would result in less than 2 spills, most likely at the tanker loading dock. For very large spills, the following recurrence intervals are given in Appendix E: marine transportation, 11,580 years for spills greater than 10,000 barrels; pipelines, 200 years for spills greater than 1000 barrels for terminals, 153 years for spills greater than 1000 barrels.

Because of the disturbed nature of the Bryan Mound site due to its earlier industrial development, the design safeguards provided in the storage system, and the fact that the area is mostly cleared land, the potential biological impact from small, chronic oil spills at the Bryan Mound storage site is expected to be small. The oil surge tanks at the site would be diked to prevent escape of the oil in the event of a major spill. The wellheads would also be diked to contain minor spills.

Cowell (1970) describes two forms of chronic pollution: 1) pollution that results from small successive spills occurring with a frequency greater than that which would allow complete recovery of the ecosystem; and 2) pollution that results from continuous discharge of low levels of oil and effluents such as those from refinery outfalls. Plant species have been shown to vary considerably in their tolerance to successive spillage, with annuals being the most susceptible and perennials somewhat more tolerant. Seedlings and annuals seldom recover from either acute or chronic oil spillage, but perennials are capable of producing new shoots from unaffected root systems, some within three weeks after contamination (Cowell, 1971). When oiling of vegetation occurs during floral induction, seed germination of marsh species is reduced and flowering is inhibited (Baker, 1971c).

The effects of oil on vegetation depend upon several factors such as species and age of plant; time of year; whether plants are actively growing or dormant, the amount and type of oil involved and the degree of weathering of the oil (Baker, 1970). Physical weathering, total chemical decay, and biological breakdown are important in the degree and rate of degradation, but the relative importance of each factor has not been ascertained. Baker (1971a) concluded that a single oil spill does not cause long-term damage to marsh vegetation but successive spills result in a rapid decline of vegetation (Baker, 1971b). The primary effect of an oil spill on vegetation is that of developing an oil film on the stems and leaves of the plant. The film is difficult to wash off and subsequently the leaves turn yellow. Successive oil spills of any significant magnitude have been shown to be statistically unlikely for the SPR expansion facilities.

Short term exposure of marsh plants to small or intermediate oil spills have been reported to not be exceedingly harmful, but chronic releases are lethal. The active growth process of many plants during the spring season are adversely affected. Annual plants tend to be affected more if they are coated with oil during these active growth periods but perennial plants have been shown to regenerate new stems if their root systems are protected. The influence of oil spills on coastal prairie systems or cleared land is even less well known than the influence of oil on coastal marshes but it may be assumed that factors influencing damage to these systems would be similar to those described for marshland.

Biological degradation of crude oil appears to be an important factor in vegetative recovery after a spill. The rate of degradation is related to the type of oil, temperature, and the makeup of soil microflora. Other soil organisms such as bacteria, fungi, algae, etc., would not be affected uniformly since under conditions of a good oxygen, phosphate, and nitrogen supply these organisms could grow and eventually degradation can take place (Davis, 1976). This degradation is an important factor to the recovery of the vegetation following a spill. The rate of degradation is related to the type of oil spilled, the ambient temperature, and the composition of the soil microfauna.

If a large oil spill occurred along the Bryan Mound pipeline the direct effect upon land mammals could be significant. Although most land mammals are highly mobile and could escape small spills on land, a large spill could cover a wide area in a short time. Animals that cannot escape the oil may be killed by ingestion of contaminated foods and from products contacting the skin, or may suffer chemical burns from being coated (Texas A&M University, 1972). Oil spills on land may also adversely affect large areas of habitat, making it necessary for animals to leave the area. All habitats have a carrying capacity that limits the number of organisms supported without placing any undue stress upon individuals in the area. The introduction of large populations from one area to another can adversely affect the populations already inhabiting the area and death may occur from over-crowding, starvation, predation, and disease. These impacts would be especially severe among terrestrial mammals suited to the marsh habitats since these areas are easily destroyed by oil pollution.

Oil spills can also affect the various species of herpetofauna through direct contact of the oil on the skin; some species of frogs and toads breathe through their skin and oil contact would reduce their rate of respiration, possibly resulting in death. Large oil spills adjacent to marsh areas could spread rapidly across wet areas and could destroy the vegetative cover that serves as habitat for many species of herpetofauna. These spills could also kill many insect species that are aquatic during their reproductive cycles and provide food for other animal species.

Bird life at Bryan Mound could be affected by direct contact with the oil and by loss of food and cover since many species of birds are attracted to the marshland at the site. Data are not available to provide an estimate of the number of birds that may be directly affected, but the losses in the marsh are likely to be severe. The primary factors which would influence the extent of the damage of a major spill on bird life are:

- o The location, size, and duration of the spill
- o The particular species present and their behavior
- o The time of year
- o The reproductive capacity of the species involved.

The primary causes of bird mortality due to oil spills are: destruction of the waterproofing and insulating properties of feathers and the ingestion of the oil when the birds attempt to clean themselves. Oil-fouled birds preen excessively in their attempt to remove the contaminant. Autopsies have shown this preoccupation to be so great as to supercede the need for food; most gastrointestinal tracts of autopsied birds contain little, if any, food. Physiological weakening of the body, coupled with reduced food intake, will eventually result in the death of the bird. Experience has shown that 20 percent or less of the birds directly affected can be expected to survive (Boesch, et al., 1974). Indirect effects may be caused by loss of a food supply when birds eat oilcontaminated food.

Reduction in the insulating capacity of the feathers causes an increase in metabolic rate to maintain the bird's body temperature. Heat loss in an oilfouled bird has been shown to be approximately twice that of a normal bird (Hartung, 1967). Dietary intake must then be doubled to maintained body temperature and this is difficult because energy is expended during the increased foraging activities and because the ingestion of oil has reduced the efficiency of the body's system. Foraging may decrease and actually cease altogether, resulting in starvation. The metabolic rate has been shown to increase linearly with a decrease in the ambient temperature; therefore, the rate of starvation can be accelerated by cold weather (Hartung, 1967).

Although many cattle graze in the Bryan Mound area the effects of oil spills upon livestock are limited. Spills may result in shortterm damage to the vegetation, however.

The impact of an aquatic oil spill becomes particularly farranging in highly turbid aquatic systems, such as the Brazos River, since oil and petrochemicals are quickly absorbed by suspended matter such as clay. These particles may be transported over wide areas by the strong currents and large heavy oily globules may be formed and deposited on the river bottom far from the source. On the bottom, the globules can release water soluble substances which are toxic to aquatic life. Sediments which are covered by oil can become low in oxygen and subsequently may become anaerobic. Under these conditions, oil degradation is very slow and many of the toxic components are the last to be broken down (Murphy, 1971).

Petroleum products have been shown to damage aquatic biota in four principal ways (FWPCA, 1968):

- By direct contact with the organism
- By smearing gills or being swallowed with water and food
- By forming a surface film that may interfere with gaseous exchange or respiration
- By poisoning organisms with various water soluble substances leached from the oil

All components of aquatic ecosystems can be damaged. Phytoplankton and zooplankton, primary food sources in the food web, may be destroyed or coated with oily substances. If these coated plankton are ingested by fish, an oily smell and taste may be imparted to the fish flesh. Fish may also be impaired or killed directly when the epithelial surfaces of their gills become coated with a film, thereby inhibiting respiration. Oil which settles to the bottom may also coat river sediments and destroy benthic organisms and also interfere with spawning activities. The reproductive capacity of benthic organisms may also be impaired (Murphy, 1971).

The biological communities in the dock areas include some of the organisms which would be found in both the marsh and coastal prairie biotopes through which the pipeline to the SEAWAY Tank Farm would be developed. However, many of the species normally found in these biotopes are missing and other species not normally present are common. An oil spill on this poor quality habitat would have a minimal effect on the biotic community (see Section B.2.5) since the endemic species which inhabit these cleared areas are low both in numbers and diversity.

The main groups of aquatic organisms which could be affected by oil spills into water at the dock include plankton, nekton, benthos, macrophytes, periphyton, microbes, and aquatic birds and mammals. Aquatic organisms associated with the water surface, the neuston, would presumably be most subject to the toxic or mechanical (smothering or coating) effects from contact with fresh oil slicks.

Under laboratory conditions, droplets of oil have been noted to adhere to spines of marine phyto and zooplankton, especially after they had come in contact with the surface film (Ministry of Defense, 1973). Plankton, which float with the water currents at relatively slow speeds would be unable to effectively avoid the spill areas. Photosynthetic activity of phytoplankton was accelerated at lower concentrations (1 to 3 mg/l) and diminished at higher ones (6 to 20 mg/l) (Boesch et al., 1974). Eggs and larvae of many benthic organisms such as oysters, shrimp, crabs and demersal fish are major temporary components of the zooplankton. These immature stages are often highly susceptible to toxic materials. Many zooplankton which exhibit a diurnal vertical migration in the water column could also be destroyed by a major oil spill. However, field data do not conclusively demonstrate a measurable effect. There is little evidence for concentration of oil ingested by zooplankton at higher tropic levels in the food web.

Fish usually are able to avoid spilled oil and there is evidence confirming this avoidance (Boesch, et.al., 1974). Large fish kills have generally occurred in only restricted water bodies. These kills are attributable to direct toxic effects of the oil or lowered dissolved oxygen levels in the water, caused by restricted oxygen diffusion from the atmosphere, or the increase of biochemical oxygen demand by the oil particles, or a combination of these factors. Fish appear to be more resistant to the toxicity of oil products than many other aquatic organisms because the mucus coating on their exterior body surface is oil repellant (Boesch, et.al., 1974). Direct toxic effects on fish exposed to oil spilled off the Louisiana coast showed the loss of gill tissue cells or "sloughing," and swollen branchial filaments (U.S. Environmental Protection Agency, 1972). It has been suggested that the toxic effects of aged crude oil may be greater than that of fresh crude oil (Benter, 1976). Fish may be contaminated because of intake of petroleum hydrocarbons during their feeding activities; this tainting may persist for several months (Boesch, et.al., 1974).

Benthic organisms would be affected mainly by oil that sank to the bottom and coated the plants and animals. Reduced oxygen levels in the benthos could be an important factor in this impact. All organisms are not equally successful at recolonizing polluted areas and several years may be required to re-attain pre-impact levels of diversity and community structure. Some bottom organisms accumulate petroleum hydrocarbons in their tissue after ingestion (Boesch et. al., 1974).

Periphyton communities, which tend to be made up of very small organisms, are dependent on substrate and therefore oil would probably have a very great impact on this community. However, since these organisms have very short life cycles they should be able to recolonize suitable surfaces relatively rapidly after the oil is degraded or has been removed.

Effects of oil on bacteria, fungi and yeasts are not well known (Boesch, et.al., 1974); however, bacteria are generally thought to contribute greatly to the degradation of oil in the sea.

In summary, the impacts to biota due to normal operations of the Bryan Mound storage site are not expected to be significant. Even in the case of occasional small oil spills, impacts are not expected to be widespread or serious. However, depending on the specific conditions, including location, season, volume, and spill control effectiveness, a large oil spill may have a serious impact on the biota in the local environment.

The type of exposure to be expected differs in accordance with the mode of transport and handling (see Tables C.2-1 and C.2-2). Tanker and barge casualty spills may be quite large but are relatively infrequent. If a large spill reaches the marshes of the Texas coast, impacts could be severe but the chance of such an event is fairly low (for example 0.25 vessel casualty spills are projected to occur in the Gulf of Mexico during project lifetime from both early storage and SPR expansion operatives). Effects on marsh inhabitants, such as waterfowl and fur bearing animals, in addition to primary productivity, could be severe.

A pipeline spill would likely have the most intensive, localized biological impact. The recurrence interval of an oil spill, even with oil left in the line during standby storage is more than 200 years, however.

The small spills accompanying oil transfer operations constitute the vast majority of all spills expected from the SPR program. With appropriate deployment of booms and other oil recovery equipment, effects should be localized.

Several scenarios may be described to evaluate potential effects of maximum credible spills for various oil spill modes. The bases of selected maximum credible spill sizes are provided in Appendix E. Ecological impacts are quantified on the basis of acres expected to be severely impacted using 25 barrels per acre of fresh crude causing 100 percent loss of vegetation for a period of at least two years in wetlands or coastal prairie. In open water bodies, it has been estimated that, on the basis of a damage threshold of 10 ppm hydrocarbon, a contamination of 6 barrels per acre could cause total loss of productivity in shallow waters (2 to 4 feet deep) for periods of two weeks to several months, depending on water circulation and species affected (Dames & Moore, 1975).

Using the above oil spill damage parameters as indicators, the following impacts may be estimated. For a tanker accident of 60,000 barrels, a possible marsh impact on 1680 acres or a shallow water impact on 7000 acres might result. Avifauna, fur animal and shellfish impacts could be severe in the coastal Texas marshes. Vulnerable areas include the lower San Bernard River and associated lakes, bays and marshes west of Freeport and the Christina, Drum and Bastrop Bays to the east (Figure C.3-2).

For an oil transfer accident of 500 barrels at the tanker docks, possible marsh impacts on 14 acres (highly unlikely) or a shallow water impact on 60 acres might result. Avifauna, fur animal, and shellfish impacts should be small because of the industrial nature of Freeport and Brazos Harbors.

For a pipeline spill of 10,000 barrels, assuming 20 percent lost to evaporation and none recovered, a possible wetland impact of 320 acres or a shallow water impact of 1340 acres might result. The lower Brazos River Diversion Channel and lakes and marshes on Bryan Mound are potentially vulnerable.

In summary, it may be concluded that the very low frequency of oil spills indicates that chronic biological impacts should not be experienced. Very large spills are so improbable as to represent a very small liklihood of adverse impact but the potential for impact is fairly large depending on spill location. Except for the case of a large spill in the gulf being transported to near shore waters and coastal bays prior to recovery, adverse impacts should not be of regional significance.

Accidental Brine Release

The potential for brine or raw water spills during project operation is described in Appendix E; expected annual spill volumes by mode of operation and by geographical location are summarized in Section C.2, particularly Table C.2-3. In the event of an brine or raw water spill, the expected movement from various spill locations and the potential for water quality degradation are described in Section C.3.2.2. The section treats some of the biological effects which can occur as a result.

Brine and raw water spills are expected to occur only from the piping system. Total spillage is estimated to be 75 barrels of brine and 115 barrels of raw water from SPR expansion facilities of the total, 198 barrels of brine and 78 barrels of raw water would spill into the Gulf of Mexico, 40 barrels of brine and 43 barrels of raw water would spill onto coastal prairie and marshland inshore of Bryan Beach (Table C.2-3). The maximum credible spill event is estimated to be 30,000 barrels of brine exculding possible release of up to 100,000 barrels of brine due to hurricane breaching of the storm levee and brine reservoir.

Frequencies of spills are also given in the summary tables. For brine spills, there is a 96.8 percent chance of having no spills during the project lifetime for the SPR expansion, similarly there is a 99.9 percent chance of having no raw water spills.

A 30,000 barrel spill of brine from the disposal pipeline would probably have no serious biological impact unless it occurred from the inshore portion of the pipeline or very near shore. No comparable damage parameters are available to estimate acreage impacts; the effects are mitigated by dilution, circulation, and mixing. Assuming uniform mixing, it would take approximately 130 to 150 acre-feet of 20 ppt water to dilute the brine to 22 ppt, a reasonable threshold for measurable salinity effects. For brackish water of salinity 5 ppt, over 500 acre-feet would be required to dilute 30,000 barrels of brine to 5 ppt. Thus, the potential for adverse impact in Mud Lake, Unnamed Lake, or any other poorly flushed, low salinity lake is great should a maximum credible brine spill occur.

In summary, it may be concluded that the very low frequency of brine spills indicates that chronic biological impacts should not be experienced.

Alternatives

Construction of a ground water supply system, a 12.5 mile offshore brine diffuser to the Gulf or a deep well brine injection system would expose additional portion of brackish marsh to possible brine or raw water spills. Construction of an offshore terminal and pipeline would reduce the total quantity of oil spills expected and would replace exposure to tanker casualties with exposure to pipeline spills. Delivery of water from Dow reservoirs would not impose any significant spill risk as fresh water would be pumped through the pipeline.

C.3.2.6 Natural and Scenic Resources

Operation and standby storage at Bryan Mound would have no significant impact on natural resources or recreation during normal procedures. The potential does exist for oil spills to occur in the process of shipping oil to SPR sites. If an oil spill reached the shoreline, beaches used for recreation such as Bryan or Quintana Beach could be significantly impacted. Beach visitors are estimated at about 3 million per year. Though oil could be fairly rapidly cleared from the beaches, residues deposited on offshore substrate could drift to shore for a period of many months afterwards.

Aesthetics

Operation of the SPR site should have no adverse aesthetic impacts during normal operations. The project would have small amounts of fumes, vibrations, or noise and would be consistent with existing industrial development in the surrounding area. Burial of all pipelines on the site would help minimize visual impacts. Oil spills reaching coastal beaches would have significant adverse aesthetic impact, however.

C.3.2.7 Archaeological, Historical and Cultural Resources

No impacts on archaeological, historical, or cultural resources are expected from operations of the Bryan Mound SPR facility.

C.3.2.8 Socioeconomic Environment

Land Use

The addition of the 100 MMB storage reserve at Bryan Mound would have little additional impact on land use during operation. The land at the site and along pipeline routes to the site would already be dedicated to these uses. The additional 240 acres or total of 390 acres enclosed at the site during construction would be enclosed by a fence and restricted for the life of the project. Of the 425 acres required for construction offsite and within the fenced area, 275 acres would be needed for maintenance of the project. The new DOE docks would be consistent with existing land uses and restrictions, and would require a relatively small land area. The use of the brine diffuser may have a minor adverse impact on the use of the small area in which it is located for fishing.

Transportation

Very little traffic related to the project would be generated during operation. A small crew (estimated at 10 employees during standby operation and 55 during oil fill or withdrawal) would be necessary to carry out fill and storage activities; however, commuting traffic would be insignificant in comparison to current traffic volumes on county roads.

A small increase in tanker traffic would result from the project during filling and withdrawal; however, it is not expected to significantly affect port operations. During oil withdrawal, approximately 1.5 tankers (32,000 DWT) per day for 165 days would constitute the major increase in tanker traffic in Freeport Harbor.

Population and Housing

The operation of the SPR project site would have very little effect on population in the surrounding area. The project would have a total of 55 employees onsite in three shifts during fill and withdrawal operations. During standby operations, only about ten employees would work at the site. Even if all the employees were to migrate to the Brazosport area with their families, the impact on the local population would be negligible. Brazosport has grown rapidly since 1970 and the population associated with this project would constitute only a minor increment compared to this increase.

Project operation would have a minimal impact on housing. Many of the maximum 55 workers employed are expected to come from the Brazosport area and other communities within commuting distance.

Economy

The operation of the Bryan Mound storage site would have an insignificant effect on the basic economy of the area. Supplies for some operations may be purchased from existing petrochemical and service industries.

Operation of the project would require a relatively small work force (see above), and this would cause an insignificant impact on the local labor pool.

Employment income from the project would average $96,000 per month during the filling and withdrawal phase. Most of this income is expected to stay in the Brazosport area for the three years of filling and withdrawal associated with each oil supply interruption. During standby operations, income would average approximately $17,500 a month for the 10 employees. This income alone is not expected to be sufficient to stimulate the local economy. The indirect and induced incomes derived from these activities have not been estimated, but are not expected to be significant.

Purchases of supplies associated with the storage facility during operations could provide, as well, economic stimulus to the extent these purchases are made in the Brazosport area.

Urban Services

The operation phase of the SPR project would have less impact on police and fire services than construction phase, as fewer workers would be required.

No adverse impacts on health services are expected during normal operations.

The small number of workers and their families with children that may permanently relocate in the area would have no significant impact on schools in Brazosport.

Brazoria County would lose some property tax revenue, since this project will remove the site from the tax roles. As discussed in Section C.3.1.8 the annual tax loss would be approximately $690 per year.

Alternative Facilities

The use of alternative facilities to draw water, dispose of brine, or transport oil would not significantly alter the socioeconomic effects of operation described above. Use of an offshore marine terminal would eliminate tanker traffic from the Freeport and Brazos Harbor area, however.

C.3.3 Impact Due to Termination and Abandonment

No specific plan for termination and abandonment of the Bryan Mound oil storage site has been established. To date, no specific experience with the abandonment of an oil storage cavern facility has been developed in the United States. Various feasible plans are available. Environmental hazards that must be considered include surface subsidence and release of residual oils squeezed from the workings by possible long-term plastic closure.

At present, it is intended to put the facility to some beneficial use, rather than abandon it. Beneficial uses might include disposal of wastes, such as dredge spoil, slurried fly ash, radioactive waste, or other polluted or toxic materials. Another possibility is to develop a compressed air storage facility for peak power use. The final selection of an abandonment plan will likely depend on the economic and environmental tradeoffs and regulations that are in effect at the time of termination.

Use of the facility in the manner described above would assure continued surveillance of the cavern. The inherent integrity of the cavern would prevent any leakage of material into the environment. Certain activities associated with the specific use, such as waste transport, would impose some potential for environmental damage resulting from traffic, spillage and noise.

Should no beneficial use be found for the facility, the wells could be sealed and the caverns left filled with brine. No adverse environmental effects are likely to result from such action.

C.3.4 Relationship of the Proposed Action to LandUse Plans, Policies, and Controls

Brazoria County is a member of the Houston/Galveston Area Council of Governments. The Council makes studies and plans to guide unified development of the area, eliminate duplication, and promote economy and efficiency in coordinated area development. The Council makes recommendations to member governments and may, upon request, assist in implementation of those plans. The Brazosport Planning Board is a part of the Brazosport Chamber of Commerce. The Board maintains a master plan for

Brazosport and coordinates planning for the Brazosport area. Current plans are considered highly flexible and appear to be designed to accommodate the needs of expanding industrialization along the Brazoria County Gulf Coast area.

The projected land use plan, as developed for future development in Brazoria County, is shown in Figure C.3-3. It indicates anticipated growth relationships, rather than providing a definitive land-use program for Brazoria County in 1990. The allocation of large areas of land for controlled open space will become increasingly important in the context of both county and regional needs.

Recommended land-use goals for guiding growth within Brazoria County include establishment of a program for the optimum use of resources (natural and human), ensuring orderly economic growth, enhancing and preserving unique regional advantages or assets, providing for quality in the total environment, and compatibility and functional efficiency among the various land use components that comprise the regional community, and ensuring the health and safety of the populace.

In light of the goals, development concepts, and future land use plans, and considering the existing land use patterns, it is not anticipated that any land use policies or plans would be in conflict with the proposed Bryan Mound Strategic Petroleum Reserve facility.

C.3.5 Summary of Adverse and Beneficial Impacts

Land use impacts of expanding this proposed site center on the amount of land required. At the dome, 240 additional acres or a total of 390 acres would be enclosed by a security fence. Within this area, approximately 36 areas would be required for construction of onsite facilities. Construction of systems common to each site would require 185 acres for the offshore brine diffuser pipeline, pipeline connections to Brazos Harbor and the new tanker docks.

Development of the Bryan Mound salt dome as an oil storage facility is not likely to generate significant regional environmental impacts except for the remote possibility of a major oil spill and the uncontrolled release of hydrocarbon vapors during oil transportation. Construction

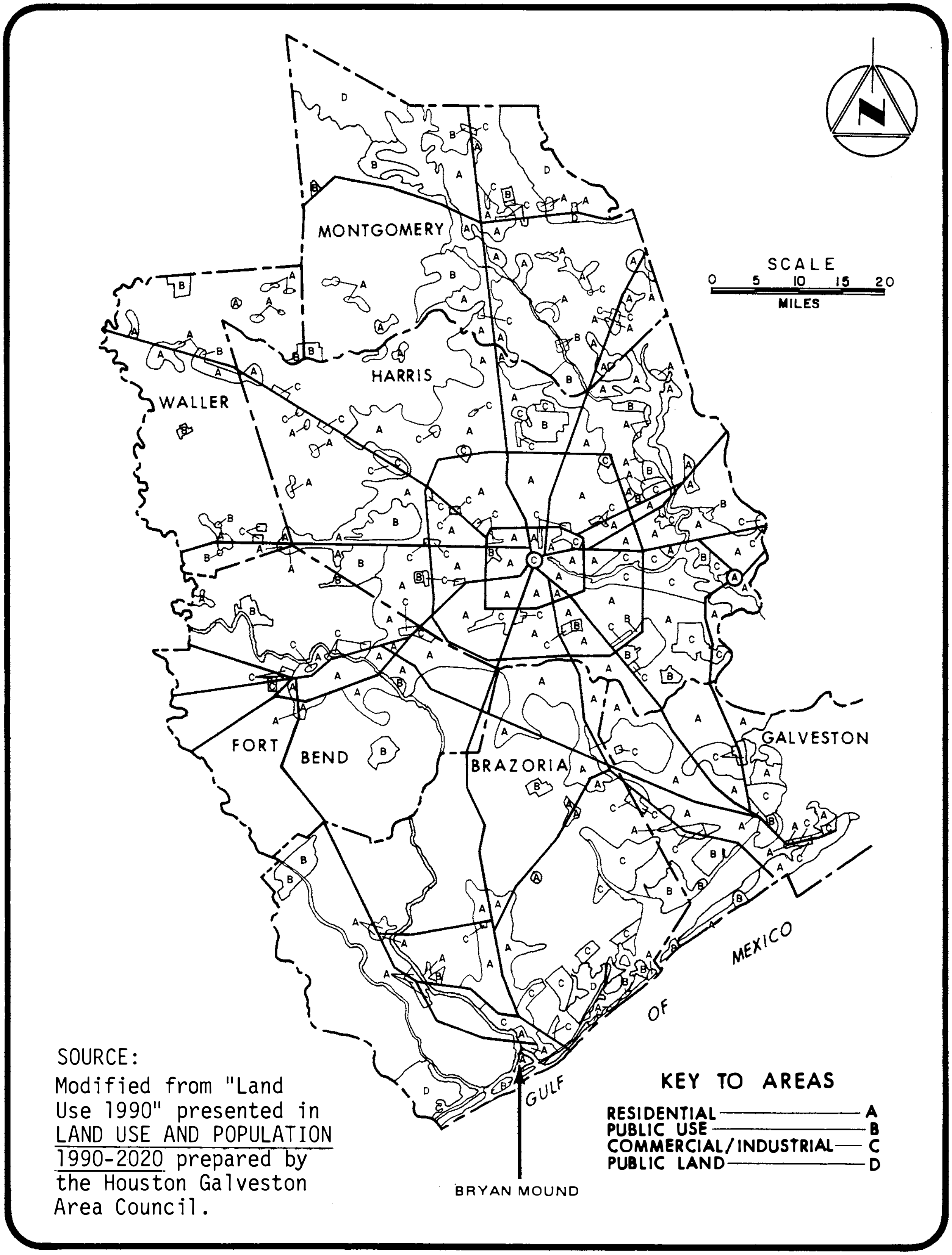

FIGURE C.3-3 Future land use in the Houston-Galveston area in the year 2000 and use of a marine terminal would reduce hydrocarbon emissions by more than 50 percent and would minimize the chance of a near-shore oil spill. The fact that the site has long been used for such industrial purposes as brine production minimizes the scope of changes resulting from construction activities. Although portions of the area have a high primary biological productivity, the amount of land affected by the project is small in relation to the amount of similar land in the area. Noise is not expected to cause adverse affects, due to existing industrial land uses, either during the construction or operation phases.

Although the project would require large quantities of water for solution mining and oil displacement, the total raw water demand of the project constitutes less than one percent of the average flow from the Brazos River Diversion Channel. The disposal of brine in the Gulf of Mexico is expected to increase the salinity of the waters adjacent to the brine diffusers. This increase could have an adverse effect on marine organisms in the area and could interfere with migration of a minor population of some estuarine species. The construction and operation of dock facilities in Freeport Harbor is not likely to have a significant impact on either the ecology of the area or the water quality of the harbor, as the area is extensively dredged.

During the construction phase of the development of Bryan Mound, increases in income and employment in the Freeport region are expected. These increases will be of short duration and are not expected to provide long-term stimulation sufficient to significantly affect the area's economy. The operation of the Bryan Mound SPR facility is expected to be small and will provide approximately $17,500 per month in additional income to the local area during standby storage and $96,000 during oil fill and withdrawal. Temporary increases in traffic congestion in the Freeport area could be expected during the construction phase. The economic benefits, however, of the Strategic Petroleum Reserve program are of considerable importance to the local economy, as the area is highly dependent upon the petroleumpetrochemical industry for employment. Assurance of a continued oil supply in the event of a national emergency would provide a measure of security for the residents of the area.

C.4 ALLEN DOME ALTERNATIVE SITE

Four sites are under consideration as alternatives to the proposed expansion of Bryan Mound for SPR storage. These sites are Allen dome, West Columbia dome, Damon Mound, and Nash dome (see Appendices A and B). Storage capacity planned for each of these sites is 100 MMB. Development of one of these alternate sites would bring the total storage capacity for the Seaway Group to 163 MMB. The following sections are a description of the environmental impacts associated with the development and operation of the Allen Dome candidate SPR site. Allen dome is located approximately 15 miles west of Freeport and seven miles north of the Gulf of Mexico (Figure A.4-1).

As described in Appendix A, maximum use would be made of early storage development facilities at Bryan Mound in developing the alternative site. These include the pump station/control house, raw water supply system, and oil pipelines connecting Bryan Mound to tanker docks and the SEAWAY Tank Farm. In addition, the two tanker docks in Freeport Harbor would be the same as described for Bryan Mound expansion.

New facilities required for the Allen dome alternative site are backup brine disposal wells; brine ponds; 5.8 mile brine disposal system to the Gulf of Mexico via Bryan Mound; roads and pipelines on site; construction of flood dikes; onsite pump and control house; blanket oil tank; onsite sanitary sewage holding tank; and oil, brine and raw water pipelines leading to Bryan Mound and SEAWAY Tank Farm. System alternatives include ground and surface water supplies; deep well brine injection, brine disposal directly to the Gulf or to a diffsuer 12.5 miles offshore of Bryan Mound; onsite power generation; construction of a marine terminal, and use of existing Philips or SEAWAY Docks.

C.4.1 Impact of Site Preparation and Construction

C.4.1.1 Land Features

Grading at the 184-acre Allen dome site would disturb about 31 acres of the surface. After construction, some of the disturbed areas would revert to natural vegetation. Fill onsite would total about 410,200 cy, most of which would be required to elevate the plant area to elevation 22 feet (Table A.4-1). The plant will be graded to this elevation to provide 1 foot of freeboard during the 100-year flood (elevation +21 feet). Of this total, fill for roads, drill pads, and other facilities onsite would be about 28,800 cy.

Construction of the two tanker docks in Freeport Harbor and the brine disposal pipeline 5.8 miles offshore of Bryan Mound would create impacts described in Section C.3.1.1.

Pipelines constructed for the Allen dome site from Bryan Mound and the three backup brine disposal wells would temporarily affect 125 acres in a 100-foot right-of-way. Excavation volume is estimated at about 191,300 cy. Most of this right-of-way would revert to its natural vegetation after construction is completed.

Leaching of twelve storage cavities in Allen dome would involve removal of 100 MMB of salt by leaching and brine disposal in the Gulf of Mexico. This is equivalent to 20.8×10^6 cy of salt. Sufficient space is to be left between cavities to preserve structural integrity.

A transmission line could come from either the Houston Lighting and Power substation in Freeport or from Community Service Electric & Gas substation in West Columbia.

Alternative Facilities

Excavation and right-of-way acreage required for system alternatives are summarized in this section. For alternative water supplies: (1) Development of a well field may require 22 acres and 28,800 cy of excavation; (2) Use of the San Bernard River would require construction of an intake system, and a short pipeline (less than 1/2 mile); (3) Water could be taken from the Gulf of Mexico by constructing a pipeline along the east bank of the San Bernard River. Approximately 141 acres of offshore right-of-way and 93 acres of onshore right-of-way, would be required.

For brine disposal alternatives the following impacts would be expected: (1) the alternative brine disposal system to deep aquifers would require disturbance of 19 acres offsite and possibly up to 19,000 cy of fill to construct the drill pads for 19 additional brine injection wells and for pipeline installation; (2) brine disposal directly to the

Gulf would utilize the same pipeline right-of-way along the San Bernard River as the Gulf water supply alternative; and (3) brine disposal to a diffuser 12.5 miles offshore from Bryan Mound would have impacts as described in Section C.3.1.1.

Onsite power generation would require insignificant additional land disturbance.

For oil supply, alternatives could involve the following impacts: (1) Phillips or SEAWAY Docks could be used as described for Bryan Mound; (2) a marine terminal could be constructed in the Gulf of Mexico with a pipeline connecting a monobouy to the Bryan Mound storage tanks. Impacts would be the same as described for Bryan Mound.

C.4.1.2 Water Resources

Site preparation and construction of the proposed facilities at Allen dome may impact the water resources of several water bodies, including: the San Bernard River, Jones Creek, the Intracoastal Waterway, the Brazos River Diversion Channel, Freeport Harbor, the Gulf of Mexico and ground water aquifers. Potential impacts are treated according to specific aspects of facility development.

Raw Water Withdrawal

It is proposed to take raw water for cavity leaching from the Brazos River Diversion Channel, using the same facilities as for Bryan Mound. The withdrawal rate would be 534,000 B/D; thus, impacts to water supply and quality would be identical to those for Bryan Mound site expansion (Section C.3.1.2).

Brine Disposal

An estimated 684,000 B/D of brine would be discharged to the Gulf through a diffuser located approximately 5 miles south of Bryan Beach. Expected impacts described in Section C.3.1.2 for Bryan Mound (and in Appendix G) are applicable.

The impact of backup brine disposal on water quality of ground water aquifers would be limited to increased salinity in the receiving formations which already contain saline water. Because of the intended depth of injection, the possibility that freshwater aquifers may be affected due to migration or leakage of brine is considered remote.

Dock Construction

Construction impacts associated with tanker docks in Freeport Harbor would be identical to those described in Section C.3.1.2 for Bryan Mound.

Construction of Surface Facilities at Allen Dome

The site preparation and construction activity would involve a significant amount of earth movement. Approximately 428,000 cubic yards of earth would be displaced during this process. Natural site drainage is toward the San Bernard River to the east. Standard engineering practices such as interceptor ditches, dikes, and sedimentation ponds would be utilized to prevent any significant degradation of water quality due to plant site runoff. Pollutants which would degrade the water quality are discussed in Section C.3.1.2.

Construction of Oil, Brine and Water Supply Pipelines

The proposed water supply, brine disposal, and oil pipelines would cross the San Bernard River east of the site. The water supply and brine pipelines would also cross Jones Creek and the Brazos River Diversion Channel between the SEAWAY Tank Farm and Bryan Mound. It is expected that pipeline installation and burial across the water courses would cause some temporary local degradation of water quality. Excavation of the pipeline channel would cause an increase in turbidity and the release of soluble substances contained within the bottom sediments. The amount of chemical constituents released from the bottom sediments during the excavation and backfill operations is difficult to estimate in the absence of standard elutriate samples. In all instances, sound engineering practices for excavation, disposal, and transportation of alluvial material would be followed. Such activities would be performed in accordance with all applicable Federal laws and regulations. Any impacts which might occur would be temporary and predominantly local in extent.

There should be no impact on ground water supply or quality due to pipeline installation.

Accidental Brine Release

Leaching of 100 MMB of oil storage capacity from Allen dome requires transport of saline water from the Brazos River Diversion Channel and disposal of brine to the Gulf of Mexico. In addition to the impacts previously described for normal operations, a possible brine (or raw water) spill could affect water resources in the San Bernard River, Jones Creek, Brazos River Diversion Channel, lakes and ponds on Bryan Mound, the ICW and the Gulf of Mexico.

The estimated quantity of brine that would be spilled during leaching of Allen dome expansion cavities is 50 barrels into Gulf of Mexico waters and 120 barrels onto land and water bodies between Bryan Beach and Allen dome (Table C.2-3). In addition, an estimated 120 barrels might be spilled from the raw water supply system. Maximum credible spills of up to 30,000 barrels are considered possible, though highly unlikely.

Since average brine spill volumes are estimated to be 5000 barrels, the computation of such low spill expectation reflects the remote chance of any spill occurring. Thus, there is a 90 percent chance that no brine would be spilled from all pipeline uses (including operation) during the project lifetime (see Appendix E). If a pipeline rupture does occur, release of 5000 or more barrels of brine could significantly degrade water quality, especially in smaller water bodies such as Jones Creek or the lakes and ponds at Bryan Mound. Quantities of water required to dilute a maximum credible brine spill to concentrations near ambient are estimated in Section C.3.2.5. Prior to achieving this mixing, salt concentrations would be abnormally elevated.

A brine spill at the site or along the disposal pipeline could locally impact the water quality in the upper unit of the Chicot aquifer. The brine would tend to migrate downward within the formation and downdip along the formation due to density differences. A massive spill, although highly unlikely, could possibly impact the quality of municipal water supplies pumped from aquifers in the Brazosport area by causing increased salinities in those aquifers. As local recharge of near surface aquifers has been found to be minimal, potential seepage from the brine pit or minor pipeline, spills are likely to have negligible impact on water quality.

Hurricane surge studies conducted by the U.S. Army Corps of Engineers indicate that the 100-year flood elevation, excluding wave run up, at Allen dome is +14.0 feet MSL (Trahan, personal communication). As the brine pond would be protected at elevation +22 feet MSL, there is little liklihood of a catasrophic failure resulting in release of up to 100,000 barrels of brine. Should a storm surge of sufficient magnitude occur to breach the levee, impacts caused by loss of the brine would not be separable from storm wave and saltwater damage.

Alternative Facilities

Alternative systems to provide raw water for cavity leaching include withdrawal of saline ground water, withdrawal of water from the San Bernard River adjacent to the site, or withdrawal of water from the Gulf of Mexico. Withdrawal of ground water is feasible but has the same potential for lowering the piezometric head, saline water intrusion, and land subsidence that is a particularly troublesome result of ground water pumping in Brazoria County.

The San Bernard River has an average flow of 508 cfs and a recorded minimum of 2.4 cfs; water quality is generally good. The required withdrawal rate of 43 cfs is, thus, frequently a substantial fraction of freshwater flow. In the vicinity of the site, however, the river is a tidal estuary, approximately 400 feet wide, with a dredged navigation channel 9 feet deep and 50 feet wide. There is usually a substantial flow of saltwater up river to the site. Withdrawal of water for leaching would induce a somewhat greater inflow of Gulf waters. This should not alter water quality beyond the normal range of seasonal salinity fluctuation but would probably increase average salinities during the period of withdrawals.

A pipeline could be constructed along the east bank of the San Bernard River to the Gulf of Mexico for withdrawal of ocean water for leaching. If the intake were located deep enough (20 to 30 feet) there should be no measurable effect on water quality in the Gulf. There would be sedimentation and other normal construction impacts to the San Bernard River and to the near shore Gulf waters during and immediately following pipeline installation, however.

Alternative systems for disposal of brine include deep well injection disposal directly to the Gulf through a pipeline along the east bank of the San Bernard River and disposal 12.5 miles offshore from Bryan Mound.

Although occuring at a different location, brine injection to saline aquifers at Allen dome has the same potential for adverse impacts as at Bryan Mound. It is expected that proper injection methods would avoid any impacts.

Brine disposal directly to the Gulf would use the same pipeline right-of-way as indicated above for water withdrawal. Impacts to ocean water salinity in the vicinity of either diffuser location would be essentially the same as described in Section C.3.1.2 for disposal south of Bryan Mound.

Alternative oil distribution facilities include use of Phillips or SEAWAY Docks, or construction of a marine terminal. Water quality impacts of the marine terminal alternative are described in Section C.3.1.2.

C.4.1.3 Air Quality

The quality of air at the Allen dome and Bryan Mound sites would be slightly affected during site preparation and construction; impacts would be short term and confined to a relatively small area. The principal pollutant of concern would be hydrocarbon emissions since data presented in Section B.2.3.3 indicate that hydrocarbon concentrations in the vicinity of Allen dome frequently exceed the NAAQS, as indicated in Section B.2.3.3.

Sources of Emissions

The quality of air at the sites during construction would be affected by general construction vehicles, drilling equipment, and fugitive dust. The data presented in Section C.3.1.3 for Bryan Mound are generally applicable at Allen dome and along the pipeline right-of-way.

Impacts on Air Quality

The impact of expected emissions at Allen dome and Bryan Mound is dependent on the ambient air quality and the dispersal characteristics of the atmosphere. "Worst case" downwind concentrations at Allen dome would be similar to those calculated in Section C.3.1.3 for Bryan Mound. Therefore, the impact upon air quality would be essentially the same at Allen dome as at Bryan Mound, where it was concluded that downwind concentrations resulting from construction activities are quite small when compared to the state and National standards, but that since background HC levels in the area often exceed the 3-hour NAAQS, infrequent additional exceedances may be expected.

Alternatives

Construction of a raw water supply well field or a brine injection field would involve a significant amount of drilling activity. Air quality impacts associated with these activities would be similar to those expected from cavity drilling operations. Construction of pipelines to the Gulf of Mexico would constitute a relatively insignificant source of pollutants along the pipeline corridors, distant from most other development. Construction of a marine terminal would involve more emissions from barges and pile driving equipment but would not contribute measurably to onshore air quality degradation.

C.4.1.4 Noise

Site preparation and construction at the Allen dome site would adversely impact the ambient noise in the vicinity of the site. The increase in noise resulting from these activities, with the exception of the plant facility construction, is identical to the increases expected from the proposed development of the Bryan Mound site as discussed in Section C.3.1.4. The equivalent sound level, L_{eq}, contribution from the construction of support facilities would be expected to be 68dB, at 500 feet. Impact zones are shown in Table C.4-1 and Figure C.4-1 for Allen dome and in Table C.3-4 and Figure C.3-1 for Bryan Mound; these represent the radii of areas experiencing an increase of 3 dB or more over the ambient sound levels.

Approximately 16 residences located south of Allen dome may be exposed to sound levels in excess of the U.S. Environmental Protection Agency recommended sound level, L_{dn}, of 55 dB. As the construction activities would occur over an estimated 15 month period, this impact is only of short term significance.

Alternatives

Construction of a raw water or brine disposal well field in the vicinity of Allen dome would contribute noise levels of a magnitude similar to the onsite activities. The zone of impact would then be

TABLE C.4-1 Summary of construction noise impact - Allen dome candidate SPR storage site (alternative site)

Area	Activity	Impact Zone Radius (feet)[a]
Allen Dome Site	Drilling New Shafts	4500
	Construction of Support Facilities	2000
Pipeline Routes	Laying of Pipe	1800
	Access Road Construction	1400
Freeport Harbor Brazos Harbor	Construction of DOE Docks	2200

[a] This is the distance within which sound levels are raised at least 3 dB by activity described. A baseline ambient day/night sound level of 54dB is assumed for the calculations.

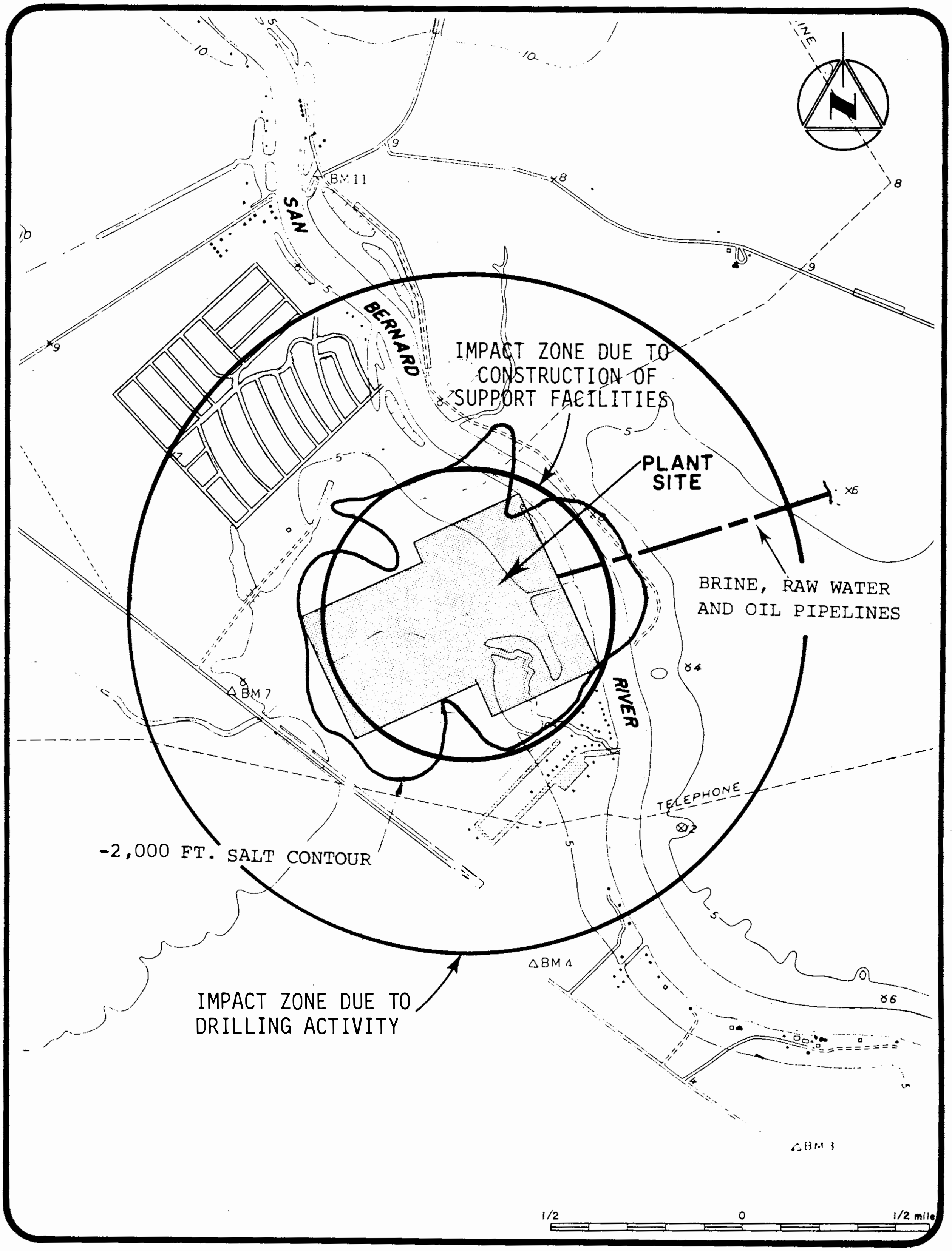

FIGURE C.4-1 Noise impact zones - Allen dome candidate SPR storage site (alternative site) extended further to the east in a sparsely inhabited area of marsh and coastal prairie. Construction of pipelines to the Gulf would increase noise levels in some sensitive areas such as Bernard Acres very briefly (2 to 3 days). Construction of a marine terminal would have no measurable effect on onshore noise levels.

C.4.1.5 Ecosystems and Species

Site preparation and construction of the proposed facilities at Allen dome may affect both terrestrial and aquatic resources in the area. Terrestrial habitats potentially affected include undeveloped coastal prairie grassland, fluival woodlands and brackish marsh (Table B.4-1). Aquatic habitats include the San Bernard River, Jones Creek, Brazos River Diversion Channel, ICW, several lakes and ponds at Brayan Mound, Freeport and Brazos Harbors and the near shore Gulf of Mexico. Figure C.4-2 shows the major habitats in relation to proposed and alternative SPR facilities.

Unlike SPR expansion at Bryan Mound, development of Allen dome would affect relatively undeveloped lands of moderate to high natural productvity.

In the following subsections, potential impacts to biological resources are treated according to specific aspects of facility development.

Raw Water Withdrawal

Withdrawal of 534,000 B/D of water from the Brazos River Diversion Channel for cavity leaching at Allen dome would result in a loss of phytoplankton and zooplankton and other small aquatic biota unable to avoid the 0.5 ft/sec intake stream. Expected impacts are not considered significant (Section C.3.1.5), in relation to aquatic biotic resources in the project area. Water quality should not be affected sufficiently to affect aquatic habitat.

Brine Disposal

The proposed diffuser 5.8 miles offshore Bryan Mound would have impacts on the ecosystems and species in the vicinity as described in Section C.3.1.5.

FIGURE C.4-2 Air photo - Allen dome candidate SPR storage site (alternative site)

Dock Construction

Impacts are considered minor and are given in Section C.3.1.5.

Construction of Surface Facilities at Allen Dome and Bryan Mound

The new facilities to be constructed at Allen dome which involve potential impacts to the site ecology include the construction of the pump house and control buildings, three brine disposal wells at the site, the brine settling pond and a 10-mile long utility power corridor.

The Allen dome storage facilities are located on a 184 acre tract of land which consists mostly of coastal prairie and fluvial woodlands. The plant area, equipment yard and 12 new entry wells would reduce the coastal prairie habitat by 28-acres. The major flora impacted by site development are Gulf cordgrass, bunch grass, switch grass, bluestem and live oak. The common wildlife at the dome are the ornate box turtle, western diamondback rattlesnake, eastern gartersnake, cotton and rice rats, rabbits, and numerous song birds (see Section B.4.5).

Clearing of this land would reduce primary productivity of the coastal prairie by about 2.8×10^8 Kcal per year or 5.1×10^4 pounds of carbon annually. Many small invertebrates which inhabit the upper soil layers (such as nematodes, mites, spiders and worms) would also be destroyed. Protective fencing at the site would also restrict the area to those small animals and birds that can pass through the barrier. In addition to habitat loss and death during site clearing, the direct effects of construction activities would include forced abandonment of nests and homes, and the loss of food, cover, and breeding areas for many smaller animals. After construction has ceased some wildlife species would return to re-inhabit the site.

The clearing of the site would result in increased soil erosion (as discussed under Water Resources, C.4.1.2) but this impact should be of a minor and temporary nature.

Clearing the land for the utility corridor should cause minimal losses of habitat, as little ground disruption would occur. The most significant and longest lasting impacts would be to wooded areas, should they be cleared, as these areas would take years to be reestablished.

Construction of Pipelines

A total of 99 acres of land could be required for construction of the proposed raw water, brine and oil pipelines between Allen dome and the SEAWAY Tank Farm. Between SEAWAY Tank Farm and Bryan Mound, raw water and brine pipelines would be constructed on an existing right-of-way. Construction activities associated with this land clearing and modification would produce several impacts to the terrestrial environment since the right-of-way would pass through coastal prairie marshland, fluvial forest lands and brackish marsh. A primary impact would be the elimination of cover vegetation within the pipeline right-of-way.

The clearing of a 100 foot right-of-way for the length of the line would result in a loss of habitat, feeding area, and nesting and protective cover for various wildlife species. Human activities, construction, and the release of dust, dirt, and fumes would most likely cause the emigration of resident wildlife species from the direct impact area. Small rodents and non-mobile species would be affected most. Some animal deaths are expected from direct and indirect effects of pipeline construction. Losses associated with construction may be high if construction takes place during the major nesting and young bearing season (generally spring).

Habitat loss in the coastal prairie would be temporary. Most prairie wildlife species are mobile and, once human activities are underway, would move to adjacent areas. However, some species loss may occur in the direct impact area or in adjacent areas, particularly if those species forced to move are subjected to competition for space with other animals. The displacement of small rodent species would most likely be permanent within the pipeline right-of-way. The introduction of grassland species of plants as a result of seeding may afford additional food sources; however, unless the vegetation is allowed to reach medium-tall dense stands, rodents may be subjected to heavy predation, particularly by avian species.

Livestock (i.e., cattle) would be adversely affected by the construction of the pipeline. In addition to the loss of acreage available for grazing, care would need to be taken to keep animals away from the construction area, particularly areas where the line is left open for any period of time or where cattle may ingest crankcase oil and grease from machinery, which in rare instances could lead to lead poisoning (Buck, 1970).

The effects of pipeline construction upon wildlife in marshland and wetland areas would probably be locally significant because of the vast number of wildlife species which inhabit these areas. Losses may be magnified if construction of the pipeline occurs during the major young-bearing season.

Any alteration of existing drainage patterns in the marsh could force water dependent herpetofauna into marginal habitats where their chances of survival would be greatly reduced. Temporary loss of habitat, feeding, nesting and breeding areas would adversely affect wildlife presently within the pipeline right-of-way. Permanent loss of some non-mobile species is likely to occur in the construction zone. Additional loss of some animals is expected as a result of forced migration away from the construction and activity zones and the resulting competition for resources in new areas. The magnitude of losses would depend upon suitability of adjacent habitat and the condition of existing wildlife populations.

The large numbers of waterfowl (winter) and other aquatic bird species inhabiting the marsh would be adversely affected by pipeline construction. Loss of feeding and nesting areas would result from line construction. The mobility of avian species would aid in reducing some of the anticipated impacts. Effects of construction upon marsh and wetland areas may be evident for 1 to 2 years.

In addition to direct loss of wildlife habitat, clearing of the cover vegetation and removal of topsoil from the proposed pipeline right-of-way causes several secondary impacts. Most important of these is a decrease in productivity (forage material) within the right-of-way corridor. Another impact results from altering the composition of the vegetative community; an example is the "invasion" of the right-of-way by low-productivity plant species having little or no forage value. In addition, clearing and/or spraying the right-of-way with weed-control agents would have the secondary effect of increasing the fire danger due to drying out the brush and a general increase in human activity. Restoring the topsoil and reseeding the right-of-way with native grasses would minimize the impacts of construction.

Another secondary impact of construction of the proposed pipeline is the compaction and random mixing of the soil by heavy equipment and vehicles within the right-of-way. This impact can be minimized by proper ditch and backfill methods. A majority of the topsoil would be placed at or near the top of the ditch by reversing the ditching steps when backfilling.

Construction activities (including trenching, pipe laying and backfill operations) at river crossings have several potentially adverse effects on the aquatic environment. Physical disruption of streambeds would destroy some existing aquatic habitat at the crossings. Mobile organisms, primarily fish, would move to other areas within the river system, possibly exerting slight population pressures on adjacent habitats. If construction occurs during the spawning and egg maturation periods local fish populations could be locally affected. Immobile benthic organisms and rooted vegetation in the dredged area and in areas of high turbidity immediately downstream would be directly eliminated. The time required to reestablished these populations is dependent upon water quality, substrate and biological communities at each crossing.

Organisms inhabiting the river banks would also be affected. Noise, dust, and fumes during construction would probably cause wildlife to retreat from construction sites. Waterfowl, reptiles, amphibians, and other riparian fauna would migrate from direct impact areas. At certain crossings, use of explosives may be required.

Some erosion of the disturbed stream banks and displacement of dredged materials downstream would occur. The extent of the impact would depend upon the time of year that construction takes place and the amount of runoff. Increased turbidity of river waters and sedimentation would be short term effects, since measures to ensure bank stabilization and proper disposal or containment of dredged material would be implemented. The San Bernard River, in particular, is a high quality habitat for fresh and brackish water species.

Increased dissolved and suspended solids in a river system can alter water quality and affect the aquatic biota by increasing nutrient levels, increasing the biochemical oxygen demand, and releasing toxic materials to the system. An increase in nutrient levels may be desirable in systems with low biological productivity, but the effects would be detrimental to a system in a state of accelerated eutrophication, such as may exist below a raw sewage effluent outfall. Such a system would undergo further stress if the biochemical uptake demand of resuspended bottom sediments are exceedingly high compared to rates in undisturbed sediments (Seattle University, 1970).

Heavy metals, pesticides, and other toxic materials may be released into the water where streambeds are altered. Concentrations of heavy metals such as lead, mercury, arsenic, and copper have been reported to be present in tissues of oysters or other bivalve mollusks (Galtsoff, 1960).

Increased turbidity can decrease photosynthesis of phytoplankton, attached algae, and submerged vegetation. If high turbidity levels persist for extended periods of time, food supplies may be reduced for organisms (primarily fish) on the highest trophic level. According to the FWPCA (1968), plant life and bottom fauna, upon which fish depend, cannot be very productive if turbidity levels continuously exceed 200 Jackson Turbidity Units (JTU). The FWPCA consider turbidity levels of 50 JTU or less, satisfactory for aquatic life in warm water streams. Increased turbidity not only adversely affects fish by altering the food chain, but can also impair vision and respiration. High levels of suspended solids can clog gills of fish but fish usually try to avoid these conditions.

Heavy siltation can impair respiration and growth of attached algae, rooted vegetation and grasses, and alter species composition and numbers of the bottom fauna. Tarzwell (1957), as cited by the FWPCA (1968), found that bottom organisms from a silted area averaged only 36 organisms per square foot compared to 249 per square foot in a non-silted area.

Accidental Brine Release

Expected quantities of brine and saltwater spilled during cavern leaching are 170 and 120 barrels, respectively (Table C.2-3). Impacts from such quantities would be of only local importance to terrestrial or aquatic biota. However, should a pipeline spill occur, the average size is expected to be 5000 barrels, with maximum credible spills of up to 30,000 barrels; such spills could have considerable adverse impact.

The most likely location for the occurrence of a major brine spill would be onshore between Allen dome and Bryan Beach. In such an event, brine (or saltwater) could spread across coastal prairie, brackish marsh, or into San Bernard River, Jones Creek, Brazos River Diversion Channel, lakes on Bryan Mound, or the ICW. Impacts on vegetation, and on animal life which could not avoid the brine would be locally devastating, particularly on terrestrial habitat and in Jones Creek or Mud Lake. Tens of acres of habitat could be destroyed and salt concentrations in the soil could remain above levels tolerated by new growth for several years. However, it must be emphasized that such a spill is statistically very unlikely to occur especially from so short a section of pipeline.

Should a maximum credible brine release occur in the near shore Gulf of Mexico, bottom organisms, and possibly some organisms in the water column, could be destroyed over an area of several acres. However, the biological impact would be only of local significance; recolonization would begin almost immediately.

Alternative Facilities

Alternative sources of raw water which could affect biotic resources include development of a ground water well field and withdrawal of water from the San Bernard River or from the Gulf of Mexico. Well field construction may require 22 acres of coastal prairie habitat; a pipeline right-of-way to the San Bernard River would require 5 acres of coastal prairie and 1 acre of fluvial wetlands; a pipeline to the Gulf would require 93 acres of right-of-way onshore (primarily brackish marsh) and up to 141 acres of offshore substrate.

Changes in water quality associated with withdrawal from the San Bernard should not be of great significance because the river is a dredged tidal estuary between the Gulf and Allen dome. Losses of phytoplankton and zooplankton would probably be of somewhat greater magnitude than for the Brazos because the aquatic habitat is of higher quality. Losses should not be of regional significance, however.

Withdrawal of water from the open Gulf would have no measurable affect on water quality. Substantial numbers of plankton would be destroyed in the process but again impacts should be of local significance only.

Alternative brine disposal methods include deep well injection and diffusion in the Gulf south of Allen dome or 12.5 miles off Bryan Mound. Deep well injection would have no impact on biota except for losses of 19 acres of coastal prairie habitat. The effects of disposal in the Gulf south of Allen dome should be nearly similar to disposal south of Bryan Beach.

Effects of constructing alternate oil transportation facilities would be identical to those described for Bryan Mound in Section C.3.1.5.

C.4.1.6 Natural and Scenic Resources

The project site and pipeline route construction would have a significant but temporary effect on some of the natural resource and recreational areas in Brazoria County. Construction activity may temporarily disrupt hunting and fishing activities adjacent to the site and along the pipeline route. The impacts would affect only a small portion of the total available habitat areas.

Construction activity would have a temporary negative effect on the local ambience. Residents in the small subdivision nearby would be subjected to construction noise, dust, vibration, and fumes. Construction along the pipeline would disrupt the undeveloped quality of Coastal Prairie and marsh environments crossed. There may be some temporary disruption of wildlife in parts of the San Bernard National Wildlife Refuge located south of Allen dome on the west bank of the San Bernard River due to onsite construction noise.

Alternatives

Development of a raw water supply or brine injection field in coastal prairie east of Allen dome would not significantly affect natural or scenic resources. Construction of pipelines to the Gulf would temporarily disturb residents of Bernard Acres and may disrupt wildlife population in coastal areas such as the nearby San Bernard Wildlife Refuge.

C.4.1.7 Archaeological, Historical and Cultural Resources

A comparison of the location of sites listed on the National Register of Historic Places and those sites identified by the Historic Preservation office for Texas and this location of the SPR facilities has been made. Based on this comparison there are no known sites of historic significance that would be affected. Section 2(a) of Executive Order 11593, "Protection and Enhancement of the Cultural Environment" (May 13, 1971) would be complied with as detailed in Section C.3.17.

C.4.1.8 Socioeconomic Environment

Land Use

Developing Allen dome would change the primary land use of the site from a non-cultivated cattle grazing area to industrial use. Approximately 184 acres would be enclosed by a security fence eliminating those acres from grazing use. However, only 7 percent, or 31 acres, would be physically changed into pipeline alleys, roads, drill pads, brine reservoir, and plant structures.

The seven mile pipeline corridor between the site and the SEAWAY Tank Farm would have a right-of-way through the predominantly coastal prairie and marsh area which would alter land use on approximately 99 acres during the construction period. Pipeline construction between SEAWAY Tank Farm and Bryan Mound would follow an existing pipeline right-of-way (planned for early storage development) and would not affect land use. Construction impacts of the brine disposal pipeline from Bryan Mound 5.8 miles offshore to the Gulf are described in Section C.3.1.8.

One dock would be constructed at the SEAWAY Dock site. A second would be built in Brazos Harbor. Land use at the dock sites is industrial, there would be no land use impact.

Alternative water injection and brine disposal systems would require additional pipeline construction: to off-site wells (19 acres); to the San Bernard River (6 acres); and directly to the Gulf (234 acres); to the Gulf through Bryan Mound (326 acres); each of these alternatives would eliminate acreage from current land use. Assuming that the necessary pipelines would all be buried, most of the coastal prairie land use can revert back to its current use. Marsh land may lose productivity if permanent canals are left in place of marsh grass.

Water withdrawal and brine disposal to the Gulf of Mexico directly would involve pipeline construction through the marsh area east of the San Bernard River, which is considered a critical wildlife habitat by the Texas Parks and Wildlife Department. The effects of the pipeline through Bryan Mound 12.5 miles offshore are described in Section C.3.1.8.

Onsite power generation would eliminate the need for a 10 mile transmission corridor to the site.

Use of SEAWAY or Phillips docks by DOE would require no alteration in existing land use. Development of marine terminal would dedicate a few acres of ocean water for the monobuoy and a few acres of coastal prairie for a pipeline corridor.

Transportation

During the construciton period, traffic will increase on the major highways and roads that connect Allen dome to the Freeport, Galveston, and Houston areas. Impacts would be most noticeable during the first year of construction activity, when the largest numbers of employees are commuting. Construction crews would be working long shifts and their commuting hours are not expected to be concurrent with other commuters in the area. This would, therefore, reduce the impacts on traffic flow in the county. The impact on county roads 2611 and 2918 which connect the site with Route 36, the major traffic artery leading to the site, would be quite large during heaviest construction. Current traffic on these roads ranges from 1230 average daily trips near the junction of Routes 36 and 2611, to only 460 trips on Route 2918 near the site entrance. During the peak month of construction over 500 workers would commute to the site daily (Table C.4-2) and additional traffic would be generated by truck traffic to the construction site. As can be seen from these figures, traffic in some sections would more than double. While the capacities of existing roads are unlikely to be exceeded in the project area, some congestion may occur at shift changes.

Even when the work force decreases to 132 in the seventh month and 109 in the twelth month, the previously existing traffic pattern would be significantly altered. It is anticipated that in non-peak hours, traffic in the project area would be only minimally impacted.

The other transportation systems in the county - such as the county and Galveston airports, rail and bus services - would likely experience some increases, especially during the peak construction period.

The project may have a minimal impact on waterborne transportation in the Freeport Harbor due to the increase in oil tanker traffic. All traffic in this harbor, in 1976, amounted to 436 vessels (Brazos River Navigation District). The "worst case" increase in tanker traffic during the initial fill of the 100 MMB storage capacity would amount to one tanker every day. This assumes a tanker capacity of 32,000 DWT, or 254,000 BBL of oil. If SEADOCK is constructed, overall traffic, particularly tankers, in Freeport Harbor would be significantly reduced.

Waterborne traffic in the area may be temporarily disrupted during pipeline construction across navigable waterways. Barges may be used to transport construction materials to the site on the San Bernard River.

Construction of the alternative water injection, brine disposal, and oil transport facilities is not expected to significantly affect the area's transportation facilities. Construction activities may require some additional manpower which would increase the amount of vehicular traffic. Should SEADOCK be under construction simultaneously with SPR expansion, there may be some additional traffic congestion in Freeport but not at Allen Dome.

Population

Construction employees are expected to commute from nearby urban centers and would therefore have an insignificant growth-inducing effect on population in Brazoria County. The Allen dome vicinity would experience a substantial increase in daytime population, especially during the peak construction period.

The use of several of the alternative water injection, brine disposal, and oil transport systems would require some additional manpower but would not significantly increase populations above the anticipated levels. Use of existing SEAWAY or Phillips Docks, or withdrawal of water from the San Bernard River, would reduce manpower requirements and therefore possible population increases.

Housing

Significant impacts on housing are not anticipated, since the construction employees are expected to commute from their current places of residence. Some increase in demand for temporary housing in the Brazosport area an be expected since some employees may choose to stay near the project during their workweek. As noted in Section B.3.6, temporary housing is in short supply in the Brazosport area due to the area's growth. Consequently, this may force more construction employees to commute.

Adoption of any of the alternative systems would have an insignificant additional impact on housing availability.

Economy

Construction of SPR facilities at Allen dome would have a significant impact on construction employment in the region. The project would have a peak construction force of nearly 550 employees during the second month (Table C.4-2). The first six months would be the most labor intensive, with employment levels declining during the following months (down to 55 employees). The Brazosport area has a low rate of unemployment, so much of the labor force would likely commute from the Texas City-Galveston area or from Houston.

The project may be served by the extensive petrochemical, fabricating, rapair, and maintenance industries that are available in the area. The project is not expected to generate much, if any, additional long term economic growth in the area due to the temporary nature of the construction activity.

Approximately $3 million, over 35 percent of the total project payroll, would be earned during the second through sixth months of the project. The disposable income (after taxes) over the life of the project would be approximately $6.6 million or 80 percent of gross income. Most of the income resulting from the project would be spent in the larger urban areas where the commuting workers reside. The remainder would be dispersed throughout the local area. The relative effect

TABLE C.4-2 Estimated Construction Employment and Wages by Month - Allen Dome candidate SPR storage site (alternative site)

Month	Number Employed	Monthly Wages
0-1	125	$218,750
1-2	545	953,750
2-3	453	792,750
3-4	254	444,500
4-5	232	406,000
5-6	207	362,250
6-7	132	231,000
7-8	132	231,000
8-9	132	231,000
9-10	132	231,000
10-11	132	231,000
11-12	109	190,750
12-13	109	190,750
13-14	109	190,750
14-15	109	190,750
15-16	109	190,750
16-17	109	190,750
17-18	109	190,750
19-46	55	96,250
Construction Total		$8,267,000

would be slight in the highly developed centers such as the Houston-Galveston area, but more noticeable in the communities in southern Brazoria County. Construction workers would patronize the area's retail services (such as gas and food), increasing the income of people operating those services. Income earned by the construction force would decline during the last three years of the project construction and the impacts on area income would be correspondingly less.

Total income resulting from construction employment has been estimated using the projected employment for each month at an average income figure of $1750 per month for each worker. The resulting income, shown on Table C.4-2, would be highest in the second and third months of construction and would total over $8.2 million over a four year period. These expenditures for labor would have a multiplier effect on the local and regional economy, in which direct income accruing to households would be spent in other sectors of the economy. Some of these expenditures would, in turn, be realized as direct income to other households. In Texas, the relationship of one dollar of direct income (expenditure) in the indust ial construction sector to income received by all other sectors of the economy has been estimated to be a multiplier of $2.51 (Office of the Governor), or more simply stated, for every dollar spent to construct the SPR facilities, $2.51 would be generated as income within the region. This relationship, a Type II multipliers, expresses the direct, indirect, and induced income paid to households per dollar direct income paid to households. Thus, the $8.2 million of direct income from over the four year construction period would result in $20.6 million direct, indirect, and induced income to accrue to households in the region. The geographic distribution of this income would be determined, in part, by the worker's place of residence and location of retail facilities.

Alternative project facilities, such as construction of the ground water supply field, a brine water injection field, pipelines to the Gulf of Mexico or a marine terminal, could provide significant increases in construction payroll.

Government

Security and fire protection to protect the project personnel, equipment and supplies would be provided by the project. Additional police surveillance and traffic control in the project area may be required, especially during the peak construction period.

Since most construction employees are expected to commute from their homes, few would relocate to the project area with their families. Therefore, the small number of new school children have a negligible effect on the local school systems.

Construction of the fenced Allen dome facility would involve the removal of 184 acres from the tax rolls of Brazoria County. The tax rate for the County is $1.44 per hundred dollars of assessed valuation. Assessed valuation is 20 percent of fair market value. Assuming that the land at Allen dome has a fair market value of $1000 per acre, the tax loss to the county would be $530 per year, for the life of the project (assuming property value and tax rate increases to be minimal).

Based upon a four percent sales tax on retail sales, and assuming that 50 percent of the total direct, indirect, and induced household incomes discussed above would be spent on taxable purchases, an increase of over $250,000 in tax revenues would be experienced over the construction period.

Implementation of any of the alternative water supply or brine disposal systems could require additional manpower, which in turn would increase the demand for urban services such as police surveillance and hospitals. However, unless several of the alternatives were selected, the impact would be a minor addition to total project impacts.

C.4.2 Impacts from Operation and Standby Storage

Developmental of 100 MMB storage capacity at Allen dome means that in the event of an oil supply interruption, a total of 163 MMB of oil would be available from the Seaway Group of SPR sites for delivery to SEAWAY Pipeline or to tankers at Freeport. Oil would probably be pumped from Allen dome to SEAWAY Tank Farm for pipeline transport north; oil in excess of SEAWAY capacity (600,000 B/D) would then be pumped to the tanker dock along with oil from the Bryan Mound early storage development. Principal impacts are those associated with oil or brine spills and with hydrocarbon emissions. Where appropriate, impacts which are cumulative are given for both Allen dome and Bryan Mound early storage facility operation in order to provide perspective on site expansion significance and total Seaway Group impact.

C.4.2.1 Land Features

Effects of normal operation and standby storage on land features are expected to be minimal. Soils would stabilize soon after they are revegetated following construction.

Allen dome is located in an area having no reasonable expectancy of earthquake damage. The only potentially significant impact on land features would be a extremely unlikely roof collapse of one of the storage cavities. As at Bryan Mound, this could destroy a portion of the surface storage facilities, create a lake over Allen dome, and release large quantities of oil to the surface. The likelihood of such a collapse is considered extremely remote, however.

Use of alternative facilities would have no impact on land features during project operation.

C.4.2.2 Water Resources

Impacts to water resources as a result of operating oil storage facilities at Allen dome would result from withdrawal of water for oil displacement, discharge of brine during oil fill, maintenance dredging at dock sites, and possible oil or brine spills.

Raw Water Withdrawal

Effects on water quality in the Brazos River Diversion Channel would be essentially the same as for Bryan Mound site development (Section C.3.2.2). It is concluded that water quality and quantity in the Brazos River Diversion Channel should not be measurably affected.

Brine Disposal

Effects of brine disposal into the Gulf of Mexico during oil filling would be the same as for Bryan Mound site development (Section C.3.2.2).

Disposal of brine into deep water bearing sands through the 3-well backup system east of Allen dome during refills would have significantly less potential for adverse impacts than disposal at full leaching rates.

Maintenance Dredging

Water quality impacts due to maintenance dredging of the dock sites are considered to be minimal, especially considering present quantities of maintenance dredging (1 million cy every year).

Oil Spills

During project operation, oil spills could occur in the Gulf of Mexico, in Freeport Harbor, from pipelines connecting the storage site with the tanker docks and SEAWAY Tank Farm, from the wells at Allen dome, and from the early storage phase oil surge tanks at Bryan Mound (releases from the underground storage caverns are not quantified, see Appendix E). A thorough description of possible modes of spills, methodology of spill calculation, quantification of expected spill volume and frequencies, spill dispersion characteristics, and spill prevention and control measures is provided in Appendix E. A summary of oil spill expectation is also given in Section C.2 and in Tables C.2-1 and C.2-2. Possible effects on water resources are considered in this section.

Probable movements of spills occurring east of SEAWAY Tank Farm are identical to those for Bryan Mound (see Section C.3.2.2).

Spills from Allen dome not contained within diking would enter the San Bernard River watershed. The most likely drainage path is an existing swale which passes through a subdivision (Bernard Acres) and enters the river near a marina. Spills from the pipeline route west of the community of Jones Creek could enter the San Bernard watershed or diffuse southward into marsh between the San Bernard River and the proposed SEADOCK Terminal.

Oil spills are most likely to reach the Gulf of Mexico as a result of a direct release from oil tankers.

Quantities of oil expected to be released from the early storage facilities at Bryan Mound and from SPR expansion facilities at Allen dome are listed by source and location in Tables C.2-1 and C.2-2. Total oil spillage for five fill/withdrawal cycles is projected to be 1930 barrels for the early storage facility and an additional 3658 barrels for the Allen dome facilities. Of the total, 74 percent is projected to occur during fill operations, 24 percent during withdrawal, and less the 2 percent (53 barrels) during standby storage. The distribution of spills is projected to be 2746 barrels (49 percent) in the Gulf of Mexico (principally at the VLCC - tanker transfer location), 1467 barrels (26 percent) at the tanker docks, 1237 barrels (22 percent) at the Allen dome, Bryan Mound, and SEAWAY Tank Farm, and less than 80 barrels from the connecting pipelines. The maximum credible spill events are estimated to be 60,000 barrels resulting from a tanker collision, 10,000 barrels from a pipeline rupture, 5000 barrels from storage terminals, and 500 barrels from transfer operations.

Weathering processes and dispersal characteristics of oil are given in Section C.3.2.2.

Two potentially significant impacts of oil spills in water reservoirs would be the potential for buildup of toxic fractions and depletion of oxygen levels in shallow, poorly flushed water bodies. The most likely location of such waste would be in coastal bays and marshes southwest and northeast of Freeport (including the vicinity of San Bernard Natural Wildlife Refuge) and, to a lesser extent, in Jones Creek, the San Bernard River, or in Mud Lake or Unnamed Lake on Bryan Mound. Because of the 25 mile distance from the VLCC transfer point to shore, the diking around tanks at Bryan Mound, and the very unlikely occurrence of expected pipeline spills, such impacts are not expected (that is most spills should occur in open Gulf waters, at the docks, or within the diked terminals).

Oil spills reaching the Brazos River, Freeport Harbor, the ICW, or the open Gulf should not have significant impacts on water quality because of the potential for dilution and for oil recovery. Spills reaching the San Bernard River may also be diluted but the potential for adverse effects on water quality are significant. Oil which sinks to the bottom or is deposited on the shoreline or riverbanks may provide a local source of petroleum hydrocarbon to the water column for several weeks or even months.

There should be no impact on domestic or other human surface water supplies as all waters in the vicinity of project operation are too saline for consumption.

As at Bryan Mound, surface spills are not likely to affect ground water in the area because there appears to be little recharge to the Chicot aquifer. Subsurface spills caused by a highly unlikely cavern collapse could flow down gradient to Brazosport communities, however.

Thus, although the potential exists for a very large crude oil spill, calculations of spill probability and the nature of local water bodies indicate that significant impacts on local water resources should not occur.

Brine Spills

During project operation, brine spills could occur from the brine disposal pipeline and from the brine reservoir; saline water could be spilled from the raw water supply line and from the brine disposal line (during standby storage). A thorough description of possible modes of spills, methodology of spill calculation, quantification of expected spill volume and frequencies, spill dispersion characteristics, and spill prevention and control measures is provided in Appendix E. A summary of spill expectation is also given in Section C.2 and in Table C.2-3. Possible effects on water resources are considered in this section.

Probable movements of spills occurring east of SEAWAY Tank Farm are identical to those for Bryan Mound (see Section C.3.2.2).

Spills from Allen dome not contained within diking would enter the San Bernard River watershed. The most likely drainage path is an existing swale which passes through a subdivision (Bernard Acres) and enters the river near a marina. Spills from the pipeline route west of the community of Jones Creek could enter the San Bernard watershed or diffuse southward into marsh between the San Bernard River and the proposed SEADOCK Terminal.

Brine spills are most likely to reach the Gulf of Mexico as a result of a direct release from rupture of the brine line.

Brine and raw water spills are expected to occur only from the piping system. Total spillage is estimated to be 75 barrels of brine and 115 barrels of raw water from early storage operation and 513 barrels of brine and 895 barrels of raw water from SPR expansion facilities. Of the total, 210 barrels of brine and 78 barrels of raw water would spill into the Gulf of Mexico; 378 barrels of brine and 933 barrels of raw water would spill onto primarily coastal prairie and marshland between Bryan Beach and Allen dome (Table C.2-3). The maximum credible spill event is estimated to be 30,000 barrels of brine excluding possible release of up to 100,000 barrels of brine due to hurricane breaching of the storm levee and brine reservoir.

There should be no impact on domestic or other human surface water supplies as all waters in the vicinity of project operation are too saline for consumption.

As at Bryan Mound, surface spills are not likely to affect ground water in the area because there appears to be little recharge to the Chicot aquifer. Subsurface spills caused by a cavern collapse could flow down gradient to Brazosport communities, however.

Spills of brine or saline water have less potential for adverse effects on water quality than do oil spills. Except for a very large brine spill, normal flushing of most local water bodies (e.g. the ICW, Brazos Diversion Channel, Brazos and Freeport Harbors, Gulf of Mexico) would quickly dilute salt concentration to normal levels resulting in very temporary water quality degradation. Flushing is not as effective in Jones Creek or in Mud Lake and Unnamed Lake at Bryan Mound, however; salinity excesses would continue in the water bodies for several days or even weeks.

Thus, although the potential exists for a very large brine spill, calculations of spill probability and the nature of local water bodies, indicate that significant impacts on local water resources should not occur.

Hazards Due To Flooding

Surface facilities at Allen dome and Bryan Mound would be subject to potential flooding caused by hurricanes or tropical storms (flooding at Bryan Mound is considered in Section C.3.2.2). Surface elevations over the dome vary from 0 to 6 feet MSL. Elevations in the marsh and coastal prairie adjacent to the dome are less than 6 feet MSL and at the proposed dock sites are about 4 feet MSL. A storm levee would be constructed around facilities at Allen dome to a height of +22 feet MSL. Data supplied by the U.S. Army Corps of Engineers indicates that the 100 year flood level at Allen dome is +14 feet MSL, excluding the effects of wave runup.

Storm flood greater than the 100-year event could occur and could damage surface facilities. In the event of an oncoming storm, oil would be displaced from the surface tanks at Bryan Mound with water, thus eliminating the largest spill potential. If surface piping were ruptured, a few barrels of oil could escape but would be retained within the diked areas. Damage to well head piping at Allen dome could result in loss of a few barrels from the cavern. Brine from the pond would be quickly diluted by sea water.

As only limited quantities of oil could be released in the event of a damaging storm flood, environmental effects due to the flood waters and winds are expected to be much greater than those due to loss of oil or brine.

Alternative Facilities

Use of the San Bernard River for raw water supply should not create significant adverse impacts on water quality in that estuary though average salinities would be increased. As indicated in Section C.4.1, the difference between water supplied by the river and water withdrawn for this project would be made up by flow into the estuary from the Gulf of Mexico.

Use of ground water to displace oil from the cavern has roughly the same potential for adverse impact, especially surface subsidence, as described for Bryan Mound.

Withdrawal of water from the Gulf of Mexico should have no measurable impact on water quality.

As brine disposal rates during operation would be less than 40 percent of the rates needed for cavern leaching, the potential for impacts should be less than during construction. Disposal of brine directly to the Gulf through an alternative diffuser 5.8 miles off Allen dome would create a second source of high salinity water with impacts as described in Section C.4.1.2 (brine disposal from Bryan Mound would be the other). Use of the diffuser 12.5 miles offshore Bryan Mound would have effects as described in Section C.3.2.2. The influence on water quality from each would be much less than during cavern leaching.

Use of a marine pipeline for oil movement would reduce the expected quantities of oil spill volume by about 60 percent. Onshore oil spillage would be essentially unaffected.

C.4.2.3 Air Quality

Operation of storage facilities at Allen dome would result in the same type and amount of emissions as described in Section C.3.3.3 for Bryan Mound. The inventory of total hydrocarbon emissions for Allen dome development over the project lifetime are set forth in Table C.3-6. As explained in Section C.3.2.3, emissions during oil fill are larger than during withdrawal. Storage tank emissions (574 tons) and brine pond emissions (158 tons) attributable to the early storage phase would still occur but the brine pond emissions from expansion (251 tons) now occur at Allen dome. Average annual storage tank emissions (including consideration of elevated crude oil temperature) would be about 23 tons/year, except 136 tons/year if withdrawal occurs during the year.

Oil transfer scenarios for determining worst case ambient concentrations are unchanged (see Section C.3.2.3). Thus, NAAQS-HC exceedance may occur to distances of up to 34 km downwind of VLCC transfer location in the Gulf and up to 13 km from the DOE docks at Freeport. Neither storage tank nor brine pond emissions would cause standards exceedance by themselves, though occasional additional exceedances may result near these sources when background HC levels are high.

Comments on emission source interaction for Bryan Mound SPR expansion apply to Allen dome expansion.

Alternatives

As for Bryan Mound SPR expansion, alternatives which would alter air quality impacts are use of a marine terminal and onsite power generation. Estimated reductions in emissions archieved by using a marine terminal are as follows: 1) at the VLCC transfer location, reduction from 12,237 tons to 7188 tons; 2) complete elimination of tanker transit emissions (627 tons); 3) elimination of transfer emissions at tanker docks (12,187 tons). Total hydrocarbon emissions due to oil handling during the project lifetime would thus be reduced from 26,170 tons to 8171 tons. Also, the source of most serious onshore pollutant emissions, oil transfer at Freeport Harbor docks, would be eliminated so that very infrequent additional NAAQS exceedances would occur.

Onsite generation of 16,000 kilowatts of power capacity would emit pollutants on Allen dome at rates approximately one-half of those given in Section C.3.2.3. Total hydrocarbon emissions over a 22-year operating life would be 1275 tons. These emissions would not interact significantly with those at Bryan Mound, however.

C.4.2.4 Noise

Noise impacts caused by operating SPR facilities at Allen dome would be essentially the same as described in Section C.3.2.4 for Bryan Mound. Though the community of Bernard Acres is less than one-half mile from the site, noise impacts from pumping and other operations should not be noticable.

C.4.2.5 Species and Ecosystems

Raw Water Withdrawal

Biological impacts associated with withdrawal of 1 MMB of water per day from the Brazos River Diversion Channel for displacment of oil from the storage caverns would be essentially identical to those for Bryan Mound SPR expansion (Section C.3.2.5). A very small fraction (less than 1 percent) of plankton and other small organisms in the tidal estuary would be destroyed.

Brine Disposal

Brine discharge rates and biological impacts in the vicinity of the diffuser would be identical to those described in Section C.3.2.5.

Tanker Transport

Biological impacts of tanker transport in Freeport and Brazos Harbors are treated in Section C.3.2.5. and would be indentical to those from development of Allen dome.

Maintenance of Project Lands

The predominant impact on terrestrial ecology of normal operation of the proposed pipeline right-of-way (ROW) and other project lands would result from the periodic maintenance required for access, surveillance, and monitoring. During operations, right-of-way maintenance could cause a disruption of the soil and vegetation due to vehicle movement and possible spraying for weed control. Spraying and mowing operations could increase the fire hazard potential unless proper procedures are utilized. The overall impact of pipeline maintenance can be minimized if care is taken to minimize vehicular movement in the right-of-way and to be selective with weed control spraying, using only biodegradable herbicides having short half lives with minimum toxicity to animals or man.

Normal operation of project lands could have limited effects upon wildlife. Noise from operations may have an adverse effect upon wildlife. Much of the work on noise and its effect upon wildlife has been confined to laboratory studies; however, it is understood that animals directly affected by noise are those that are capable of responding to sound energy, especially those animals that rely on auditory signals to find mates, stake out territories, recognize young, detect and locate prey, and evade predators (Memphis State University, 1971). These functions could be affected even if animals appear to be adapted to the noise (i.e., even if animals show no behavioral response such as becoming startled or avoiding the area). Because of the complex interrelationships among all animals in an ecosystem, other animals may be indirectly affected by noise even if they cannot respond to sound (Memphis State University, 1971). The effect of noise upon wildlife largely depends upon the frequency, intensity, duration, and pattern of exposure to which an animal is subjected. Noise levels should not be noticeable on most portions of project lands.

Maintenance of the pipeline and the elimination of cover may have adverse effects upon some wildlife species. Continued clearing of brush could prevent small rodents and other wildlife from becoming established on the pipeline corridor. Brush clearing would maintain the "edge" effect, however, and encourage new growth of established plant species, thus providing a continued food source for herbivourous wildlife.

Human intrusion during operation and maintenance of the pipeline would have minimal short term effects upon wildlife. These brief periods of human activity along the pipeline may cause wildlife to leave the immediate area, but only for a short time (in most instances, a matter of hours).

Accidental Oil or Brine Release

The potential for oil spills during project operation is described in Appendix E; expected annual spill volumes by mode of operation and by geographical location are summarized in Section C.2, particularly Table C.2-1 and C.2-2. In the event of an oil spill, the expected movement from various spill locations, the weathering processes likely to occur, and the potential for water quality degradation are described in Sections C.3.2.2 and C.4.1.2. This section treats some of the site-specific biological effects which can occur as a result.

Summarizing the information on frequency and volume of expected oil spills for Allen dome in Tables C.2-1 and C.2-2: total oil spillage for five fill/withdrawal cycles is projected to be 1930 barrels for the early storage facility and an additional 3658 barrels for the SPR expansion facilities at Allen dome. Of the total, 74 percent is projected to occur during fill operations, 24 percent during withdrawal, and less than 2 percent (53 barrels) during standby storage. The distribution of spills is projected to be 2746 barrels (49 percent) in the Gulf of Mexico (principally at the VLCC-tanker transfer location), 1467 barrels (26 percent) at the tanker docks, 1237 barrels (22 percent) at the Allen dome, Bryan Mound, and SEAWAY Tank Farm, and less than 80 barrels from the connecting pipeline. The maximum credible spill events are estimated to be 60,000 barrels resulting from a tanker collision, 10,000 barrels from a pipeline rupture, 5000 barrels from storage terminals and 500 barrels from transfer operations.

Frequencies of spills are also given in the summary tables except for transfer spills, all modes of spills are expected to be very infrequent. For example, a single fill of 100 MMB for Allen dome site development is estimated to result in about 28 oil spills, 23 of which would occur at the VLCC - tanker transfer location. A single withdrawal would result in about 2 spills, most likely occurring at the tanker loading dock.

For very large spills, the following reoccurrence intervals are estimated for a 163 MMB facility (based on Appendix E): marine transportation, 10,650 years for spills greater than 10,000 barrels; pipelines, more than 200 years for spills greater than 1000 barrels; for terminals, more than 153 years for spills greater than 1000 barrels.

Because of the very low frequency of expected spill accidents, chronic pollution by oil spills should not occur on Allen dome, Bryan Mound, or along the proposed pipeline routes. A large spill of oil in the vicinity of Allen dome could reach the San Bernard River, the adjoining National Wildlife Refuge south of the dome, or the coastal bays and marshes. Severe impacts to vegetation, aquatic life, terresterial mammals, and, particularly, bird life could result. Other potentially sensitive areas exposed to oil spills are: Jones Creek and adjacent prairie land along the pipeline right-of-way; shallow lakes and ponds on Bryan Mound; and nearshore gulf waters and shorelines.

Estimates made in Section C.3.2.5 of habitat acreages which might be destroyed by maximum credible oil or brine spills apply to the Allen dome site alternative. As indicated above, however, habitat exposed pipeline and storage site spills for Allen dome are particularly sensitive. With maximum spreading, a large tanker spill could destroy 1680 acres of wetlands and as much as 7000 acres of benthos habitat in shallow coastal waters. A large pipeline spill could destroy 380 acres of wetlands (or prairie) and 1340 acres of shallow water habitat. Impacts of brine depend on mixing and dilution potential. The most sensitive areas would probably be the pipeline right-of-way between Allen dome and SEAWAY Tank Farm, and the lakes and ponds on Bryan Mound.

In summary, except for the case of a very large oil spill (or a moderately sized spill in a sensitive area), biological impacts are not expected to be of regional significance. The expected frequency of potentially large spills is very small.

Accidental Brine Release

The potential for brine spills during project operation is described in Appendix E; expected annual spill volumes, by mode of operation and by geographical location are summarized in Section 4.2 and Table C.2-3. In the event of a brine spill, the expected movement from various spill locations, the weathering processes likely to occur, and the potential for water quality degradation are described in Sections C.3.2.2 and C.4.2.2. This section treats some of the site-specific biological effects which can occur as a result.

Brine and raw water spills are expected to occur only from the piping system. Total spillage is estimated to be 75 barrels of brine and 115 barrels of raw water from early storage operation and 513 barrels of brine and 895 barrels of raw water from SPR expansion facilities. Of the total, 210 barrels of brine and 78 barrels of raw water would spill into the Gulf of Mexico; 378 barrels of brine and 933 barrels of raw water would spill onto primarily coastal prairie and marshland between Bryan Beach and Allen dome (Table C.2-3). The maximum credible spill event is estimated to be 30,000 barrels of brine excluding possible release of up to 100,000 barrels of brine due to hurricane breaching of the storm levee and brine reservoir.

Frequencies of spills are also given in the summary tables. Except for transfer spills, all modes of spills are expected to be very infrequent. For brine spill, there is a 90.4 percent chance of having no spills during the project lifetime for the Allen dome development; similarly, there is a 83.6 percent chance of no raw water spills.

Because of the very low frequency of expected spill accidents, chronic pollution by brine should not occur on Allen dome, Bryan Mound, or along the proposed pipeline routes. Potentially sensitive areas exposed to brine spills are Jones Creek and adjacent prairie land along the pipeline right-of-way classified as critical habitat by the General Land Office of Texas (Figure B.2-29), shallow lakes and ponds on Bryan Mound, and nearshore Gulf waters and shorelines. Impacts of brine depend on mixing and dilution potential. The most sensitive areas would probably be the pipeline right-of-way between Allen dome and SEAWAY Tank Farm, and the lakes and ponds on Bryan Mound.

In summary, except for the case of a very large brine spill (or a moderately sized spill in a sensitive area), biological impacts are not expected to be of regional significance. The expected frequency of potentially large spills is very small.

Alternatives

Use of a ground water supply system or a deepwell injection system would represent an additional, relatively small, exposure of prairie grassland to brine spills.

Use of a marine pipeline and monobuoy would substantially reduce the offshore and harbor exposure to oil spills (by about 60 percent).

Withdrawal of raw water from the San Bernard River would substantially reduce the exposure to raw water (not brine) spills, but would represent a more significant potential for loss of large numbers of phytoplankton, zooplankton, and small fish, as well as slightly modifying the salinity regime of the tidal estuary. Aquatic species common to the San Bernard River include the tidewater silverside, southern flounder, bay anchovy, Atlantic croaker and fringed flounder.

Use of pipelines to withdraw water from and dispose brine directly into the Gulf of Mexico or through a diffuser 12.5 miles off Bryan Mound would not significantly affect biota in the open Gulf as described in Sections C.4.1.5 and C.3.2.5, respectively. Maintenance of the pipeline right-of-way along the east bank of the San Bernard River would displace certain wildlife species temporarily and may result in some sedimentation. More significantly, there would be a greater exposure to brine spills in the lower San Bernard, in the adjacent wildlife refuge, and in the coastal bays and marshes. Maintenance of the onshore portion of the 12.5 mile diffuser pipeline to the Gulf would have the same impacts as those associated with the 5.8 mile diffuser dealt with earlier in this section.

C.4.2.6 Natural and Scenic Resources

Operation and maintenance of the project facilities, pipelines and alternative facilities would have no additional significant impacts on recreation or natural resources in the local area. However, in the event of an oil or brine spill affecting wildlife habitat, recreation activities could be significantly impacted because of the potential for affecting the San Bernard Wildlife Refuge.

The project facilities would continue to have an adverse aesthetic impact on the nearby residential development. The degree of impact would depend upon the flood control measures used to protect onsite facilities. If the area is protected by vegetated levees or grading, many of the facilities would be hidden from the view of the residents.

Burial of pipelines would minimize the visual impact of project facilities; however, maintenance right-of-way and the aboveground facilities at Allen dome would detract from the largely undisturbed nature of the existing local environment and nearby housing areas.

C.4.2.7 Archaeological, Historical and Cultural Resources

There would be no effect on known archaeological, historical, or cultutal resources as a result of operation of the Allen dome site.

C.4.2.8 Socioeconomic Environment

Land Use

Operation of the project would constitute a major longterm change in the existing local land use at Allen dome, which is now mostly undeveloped. The 184-acre project site would be fenced off and dedicated for use as an oil storage facility. Of the 494 acres required for construction offsite and within the fence only 313 acres would be needed for maintenance. Some of this land would be revegetated and return to present uses. No structures could be erected within the pipeline right-of-way.

Transportation

Operation and maintenance activities would have a minimal effect on local transportation facilities since the labor force would be limited to a few maintenance people (10) plus a relatively small crew (approximately 30 at Allen dome and 25 at Bryan Mound) for filling and withdrawing operations.

During withdrawal of oil during an embargo or curtailment of supplies, the tanker traffic in Freeport harbor would amount to 1.57 vessels per day for a period of 163 days. This traffic volume is based upon the assumption that 40 percent of the 163 MMB of oil stored would be transported through the harbor and that the size of vessel utilized would be 32 DWT (254,000 BBL capacity). At the time this traffic occurs in the harbor, it is likely that a concurrent decrease in other waterborne traffic would occur as a result of the oil supply interruption. Refill of the storage capacity of 163 MMB of oil would occur over a 2.4-year period, increasing traffic in Freeport Harbor by one vessel (32,000 DWT) every day.

Population and Housing

During the normal operation period, only a small number of personnel would be involved (approximately 10 persons). The impact on population and housing would be slight in the local area and insignificant in the region. During emergency withdrawal and ensuing refilling activities, some additional personnel may be required (about 55). Most of these workers would commute to the site, as housing is in relatively short supply and employment would be temporary.

Economy and Employment

Operation activities would have no significant impacts on the local or regional economy, due to the nature of the storage activity and the small size of the operational crew (estimated at about $17,500 monthly wages). Filling and withdrawal would require additional manpower, increasing monthly wages to about $96,000 per month. This would be a small and temporary increase and would have little effect on the area's economy.

Brazoria County would lose some property tax revenues since the project would remove the site from the local tax roles. This should have only a minor impact on county finances due to the current undeveloped nature of the sites. As shown in Section C.4.1.8, the annual property tax loss would be small.

Government

During project operation, no adverse impacts are anticipated on urban services, due to the small number of employees involved.

The project would supply its own security and fire protection, which lessens the need for those public services.

Alternatives

Use of alternative facilities for Allen dome SPR operation should not greatly alter socioeconomic impacts. Maintenance of well fields or pipelines to the Gulf would involve additional activity in the presently rural area. Total employment may be slightly increased for some alternatives, but not enough to represent a significant change in present conditions. Withdrawal of water from the San Bernard would not reduce the total pipeline right-of-way acreage because brine and oil lines would be in the same corridor. Use of an offshore marine terminal would eliminate SPR tanker traffic from the Freeport and Brazos Harbors.

C.4.3 Impact Due to Termination and Abandonment

Impacts caused by termination and/or abandonment of the Allen dome storage site as an oil storage facility would be essentially the same as described in Section C.3.3 for Bryan Mound.

C.4.4 Relationship of Proposed Action to Land Use Plans, Policies and Controls

The proposed project is anticipated to be generally consistent with the flexible land use planning practiced in Brazoria County (Section 4.3.4). It is not anticipated that the Allen dome site would be in conflict with any state land use plans or policies.

C.4.5 Summary of Adverse and Beneficial Impacts

Land use impact of developing this candidate site center on the amount of land required. At the dome, 184 acres would be enclosed by a security fence. Within this area, approximately 31 acres would be required for construction of onsite facilities. Construction of the backup injection wells and pipelines from Allen dome to Bryan Mound to transport oil, brine and raw water would disrupt 125 acres. Construction of systems common to each site would require 185 acres for the offshore brine diffuser pipeline, pipeline connections to Brazos Harbor and the new tanker docks.

Development of the Allen salt dome as an oil storage facility is not likely to generate significant regional environmental impacts except for the remote possibility of a major oil spill and the uncontrolled release of hydrocarbon vapors during oil transportation. Construction and use of a marine terminal would reduce hydrocarbon emissions by more than 50 percent and would minimize the chance of a nearshore oil spill. The Allen dome site has not been extensively used for industrial purposes and thus construction of storage facilities and pipeline would cause potentially significant local disruption. Although much of the area has a high primary biological productivity, the amount of land permanently affected by the project is small in relation to the amount of similar land in the area. Noise is expected to cause some adverse effects to local residents during facility construction.

Although the project would require large quantities of water for mining and oil displacement, the total raw water demand of the project constitutes less than one percent of the average flow from the Brazos River Diversion Channel. The disposal of brine in the Gulf of Mexico is expected to increase the salinity of the waters adjacent to the brine diffusers. This increase could have an adverse effect on marine organisms in the local area and could interfere with migration of some estuarine species. The construction of brine disposal wells as a backup system would temporarily disrupt approximately 26 acres of prairie land east of the site. The construction and operation of dock facilities in Freeport Harbor is not likely to have a significant impact on either the ecology of the area or the water quality of the harbor, as the area is extensively dredged. Construction of either alternative brine disposal system to the Gulf would temporarily disrupt some coastal lands.

During the construction phase of the development of Allen dome, increases in income and employment in the Freeport region are expected. These increases would be of short duration and are not expected to provide long-term stimulation sufficient to permanently affect the area's economy. The operational increase due to the Allen dome and Bryan Mound SPR facilities is expected to be small and would provide approximately $17,500 per month in additional income to the local area during standby storage and $96,000 during oil fill and withdrawal. Temporary increases in traffic congestion in the Freeport and Allen dome area could be expected during the construction phase. The indirect economic benefits, however, of the Strategic Petroleum Reserve program are of considerable importance to the local economy, as the area is highly dependent upon the petroleum-petrochemical industry for employment. Assurance of a continued oil supply in the event of a national emergency would provide a measure of security for the residents of the area.

C.5 WEST COLUMBIA DOME ALTERNATIVE SITE

West Columbia dome is located approximately 45 miles southwest of Houston and 25 miles northwest of Freeport (Figure A.5-1).

C.5.1 Impact of Site Preparation and Construction

Land Features

Grading at the 232-acre West Columbia site would disturb about 30 acres for construction of storage wells pads, a central pumping station, pipelines and access roads connecting the wells to the pumps, oil and raw water tanks, a brine pond, and transformer banks. About 63,000 cy of fill would be placed in the freshwater marsh at the site.

Pipelines connecting West Columbia to SEAWAY Tank Farm and Bryan Mound for transport of raw water, crude oil, and brine would require excavation of 419,120 cy and disruption of 279 acres (Table A.5-1). An additional 3 acres and 12,150 cy of fill would be required for pipelines and pads for 3 backup brine injection wells. Construction of the proposed brine diffuser to the Gulf of Mexico from Bryan Mound would create impacts as described in Section C.3.1.1.

Soils would stabilize soon after revegetation but filled marsh areas would become coastal prairie rather than marsh. Adequate drainage would be provided to prevent stagnation of impounded freshwater marsh.

Construction of the two tanker docks and pipeline connections to in Old Brazos Harbor would create the impacts described in Section C.3.1.1.

Leaching of twelve storage cavities in West Columbia dome would involve removal of 100 MMB of salt by leaching and disposal in the Gulf of Mexico. This is equivalent to 20.8×10^6 cy of salt. Sufficient space is to be left between cavities to insure structural integrity.

Alternatives

Feasible system alternatives at West Columbia dome include: (1) development of a well field for raw water supply; this would require about 22 acres and 31,200 cy of fill for drill pads and pipeline right-of-way, located along the proposed brine and oil pipeline right-of-way; (2) disposal of brine in deep saline water hearing sands; this would require about 19 acres and 19,000 cy of fill for drill pads and pipeline right-of-way, also located along the proposed oil line right-of-way; (3) disposal of brine using a diffuser 12.5 miles offshore from Bryan Mound which would require 163 additional acres of offshore construction right-of-way; (4) onsite power generation, which would require very little additional land disturbance; (5) use of SEAWAY or Phillips Docks by DOE or construction of a marine terminal for oil transport (see Section C.3.1.1).

C.5.1.2 Water Resources

Site preparation and construction of proposed facilities at West Columbia salt dome may impact several water bodies, including: ground water aquifers, the Gulf of Mexico, ICW, Freeport Harbor, lakes and ponds on Bryan Mound, the Brazos River Diversion Channel, Bell Creek, and, possibly Varner Creek.

Raw Water Withdrawal

Potential impacts to the Brazos Diversion Channel are identical to those described for Allen dome in Section C.4.1.2.

Brine Disposal

Potential impacts to the Gulf of Mexico are similar to those described for Bryan Mound in Section C.3.1.2.

Dock Construction

Potential impacts to Freeport Harbor are identical to those described for Allen dome in Section C.4.1.2.

Construction of Surface Facilities at West Columbia Dome

The proposed water supply, brine disposal, and oil pipelines would cross Bell Creek and several intermittent streams in the 23-mile segment between the storage site and SEAWAY Tank Farm (Figure A.5-2). East of SEAWAY Tank Farm, the water supply and brine pipelines would cross Jones Creek, the Brazos River Diversion Channel, and Unnamed Lake on Bryan Mound. Trench excavation through water bodies would create increased turbidity and release soluble substances from the substrate to the water column. Impacts would be temporary and local in extent.

There should be no impact on ground water supply or quality due to pipeline installation.

Accidental Brine Release

Leaching of 100 MMB of oil storage capacity from West Columbia dome requires transport of saline water from the Brazos River Diversion Channel and disposal of brine to the Gulf of Mexico. In addition to the impacts previously described for normal operations, a possible brine (or raw water) spill could affect water resources in Varner, Bell, and Jones Creeks, Brazos River Diversion Channel, lakes and ponds on Bryan Mound, the ICW, and the Gulf of Mexico.

The estimated quantity of brine to be spilled during leaching of West Columbia storage cavities is 50 barrels into Gulf of Mexico waters and 240 barrels onto land, and water bodies between Bryan Beach and West Columbia dome (Table C.2-3). In addition, an estimated 235 barrels might be spilled from the raw water supply system. Maximum credible spills of up to 30,000 barrels of water are considered possible, though highly unlikely.

Since average brine spill volumes are estimated to be 5000 barrels, the computation of such low spill expectations reflects the remote chance of any spill occurring. Thus, there is an 84 percent chance that no brine would be spilled from all pipeline uses (including operation) during the project lifetime (see Appendix G). If a pipeline rupture does occur, release of 5000 or more barrels of brine could significantly degrade water quality, especially in smaller water bodies such as Varner, Bell, or Jones Creeks, or the lakes and ponds at Bryan Mound. Quantities of water required to dilute a maximum credible brine spill to concentrations near ambient are estimated in Section C.3.1.2. Prior to achieving this mixing, salt concentrations would be abnormally elevated.

A brine spill at the site or along the disposal pipeline could locally impact the water quality in the upper unit of the Chicot aquifer. The brine would tend to migrate downward within the formation and downdip along the formation due to density differences. A massive spill, although highly unlikely, could possibly impact the quality of municipal water supplies pumped from aquifers in the town of West Columbia or in the Brazos port area by causing increased salinities in those aquifers. As local recharge of near surface aquifers has been found to be minimal, potential seepage from the lined brine pit or minor pipeline spills are likely to have negligible impact on water quality.

Brazos River backwater flood studies conducted by the U.S. Army Corps of Engineers indicate that the 100-year flood elevation at West Columbia is 33 feet MSL (Trahan, personal communication). Elevations in the vicinity of plant facilities range from 25 feet MSL to 35 feet MSL. Thus, the brine pond would have to be protected from backwater floods from Varner Creek by a dike. As no strong currents or waves would be generated, there is no reason to expect a possible brine pond failure.

Alternative Facilities

Withdrawal of ground water for raw water supply is potentially feasible but has the same potential for lowering the piezometric head, for saline water intrusion, and for land subsidence as described for Bryan Mound (Section C.3.1.2). Land subsidence is a particularly troublesome result of present ground water pumping in Brazoria County.

Brine disposal to deep salt water bearing sands at West Columbia dome has the the same potential for adverse impacts as at Bryan Mound and Allen dome. It is expected that proper injection methods would avoid any adverse impacts to water or mineral resources in the area.

Brine disposal through a 12.5 mile offshore diffuser to the Gulf of Mexico from Bryan Mound and impacts associated with construction of alternative oil distribution facilities are described in Section C.3.1.2.

C.5.1.3 Air Quality

Air quality impacts caused by construction of the proposed and alternative facilities for the West Columbia salt dome would be essentially identical to those for the Allen dome site alternative described in Section C.4.1.3, where the impacts were concluded to be minor.

C.5.1.4 Noise

Similar facilities and construction activities as those described for Allen dome (Section C.4.1.4) are planned for West Columbia dome.

The noise impact zone radii are presented in Table C.5-1 and Figure C.5-1. The significance of these zones is described in Section C.3.1.4. Approximately five residences may experience a noticeable increase in noise levels from construction activity at West Columbia dome.

Along the pipeline route from West Columbia dome to SEAWAY Tank Farm, residences and other public lands within 1800 feet of the pipeline route would be exposed to sound level increases of at least 3 dB. Since the route follows existing pipeline right-of-way for most of its length and construction activities would be completed within 2 or 3 days at any given location, noise impacts should not be severe.

Alternatives

Construction of a raw water or brine disposal well field along the proposed pipeline route would contribute noise levels of a magnitude similar to the onsite drilling activities. The zone of impact would thus be extended further to the west in a sparsely populated area of fluvial woodland and Coastal Prairie. Construction of a marine terminal and the 12.5 mile offshore diffuser would have no measurable effect on onshore noise levels.

C.5.1.5 Ecosystems and Species

Site preparation and construction of the proposed facilities for West Columbia dome may affect both terrestrial and aquatic resources in the area. Terrestrial habitats potentially affected include coastal prairie grassland, fluvial woodlands and fresh marsh (Table B.5-1). Aquatic habitats include Varner Creek, Bell Creek, Jones Creek, Brazos River Diversion Channel, ICW, several lakes and ponds at Bryan Mound, Freeport and Brazos Harbors, and the nearshore Gulf of Mexico. Figure C.5-2 shows the major habitats in relation to proposed and alternative SPR facilities.

TABLE C.5-1 Summary of Construction Noise Impact-West Columbia Site. candidate SPR storage site (alternative site)

Area	Activity	Impact Zone Radius (feet)[a]
West Columbia Site	Drilling new shafts	3600
	Construction of support facilities	1580
Pipeline Routes	Laying of pipe	1430 to 1800
	Access road construction	1100
Freeport Harbor Brazos Harbor	Construction of DOE docks	2200

a) This is the distance within which sound levels are raised at least 3dB by activity described, a baseline ambient day/night sound level of 56 dB is assumed for the calculations.

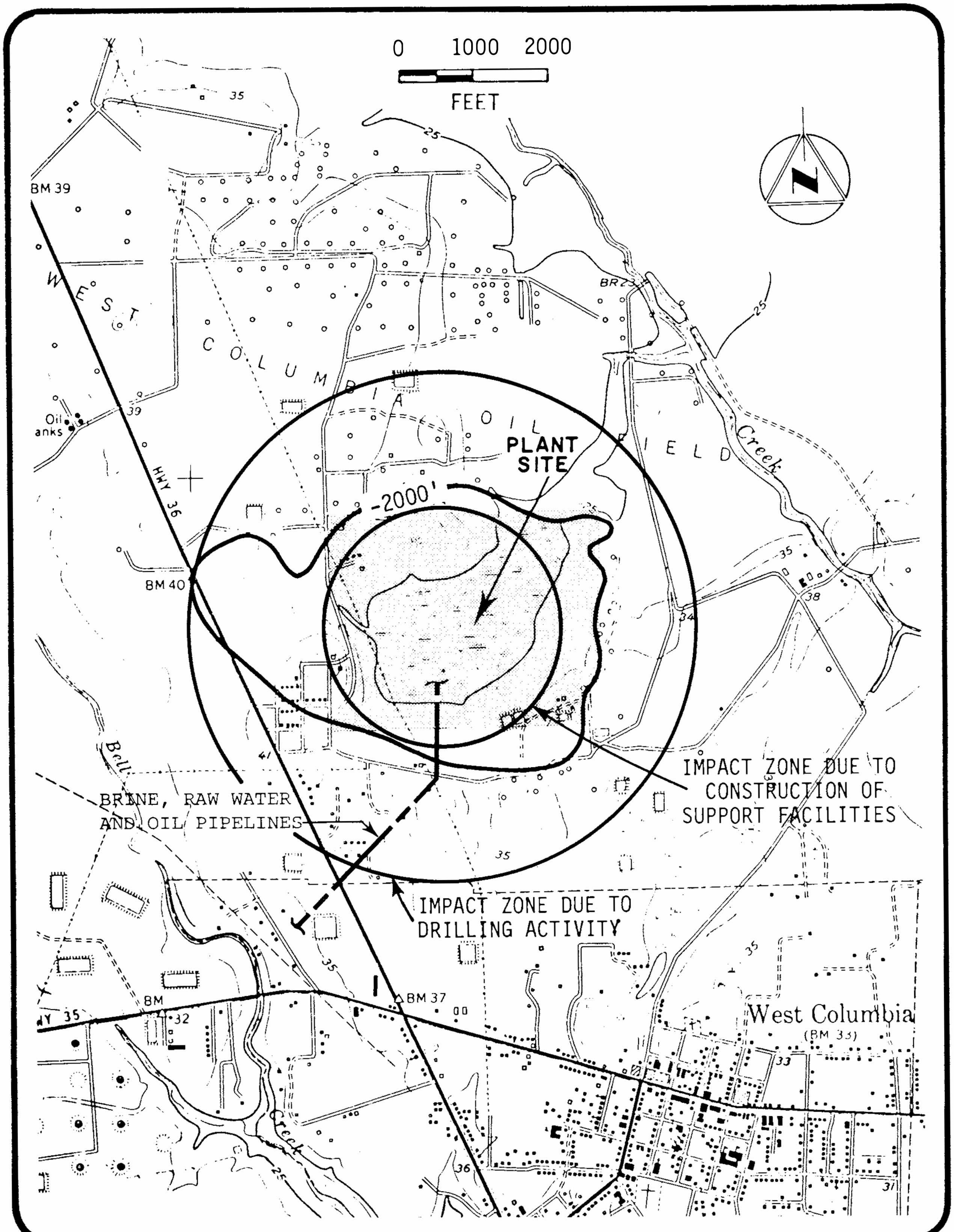

FIGURE C.5-1 Noise impact zones - West Columbia dome candidate SPR storage site (alternative site)

FIGURE C.5-2 Air photo - West Columbia candidate SPR storage site (alternative site)

In the following subsection, potential impacts to biological resources are treated according to specific aspects of facility development.

Raw Water Withdrawal

Impacts of raw water withdrawal from the Brazos River Diversion Channel would be identical to those discussed for the Allen dome site alternative (Section C.4.1).

Brine Disposal

The proposed brine diffuser 5.8 miles offshore Bryan Mound would have impacts on the ecosystems and species in the vicinity as described in Section C.3.1.5.

Dock Construction

Impacts are considered minor. They are identical to those discussed for the proposed Bryan Mound site development (Section C.3.1.5).

Construction of Surface Facilities at West Columbia Dome

New facilities to be constructed at West Columbia dome which involve potential impacts to the site ecology include the construction of 10 to 12 cavern wells, connecting pipelines, pump house, control building, brine settling pond, three brine disposal wells, and a 12 mile utility power corridor.

The West Columbia dome site is located on a 232 acre tract which consists of mostly coastal prairie and fresh water marsh. Site construction activities would reduce the marsh habitat by about 30 acres. Primary production of about 2.9×10^8 Kcal per year (52,000 pounds of carbon per year) would be lost from the ecosystem. This loss would also reduce the amount of food, cover, and nesting area available for the wildlife at the site. Bulldozing of the site would destroy small invertebrates, and perhaps some birds and mammals which inhabit the dome. As indicated in Section B.5.5 the marsh is not considered highly productive but it does provide habitat for egrets and other wading birds. Filling of 30 acres of marsh represents a loss of about 25 percent of the marshland on the dome. After construction has ceased, wildlife would be able to return to portions of the site but the protective fencing around the 232 acre tract would represent a barrier for some larger mammals, such as nutria.

The clearing of the site would result in increased soil erosion (as discussed in Section C.4.1) but this impact should be of a minor and temporary nature.

Construction of Pipelines

A total of 279 acres of land would be required for construction of the proposed raw water, brine, and oil pipelines between West Columbia dome and the SEAWAY Tank Farm. Between SEAWAY Tank Farm and Bryan Mound raw water and brine pipelines would be constructed within an existing right-of-way. Construction activities associated with this land clearing and modification would produce several impacts to the terrestrial environment since the right-of-way would pass through coastal prairie marshland and fluvial forest lands. A primary impact would be the elimination of cover vegetation within the pipeline right-of-way.

Construction activities would displace wildlife from the immediate vicinity of the right-of-way and would eliminate most useful habitat within the 279 acre right-of-way until regrowth of vegetation. Individuals displaced from the pipeline corridor would migrate to nearby lands, thus competing with the residents for food, cover, and resting space.

Significant alteration in wetland drainage patterns could result in long term alteration of habitat. However, except for elimination of woody vegetation, much of the pipeline right-of-way (especially in the coastal prairie), would revert to nearly pre-existing conditions. This would be particularly true if maintenance clearing were minimized to allow growth of natural shrubs, tall grasses and other vegetation easily cleared in case of need for pipeline access.

Loss of cover within the right-of-way would increase the predation rate on the small rodents living along the right-of-way, particularly by predatory birds. Wildlife losses associated with construction would increase if clearing and construction takes place during the nesting and breeding season. Loss of coastal prairie would also reduce the amount of grazing land available to the domestic livestock.

Brush and trees removed from the pipeline right-of-way which goes through woodland areas would result in a permanent loss of this habitat to the woodland species. The removal of this woodland habitat would especially affect arboreal wildlife such as squirrels, raccoon, opossum, and eastern gray treefrog, and woodland perching and nesting avian species such as Cooper's and sharpshinned hawks, owls, and many passerine birds.

The impact from pipeline construction on aquatic habitat would result in the temporary loss of bottom habitat and resuspension of heavy metals, pesticides, and other pollutants from the bottom sediments of Jones Creek. Sedimentation from land runoff would have a variety of effects, including loss of productivity, burying of the benthos, and interference with respiration of fish and amphibians.

Other possible effects associated with pipeline right-of-way construction and maintenance clearing are described in Section C.4.1.5. As most of the proposed route parallels the SEAWAY Pipeline right-of-way, these habitat disturbances would not be unique in the area. Very little wetland habitat is crossed except immediately northwest of Bryan Mound and at SEAWAY Tank Farm. Bell Creek and other drainageways crossed south of West Columbia are intermittent streams. Erosion, siltation and streambed disruption should be easily avoided.

There are no known populations of threatened or endangered species residing in the immediate area of the West Columbia facilities.

Accidential Brine Release

Expected quantities of brine and saltwater spilled during cavern leaching are 290 and 235 barrels, respectively (Table C.2-3). Impacts from such quantities would be of only local importance to terrestrial or aquatic birds. Should a pipeline spill occur, however, the average size is expected to be 5000 barrels, with maximum credible spills of up to 30,000 barrels. Such spills could have considerable adverse impact.

The most likely location for the occurrence of a major brine spill would be onshore between West Columbia dome and Bryan Beach. In such an event, brine (or saltwater) could spread across fluvial woodlands, coastal prairie, brackish marsh, or into Varner, Bell, or Jones Creeks, the Brazos River Diversion Channel, lakes on Bryan Mound, or the ICW. Impacts on vegetation and on animal life which could not avoid the brine would be locally devastating, particularly on terrestrial habitat and in Varner or Jones Creek or Mud lake. Several acres of habitat could be destroyed and salt concentrations in the soil could remain above levels tolerated by new growth for several years. However it must be emphasized that such a spill is statistically very unlikely to occur, especially from so short a section of pipeline.

Should a maximum credible brine release occur in the near shore Gulf of Mexico, bottom organisms, and possibly some organisms in the water column, could be destroyed over an area of several acres. However, the biological impact would be only of local significance; recolonization would begin almost immediately.

Alternatives

Construction of a ground water well field or a brine injection field along the proposed pipeline corridor would eliminate the need for multiple pipelines to Bryan Mound but would not greatly reduce the amount of right-of-way which must be cleared. It is estimated that a raw water supply wellfield would require 10 wells and about 22 acres of land. Similarly a brine injection field would require 19 acres for 19 well pads.

Effects of constructing the alternative brine diffuser 12.5 miles offshore and the oil transportation facilities would be similar to those described for Bryan Mound in Section C.3.1.5.

C.5.1.6 Natural and Scenic Resources

Project construction would have a minor adverse effect on the natural and scenic resources in the area. The storage site itself has no unique scenic characteristics and currently offers a flat, largely featureless view. Some of the proposed onsite facilities may be visible from the roads leading to the Varner-Hogg State Park entrance east of the site. It is unlikely, however, that the facilities would be visible from the park itself due to wooded areas between the facilities.

The view from the houses southwest of the site would be adversely affected by project construction.

The pipeline routes would follow established rights-of-way and would cause a temporary and very minor impact on the natural and scenic resources of the areas crossed.

The brine disposal systems would not significantly change the anticipated impacts on natural and scenic resources.

Alternatives

Development of a raw water supply wellfield or a brine injection field along the proposed DOE and existing SEAWAY Pipeline corridor southwest of the site, or the development of a 12.5 mile offshore diffuser would not significantly affect natural or scenic resources.

C.5.1.7 Archaeological, Historical and Cultural Resources

A comparison of the location of sites listed on the National Register of Historic Places and those sites identified by the Historic Preservation Office for Texas and the location of the SPR facilities has been made. Based on this comparison there are no known sites of historic significance that would be affected. Section 2(a) of Executive Order 11593, "Protection and Enhancement of the Environment" (May 13, 1971) would be complied with as detailed in Section C.3.17.

C.5.1.8 Socioeconomic Environment

Land Use

Land use impacts resulting from development of the West Columbia SPR site depend on the amount of land converted from existing uses to other uses associated with petroleum storage. At the dome, 232 acres of land would be enclosed for the storage site (see Table A.5-1). Within this area, approximately 10 percent will be required for the construcion of onsite roads, the plant area, drill pads, and laydown yards. In addition, approximately 44,000 cubic yards of fill would be required to elevate structures for protection from flooding. This land would be converted from fresh water marshland.

The construction of parallel oil, brine, and raw water pipelines would disturb an additional 279 acres during the construction phase. Most of this disturbed land would be within the 100foot right-of-way required for construction purposes. These pipelines would generally parallel the SEAWAY Pipeline to SEAWAY Tank Farm. Disruption of land for this purpose is the not expected to alter existing land uses in the vicinity. Also, pipeline construction between SEAWAY Tank Farm and Bryan Mound would parallel the planned early storage phase oil line and would not alter basic land use.

Much of the land required for these facilities is in use as range and pastureland. Disruptions during the construction phase would be temporary in duration and much of the land disturbed could return to its present use. Construction of oil tanks at Bryan Mound tanker docks on the Freeport Harbor and the proposed brine diffuser to the Gulf is discussed in Section C.4.1.8.

If raw water supply or brine disposal is accomplished through the use of wells, an additional 19 acres of land may be required for pipeline construction to the well field and for drill pad construction at the field.

Onsite power generation would eliminate the need for a 0.6 mile transmission corridor.

Impacts of construction of oil distribution and other alternatives are the same as those discussed for Bryan Mound (Section C.3.1.8).

<u>Transportation</u>

Project construction activity could significantly increase the traffic volume on Route 36. This highway would carry the over 500 workers (Table C.5-2) to the storage facility site and pipeline route from the Brazosport area in the south and from the Houston and Richmond-Rosenburg area in the north. Truck traffic related to the construction would also increase along this highway. Route 35, which connects Route 36 to the major traffic artery 288 and Angleton, east of West Columbia, is also anticipated to have a significant increase in average daily traffic (Figure B.2-31).

Current traffic volumes on Routes 35 and 36, to the east and south of West Columbia respectively, are just over 5000 vehicles per day (State Department of Highways and Public Transportation, 1975). Traffic associated with the peak month of this project could cause as much as a 20 percent increase in these volumes. Increased congestion on these roads may result during peak periods of construction activity depending upon the time of day during which employees commute to the site, and the number of workers who drive their own vehicles to the site.

Route 36 north of West Columbia has an average daily traffic volume of about 2700 trips. The additional trips related to the project could cause a larger proportional increase in traffic in this area, but is expected to result in less congestion due to the smaller total daily volumes.

Traffic impacts would be temporary in nature as most of the employment and construction activity occur between the second and sixth months of construction. As employment levels decline in later months, the impacts would become less noticeable.

Traffic impacts associated with construction of DOE docks at Freeport should not measurably increase traffic congestion.

Also, the proposed pipeline corridor does not cross many local highways and should not affect traffic flow significantly.

The alternative water supply and brine disposal systems are not expected to cause a significant change in traffic from that experienced with the proposed systems.

The project may have a minimal impact on transportation in the Freeport Harbor due to the increase in oil tanker traffic. All traffic in this harbor, in 1976, amounted to 436 vessels (Brazos River Navigation District). The "worst case" increase in tanker traffic during the initial fill of the 100 MMB storage capacity would amount to one tanker every day. This assumes a tanker capacity of 32,000 DWT, or 254,000 bbl of oil. If SEADOCK is constructed, overall traffic, particularly tankers, in Freeport Harbor will be significantly reduced. The increase in traffic from the SPR program under this assumption, would not cause appreciable congestion.

Population and Housing

The impacts on population and housing near the West Columbia site are expected to be the same as those discussed for Allen dome in Section C.4.1.8. The lack of available housing in West Columbia should further discourage migration to the immediate vicinity of the storage site.

Economy

Construction at West Columbia dome would have a positive effect on construction employment in the four county region (Brazoria, Fort Bend, Harris and Galveston). The project would have a peak construction force of 483 in the second month of construction (Table C.5-2). Most of the construction would occur during the second through sixth months, declining in later months to 132 or less. Most of the labor force is expected to come from the Brazosport and Houston areas as discussed in Section C.4.1.

The project would rely on the Brazosport and Houston areas for services and supplies required for the site preparation and construction activities, thereby providing a stimulus to some sectors of the economy. The retail sales and services sector in West Columbia may be stimulated by the increase in local daytime population.

The project would generate nearly $9.3 million in wages during construction, $3.8 million of which would be earned between and second and sixth months of construction. Some of this income may be distributed to local residents working on the construction, but most of it would be distributed in the same manner as for the Allen dome site (Section C.4.1).

TABLE C.5-2 Estimated construction employment and wages by month - West Columbia (100 MMB) candidate SPR storage site (alternative site)

Month	Number Employed	Monthly Wages
0-1	190	$332,500
1-2	523	915,250
2-3	481	841,750
3-4	374	841,750
4-5	349	654,500
5-6	309	610,750
6-7	132	231,000
7-8	132	231,000
8-9	132	231,000
9-10	132	231,000
10-11	132	231,000
11-12	109	190,750
12-13	109	190,750
13-14	109	190,750
14-15	109	190,750
15-16	109	190,750
16-17	109	190,750
17-18	109	190,750
19-46	55	96,250
Total Construction		$9,285,500

Total income resulting from construction employment has been estimated using the projected employment for each month at an average income figure of $1750 per month for each worker. The resulting income, shown on Table C.5-2, would be highest in the second through sixth months of construction and would total nearly $9.3 million over a four-year period. These expenditures for labor would have a multiplier effect on the local and regional economy, in which direct income accruing to households would be spent in other sectors of the economy. Some of these expenditures would, in turn, be realized as direct income to other households. In Texas, the relationship of one dollar of direct income (expenditure) in the industrial construction sector to income received by all other sectors of the economy has been estimated to be a multiplier of 2.51 (or, more simply stated, for every dollar spent to construct the SPR facilities, $2.51 would be generated as income within the region) (Office of the Governor). This relationship, a Type II multiplier, expresses the direct, indirect, and induced income paid to households per dollar direct income paid to households. Thus, the $9.3 million of direct income from over the four-year construction period would result in $23.3 million direct, indirect, and induced income accrued to households in the region. The geographic distribution of this income would be determined by the workers' places of residence.

The adoption of alternative brine disposal, water supply or oil transportation would not significantly affect the economic impacts of the project.

Government

The large number of construction employees required during the first six months of the project may increase the need for such services as police protection and traffic surveillance. Fire protection at the storage site is to be provided by the West Columbia volunteer fire department, which is not expected to need expanded fire-fighting capabilities. Health care facilities are currently adequate in the area and the proximity of the site to larger facilities in the Brazosport urban areas would be adequate to serve the project.

After the first six months of the construction phase, demand for these services would be greatly reduced.

Project construction is not expected to cause a significant impact on school enrollment in the West Columbia area.

Construction of the West Columbia SPR facility would involve the removal of 232 acres from the tax rolls of Brazoria County. The tax rate in the County is $1.44 per hundred dollars assessed valuation. Assessed valuation is calculated at 20 percent of the fair market value. Assuming a fair market value of $1000 per acre for the West Columbia site, the tax loss would be $668 per year for the life of the project (assuming a negligible increase in either the property value or the tax rate).

Based upon a four percent sales tax on retail sales and assuming that 50 percent of the total household income derived from the project would be spent on taxable purchases, an increase of over $450,000 in tax revenues would be experienced over the construction period.

The adoption of alternative brine disposal, raw water supply, or oil distribution systems would not significantly affect the impacts on urban services.

C.5.2 Impacts from Operation and Standby Storage

Development of 100 MMB of oil storage capacity at West Columbia dome would provide a total capacity of 163 MMB for the Seaway Group of SPR sites. Oil movements would be similar to those described for Allen dome (Section C.4.2). Principal impacts of operation are expected to result from possible large oil or brine spills and from hydrocarbon emissions near the Gulf of Mexico. Impacts from Bryan Mound early storage development are included, where appropriate, to indicate cumulative environmental effects.

C.5.2.1 Land Features

Effects of operation and standby storage on land features are expected to be minimal. The remote possibility of cavern collapse is discussed in Section C.2. There is no recognizable danger due to seismic events. Soils would stablize as soon as they are revegetated following construction.

Operation of alternative facilities would not alter the affect on land features.

C.5.2.2 Water Resources

Impacts to water resources as a result of operating oil storage facilities at West Columbia dome would result from withdrawal of water for oil displacement, discharge of brine during oil fill, maintenance dredging at dock sites, and possible oil or brine spills.

Raw Water Withdrawal

Impacts associated with withdrawing water from the Brazos River Diversion Channel for oil displacement would be identical to those described for Allen dome in Section C.4.2.2.

Brine Disposal

Impacts associated with discharging brine to the Gulf of Mexico via the 12.5 mile offshore diffuser and utilizing a backup 3-well brine injection system southwest of West Columbia dome would be similar to those described for Bryan Mound in Section C.3.2.2.

Maintenance Dredging

Potential impacts due to maintenance dredging at the DOE dock sites would be identical to those for Bryan Mound SPR expansion (Section C.3.2.2) and Allen dome (Section C.4.2.2).

Oil Spills

During project operation, oil spills could occur in the Gulf of Mexico, in the Old Brazos River, from pipelines connecting the storage site with the tanker docks and with SEAWAY Tank Farm, from the well at West Columbia dome and from the early storage phase oil surge tanks at Bryan Mound (releases from the underground storage caverns are not quantified, see Appendix E). A thorough description of possible modes of spills, methodology of spill calculations, quantification of expected spill volume and frequencies, spill dispersion characteristics, and spill prevention and control measures is provided in Appendix E. A summary of oil spill expectations is given in Section C.2 and in Tables C.2-1, C.2-2. Possible effects on water resources are considered in this section.

Probable movements of spills occurring east of SEAWAY Tank Farm are identical to those for Bryan Mound (see Section C.3.2.2).

Spills from West Columbia dome not contained within diking would flow toward Varner Creek which discharges to the Brazos River (Figure B.2-9). The most likely drainage path is via the intermittant stream which drains the freshwater marsh and enters the river northeast of the site. Spills from the pipelines west of the storage site would flow toward Bell Creek which empties into the San Bernard River. Between the Bell Creek watershed divide and the State penal farm, the drainage is generally into the San Bernard River through a number of intermittant drainageways. To the east of the penal farm, the drainage is into the Brazos River south of the Dow Chemical plant, or into the Jones Creek watershed which flows through marsh land to the ICW near the Gulf of Mexico.

Oil spills are most likely to reach the Gulf of Mexico as a result of a direct release from oil tankers in the Gulf.

Quantities of oil expected to be released from the early storage facilities at Bryan Mound, and from SPR expansion facilities at West Columbia dome are listed by source and location in Tables C.2-1 and C.2-2. Total oil spillage for five fill/withdrawal cycles is projected to be 1930 barrels for the early storage facility and an additional 3803 barrels for the West Columbia dome facilities. Of the total, 74 percent is projected to occur during fill operations, 24 percent during withdrawal, and 2 percent (133 barrels) during standby storage. The distribution of spills is projected to be 2746 barrels (48 percent) in the Gulf of Mexico (principally at the VLCC - tanker transfer location); 1467 barrels (26 percent) at the tanker docks, 1237 barrels (22 percent) at the West Columbia dome, Bryan Mound, and SEAWAY Terminals; and less than 250 barrels from the connecting pipelines. The maximum credible spill events are estimated to be 60,000 barrels resulting from a tanker collision, 10,000 barrels from a pipeline rupture, 5000 barrels from storage terminals and 500 barrels from transfer operations.

Weathering processes and dispersal characteristics of oil are given in Section C.3.2.2.

Two potentially significant impacts of oil spills on water resources would be the potential for buildup of toxic fractions and depletion of oxygen levels in shallow, poorly flushed water bodies. The most likely location of such impacts would be in coastal bays and marshes southwest and northeast of Freeport (including the vicinity of San Bernard National Wildlife Refuge) and, to a lesser extent, in Varner, Bell or Jones Creeks, or in Mud Lake or Unnamed Lake on Bryan Mound. Because of the 25-mile distance from the VLCC transfer point to shore, the diking around tanks at Bryan Mound, and the unlikely occurrence of expected pipeline spills, such impacts are not expected (that is, most spills should occur in open gulf waters, at the docks, or within the diked terminals).

Oil spills reaching the Brazos River, Freeport or Brazos Harbors, the ICW, or the open Gulf should not have significant impacts on water quality because of the potential for dilution and for oil recovery. Oil which sinks to the bottom or is deposited on the shoreline or river banks may provide a local source of petroleum hydrocarbons to the water column for several weeks or even months.

Domestic, agricultural, and industrial water supplies taken from Varner Creek, the San Bernard River, or the Brazos River could be adversely affected if oil reaches these water bodies. It would probably be necessary to use alternate supplies for a period of several days, or until hydrocarbon concentrations return to acceptable levels.

As at Bryan Mound, surface spills are not likely to affect ground water in the area because there appears to be little recharge to the Chicot aquifer. Subsurface spills caused by a cavern collapse could flow down gradient to Brazosport communities, however (particularly to the town of West Columbia).

Thus, although the potential exists for a very large crude oil spill, calculations of spill productivity and the nature of local water bodies indicates that significant impacts on local water resources should not occur.

Brine Spills

During project operation, brine spills could occur from the brine disposal pipeline and from the brine reservoir; saline water could be spilled from the raw water supply line and from the brine disposal line (during standby storage). A thorough description of possible modes of spills, methodology of spill calculation, quantification of expected spill volume and frequencies, spill dispersion characteristics, and spill prevention and control measures is provided in Appendix E. A summary of brine spill expectation is also included in Section C.2 and in Table C.2-3. Possible effects on water resources are considered in this section.

Probable movements of spills occurring east of SEAWAY Tank Farm are identical to those for Bryan Mound (see Section C.3.2.2).

Spills from West Columbia dome not contained within diking would flow toward Varner Creek which discharges to the Brazos River (Figure B.2-9). The most likely drainage path is via the intermittent stream which drains the freshwater marsh and enters the river northeast of the site. Spills from the pipelines west of the storage site would flow toward Bell Creek which empties into the San Bernard River. Between the Bell Creek watershed divide and the State penal farm, the drainage is generally into the San Bernard River through a number of intermittent drainageways. To the east of the penal farm, the drainage is into the Brazos River south of the Dow Chemical plant, or into the Jones Creek watershed which flows through marsh land to the ICW near the Gulf of Mexico.

Thus, brine spills are most likely to reach the Gulf of Mexico as a result of rupture of the brine disposal line in the Gulf.

Brine and saltwater spills are expected to occur only from the piping system. Total spillage is estimated to be 75 barrels of brine and 115 barrels of saltwater from early storage operation and 843 barrels of brine and 1853 barrels of saltwater from SPR expansion facilities. Of the total, 210 barrels of brine and 78 barrels of saltwater would spill into the Gulf of Mexico; 708 barrels of brine and 1890 barrels of saltwater would spill onto coastal prairie, fluvial woodlands and marshland between Bryan Beach and West Columbia dome (Table C.2-3). The maximum credible spill event is estimated to be 30,000 barrels of brine.

As at Bryan Mound, surface spills are not likely to affect ground water in the area because there appears to be little recharge to the Chicot aquifer.

Spills of brine or raw water have less potential for adverse effects on water quality than do oil spills. Except for a very large brine spill, normal flushing of most local water bodies (e.g., the ICW, Brazos Diversion Channel, Brazos and Freeport Harbors, Gulf of Mexico) would quickly dilute salt concentrations to normal levels resulting in very temporary water quality degradation. Flushing is not as effective in Varner Bell or Jones Creeks, or in Mud Lake and Unnamed Lake at Bryan Mound, however, and salinity excesses would continue in those water bodies for several days or even weeks until sufficient rainfall flushing is achieved.

Thus, although the potential exists for a very large brine spill, calculations of spill productivity and the nature of local water bodies indicates that significant impacts on local water resources should not occur.

Flood Hazards

Flood hazards at West Columbia dome, and along the pipeline route to SEAWAY Tank Farm, are significantly less serious than at Bryan Mound or Allen dome. Surface elevation in the fresh marsh at the storage site is about 25 feet MSL which is less than the calculated 100-year flood level of 33 feet MSL due to Brazos River flooding. High water could reach the site from Varner Creek through the stream which drains the marsh. However, no strong currents or other damaging conditions would accompany high waters. The brine reservoir and other surface facilities could be protected by a suitable levee, or by filling.

Floods pose no hazard to underground pipelines. Floods at Bryan Mound could possibly top the protection levee but oil would be removed from surge tanks, thus eliminating any spill hazard.

As only limited quantities of oil could be released in the event of a damaging storm flood, environmental effects due to the flood waters and winds are expected to be much greater than due to loss of oil or brine.

Alternative Facilities

Use of ground water to displace oil from caverns or injection of brine into deep subsurface salt water-bearing sands have the same potential for adverse impacts as described for Bryan Mound (Section C.3.2.2). Use of the diffuser 12.5 miles offshore Bryan Mound would have effects as described in Section C.3.2.2.

Use of a marine pipeline for oil movement would reduce the expected quantities of oil spill volume by about 60 percent. Onshore oil spillage would be essentially unaffected.

C.5.2.3 Air Quality

Air quality impacts associated with operation of the West Columbia dome site alternative are essentially identical to those described for Allen dome (Section C.4.2.3 and Table C.3-6).

Alternatives

As for Allen dome SPR expansion, alternatives which would alter air quality impacts are use of marine terminal and onsite power generation. Estimated reductions in emissions achieved by using a marine terminal are the same as those given for Allen dome in Section C.4.2.3.

Onsite generation of 34,000 kilowatts of power capacity at West Columbia would have the same impact on air quality as given in Section C.3.2.3 for Bryan Mound. Total hydrocarbon emissions over a 22-year operating period are estimated to be 2600 tons.

C.5.2.4 Noise

Noise impacts caused by operating SPR facilities at West Columbia dome would be essentially the same as described in Section C.3.2.4 for Bryan Mound. Though the town of West Columbia is about one mile from the site, noise impacts from pumping and other operations should not be noticeable.

C.5.2.5 Ecosystems and Species

Raw Water Withdrawal

Impacts are essentially identical to those described for Bryan Mound in Section C.3.2.5 and for Allen dome in Section C.4.2.5.

Brine Disposal

Impacts are similar to those described in Section C.3.2.5 for Bryan Mound.

Tanker Transport

Impacts are essentially identical to those described in Section C.3.2.5 for Bryan Mound and in Section C.4.2.5 for Allen dome.

Maintenance of Project Lands

Types of impacts resulting from maintenance of lands required for West Columbia oil storage are the same as those described in Section C.4.2.5 for Allen dome. Also, some typical impacts were described in Section C.5.1.5. A greater total area (more than 250 acres) would be maintained if the West Columbia site were selected because of the longer pipeline length.

Accidental Oil Release

The potential for oil spills during project operation is described in Appendix E; expected annual spill volumes by mode of operation and by geographical location are summarized in Section C.2, particularly Tables C.2-1 and C.2-2. In the event of an oil spill, the expected movement from various spill locations, the weathering processes likely to occur, and the potential for water quality degradation are described in Sections C.3.2.2 and C.5.2.2. This section treats some of the site specific biological effects which can occur as a result.

The following summarizes the information on frequency and volume of expected oil spills for West Columbia dome presented in Tables C.2-1 and C.2-2. Total oil spillage for five fill/withdrawal cycles is projected to be 1930 barrels for the early storage facility and an additional 3803 barrels for the SPR expansion facilities at West Columbia dome. Of the total, 74 percent is projectd to occur during fill operations, 24 percent during withdrawal, and 2 percent (133 barrels) during standby storage. The distribution of spills is projected to be 2746 barrels (48 percent) in the Gulf of Mexico (principally at the VLCC transfer location), 1467 barrels (26 percent) at the tanker docks, 1237 barrels (22 percent) at the West Columbia dome, Bryan Mound, and SEAWAY Terminals, and less than 250 barrels from the connecting pipelines. The maximum credible spill events are estimated to be 60,000 barrels resulting from a tanker collision, 10,000 barrels from a pipeline rupture, 5000 barrels from storage terminals and 500 barrels from transfer operations.

Frequencies of spills are also given in Appendix E. Except for transfer spills, all modes of spills are expected to be very infrequent. For example, a single fill of 100 MMB for West Columbia dome site development is estimated to result in about 28 oil spills, 23 of which would occur at the VLCC - tanker transfer location. A single withdrawal would result in about 2 spills, most likely occurring at the tanker loading dock. For very large oil spills, recurrence intervals are expected to be very large, essentially the same as given in Section C.4.2.5 for Allen dome.

Because of the very low frequency of expected spill incidents, chronic pollution by oil should not occur on West Columbia dome or Bryan Mound, or along the proposed pipeline routes. A large spill of oil in the vicinity of Allen dome could reach Varner Creek and, thus, the San Bernard River, resulting in pollution of water resources and loss of aquatic and stream bank vegetation, benthos, fish and some birds. Other potentially sensitive areas exposed to oil spills are Jones Creek and adjacent prairie land near SEAWAY Tank Farm, shallow lakes and ponds on Bryan Mound, and nearshore Gulf waters and shorelines.

Estimates made in Section C.3.2.5 of acreages which might be destroyed by maximum credible oil spills apply to the West Columbia dome site alternative. With maximum spreading, a large tanker spill could destroy 1680 acres of wetlands and as much as 7000 acres of benthos habitat in shallow coastal waters. A large pipeline spill could destroy 320 acres of wetlands (or Prairie) and 1340 acres of shallow water habitat. The most sensitive acres would probably be the pipeline right-of-way near SEAWAY Tank Farm and the lakes and ponds on Bryan Mound.

In summary, except for the case of a very large oil spill (or a moderately sized spill in a sensitive area), biological impacts are not expected to be of regional significance. The expected frequency of potentially large spills is very small.

Alternatives

Use of a marine pipeline and monobuoy would substantially reduce the offshore and harbor exposure to oil spills (by about 60 percent).

Accidental Brine Release

The potential for brine spills during project operation is Appendix E; expected annual spill volumes by mode of operation and by geographical location are summarized in Section C.2, particularly Table C.2-3. In the event of a brine spill, the expected movement from various spill locations, the dilution processes likely tc occur, and the potential for water quality degradation are described in Sections C.3.2.2 and C.5.2.2. This section treats some of the site specific biological effects which can occur as a result.

Raw water spills are expected to occur only from the piping system. Total spillage is estimated to be 75 barrels of brine and 115 barrels of raw water from early storage operation and 843 barrels of brine and 1853 barrels of raw water from SPR expansion facilities. Of the total, 210 barrels of brine and 78 barrels of raw water would spill into the Gulf of Mexico, 708 barrels of brine and 1890 barrels of raw water would spill onto coastal prairie and marshland between Bryan Beach and West Columbia dome (Table C.2-3). The maximum credible spill event is estimated to be 30,000 barrels of brine, excluding possible release of up to 100,000 barrels of brine due to hurricane breaching of the storm levee and brine reservoir.

Frequencies of spills are given in Appendix E. For brine spills, there is an 84 percent chance of having no spills during the project lifetime; similarly there is a 69 percent of no raw water spills.

Because of the very low frequency of expected spill incidents, chronic pollution by brine should not occur on West Columbia dome or Bryan Mound, or along the proposed pipeline routes. Potentially sensitive areas exposed to brine spills are Jones Creek and adjacent prairie land near SEAWAY Tank Farm classified as critical habitat by the General Land Office of Texas (Figure B.2-29), shallow lakes and ponds on Bryan Mound, and nearshore gulf waters and shorelines.

Estimates made in Section C.3.2.5 of acreages which might be destroyed by maximum credible brine spills apply to the West Columbia dome site alternative. Impacts of brine depend on mixing and dilution potential. The most sensitive areas would probably be the pipeline right-of-way near SEAWAY Tank Farm and the lakes and ponds on Bryan Mound.

In summary, except for the case of a very large brine spill (or a moderately sized spill in a sensitive area), biological impacts are not expected to be of regional significance. The expected frequency of potentially large spills is very small.

Alternatives

Use of a ground water supply system or a deep well injection system would represent an additional, relatively small, exposure of prairie grassland and fluvial woodland to brine spills. Use of the 12.5 mile offshore diffuser would have impacts as described in Section C.3.2.5.

C.5.2.6 Natural and Scenic Resources

Normal project operations would have fewer impacts on scenic and natural resources than construction. After pipeline construction has been completed most of the right-of-ways would be allowed to return to the native prairie vegetation, most of which would be reestablished during the next growing season. Some areas, including the storage site, would be permanetly altered, however. After construction, the noise, dust, fumes and vibrations related to operations would be significantly reduced. As at other sites, burial of pipelines would be significantly reduced. Above ground storage facilities at the site would be visible from several residences near the town of West Columbia south of the dome. It may be possible to screen the facilities from view by landscaping. Although portions of the pipeline right-of-way passing through woodlands would be maintained clear of trees, the route parallels the SEAWAY right-of-way and thus would expand the existing corridor width rather than create a new corridor.

C.5.2.7 Archaeological, Historical and Cultural Resources

There would be no impact on achaeological, historical or cultural resources as a result of operation of the site.

C.5.2.8 Socioeconomic Environment

Land Use

The operation and maintenance of the West Columbia SPR site would have a modest impact on land use. The 232 acres enclosed at the site during the construction phase would be enclosed by a fence, and the present use of the site for cattle grazing would be terminated for the life of the project. Of the 699 acres required for construction, 479 acres would be needed for maintenance offsite and within the fence. Some of this land would be revegetated and returned to present uses. No structures could be erected within the pipeline right-of-way.

Transportation

The operational impacts on transportation would be the same as those described in Section C.4.2.8 for Allen dome.

Population

The impacts would be substantially the same as those for Allen dome (Section C.4.2.8).

Housing

Operational personnel wishing to relocate in the West Columbia area would have difficulties similar to those discussed in Section C.4.2.8. The result may be to delay or deter personnel from locating near the site.

Economy

The project would employ 55 during filling and withdrawal operations, generating a monthly payroll of about $96,000. This income would stimulate the West Columbia economy to the extent that local residents are employed. Because filling and withdrawal would be temporary operations, workers may commute from nearby areas rather than relocating in West Columbia.

During standby operations only 10 employees would maintain the site, having little effect on the local or county economy. The effects on local tax revenues are discussed in Section C.4.2.8.

Urban Services

Project operations would place few demands on urban services such as police, fire, health facilities, and educational institutions due to the relatively small number employed and the nature of the operations. The project would supply its own security and fire protection, using local services only as backup support in case of large disaster.

Alternatives

The effect on socioeconomic conditions from withdrawing ground water, injecting brine to deep saline water bearing sands, or using a marine oil terminal instead of tanker docks in Freeport Harbor are the same as described in Section C.4.2.8 for Allen dome. Impacts from the use of the diffuser 12.5 miles offshore of Bryan Mound is described in Section C.3.2.8.

C.5.3 Impact Due to Termination and Abandonment

The impacts due to termination and/or abandonment of the West Columbia dome storage site as an oil storage facility would be the same as described in Section C.3.3.

C.5.4 Relationship of the Proposed Action to Land Use Plans, Policies, and Controls

It is not anticipated that any land use plans or policies would be in conflict with the West Columbia SPR facility. For a further discussion of the land use plans, policies, and controls in the area, refer to Section C.3.4.

C.5.5 Summary of Adverse and Beneficial Impacts

Development of the West Columbia salt dome as an oil storage facility is not likely to generate significant regional environmental impacts, except for the remote possibility of a major oil or brine spill and the release of hydrocarbon vapors during oil transport. The longtime use of the area surrounding the site for oil and gas production would tend to minimize the scope of impacts resulting from construction activities.

Land use impacts of developing this candidate site center on the amount of land required. At the dome, 232 acres would be enclosed by a security fence. Within this area, approximately 30 acres would be required for construction of onsite facilities. Construction of backup brine injection wells and pipelines from West Columbia to Bryan Mound to transport oil, brine, and raw water would disrupt 282 acres. This land could be revegetated and some returned to prior uses. Construction of systems common to each site would require 185 acres for the offshore brine diffuser pipeline, new tanker docks and pipeline connections to Brazos Harbor.

Although large quantities of water would be required to leach storage caverns, the withdrawal of this water from the Brazos River Diversion Channel would constitute less than one percent of its average flow. Disposal of brine in the Gulf of Mexico is expected to increase salinity in the water near the diffusers, but this increase is not expected to be significant though there may be some adverse effect on marine organisms. Pipeline construction could temporarily affect the water quality of Varner Creek, Bell Creek, and Jones Creek, by increasing turbidity and release of pollutants from bottom sediments. Varner

Creek and Bell Creek could receive sediments from surface runoff and erosion during site preparation and construction. Dock construction in Freeport Harbor and diffuser pipeline construction are not expected to have significant effects on either the ecology of the area or its water quality, as the area is frequently dredged.

The reduction of available wildlife habitat in the vicinity of the site and along the pipeline route to Bryan Mound is the most significant ecological impact associated with this site. Construction activities onsite would force migration of many species, and reduce the amount of food, cover, and nesting area available. Many small invertebrates, birds, and mammals would be destroyed. No rare or endangered species have been identified as existing in the area. River crossings during pipeline construction could affect benthic and other aquatic organisms. Following consturction, much of the area would return to its previous state.

During the construction phase, increases in income and employment in the Houston area are expected. These increases are not expected, however, to provide major stimulus to the economy of the region. During operation, the expected increase in income is expected to contribute about $17,000 per month in additional income during standby storage and $96,000 per month during fill and withdrawal. Temporary increases in traffic congestion in the West Columbia area are expected. These impacts should be of short duration.

The economic benefits of the Strategic Petroleum Reserve are of considerable importance to the regional economy, as the area has a well-developed petroleum-petrochemical industry. Assurance of a continued oil supply in the event of a national emergency would provide a measure of security for that industry.

C.6 DAMON MOUND ALTERNATIVE SITE

Damon Mound salt dome is located in western Brazoria County 35 miles northwest of Freeport (Figure A.6-1).

C.6.1 Impact of Site Preparation and Construction

C.6.1 Land Features

Grading and construction at the 232-acre Damon Mound site would disturb about 30 acres for development of storage wells, pads, a central pumping station, pipelines and access roads connecting the wells to the pumps, oil and raw water tanks, a brine pond, transformer banks, and power generators.

Pipelines connecting Damon Mound to SEAWAY Tank Farm for transport of raw water, crude oil, and brine would require excavation of 512,000 cy and disruption of 397 acres (Table A.6-1). An additional 3 acres would be required for drill pads for 3 backup brine injection wells.

Construction of two tanker docks in Freeport Harbor and the brine disposal pepeline to the Gulf would create the impacts described in Section C.3.1.1.

Leaching of twelve storage cavities at Damon Mound would involve removal of 100 MMB of salt by leaching and disposal of brine into the Gulf of Mexico. This is equivalent to 20.8 x 10^6cy of salt. Sufficient space is to be left between cavities to preserve their structural integrity.

Alternatives

Feasible system alternatives at Damon Mound include: (1) development of a well field for raw water supply, which would require about 22 acres for drill pads, located along the proposed brine and oil pipeline right-of-way; (2) disposal of brine in deep salt water bearing sands, which would require about 19 acres for drill pads, also located along the proposed oil line right-of-way; (3) disposal of brine through a 12.5 mile offshore pipeline to a diffuser in the Gulf of Mexico; (4) purchase of commercial power, which would require construction of a transmission corridor to the site and eliminate the need to build generators on-site; and (5) use of SEAWAY or Phillips Docks by DOE, or construction of a marine terminal for oil transport (see Section C.3.1.1).

C.6.1.2 Water Resources

Site preparation and construction of proposed facilities at Damon Mound salt dome may impact several water bodies, including: ground water aquifers, the Gulf of Mexico, ICW, Freeport and Brazos Harbors, lakes and ponds on Bryan Mound, the Brazos River Diversion Channel, and Mound, Varner, Bell, and Jones Creeks.

Raw Water Withdrawal

Potential impacts to the Brazos Diversion Channel are identical to those described for Allen dome in Section C.4.1.2.

Brine Disposal

Potential impacts to the Gulf of Mexico are similar to those described for Bryan Mound in Section C.3.1.2.

Dock Construction

Potential impacts to Freeport Harbor are identical to those described for Allen dome in Section C.4.1.2.

Construction of Surface Facilities at Damon Mound

The site preparation and construction activity would involve very little earth movement. Approximately 31,680 cubic yards of earth would be displaced during this process. Natural site drainage is toward the north down the slope of the mound; there are no significant water bodies in this area. Standard engineering practices such as interceptor ditches, dikes, and sedimentation ponds would be utilized to prevent any significant degradation of water quality in small ponds and intermittent streams due to plant site runoff. Pollutants which would degrade the water quality are discussed in Section C.3.1.2.

Construction of Oil, Brine and Water Supply Pipelines

The proposed water supply, brine disposal, and oil pipelines would cross Varner and Bell Creeks and several intermittent streams in the 32.3-mile segment between the storage site and SEAWAY Tank Farm (Figure A.6-1). East of SEAWAY Tank Farm, the water supply and brine pipelines would cross Jones Creek, the Brazos River Diversion Channel and Unnamed Lake on Bryan Mound. Trench excavation through water bodies would create increased turbidity and release soluble substances from the substrate to the water column. Impacts would be temporary and local in extent.

There should be no impact on ground water supply or quality due to pipeline installation.

Accidental Brine Release

Leaching of 100 MMB of oil storage capacity from Damon Mound salt dome requires transport of saline water from the Brazos River Diversion Channel and disposal of brine to the Gulf of Mexico. In addition to the impacts previously described for normal operations, a possible brine or raw water spill could affect water resources in Mound, Varner, Bell and Jones Creeks, Brazos River Diversion Channel, lakes and ponds on Bryan Mound, the ICW, and the Gulf of Mexico.

The estimated quantity of brine to be spilled during leaching of Damon Mound storage cavities is 50 barrels into Gulf of Mexico waters and 360 barrels onto land and water bodies between Bryan Beach and Damon Mound (Table C.2-3). In addition, an estimated 355 barrels might be spilled from the raw water supply system. Maximum credible spills of up to 30,000 barrels of water are considered possible, though highly unlikely.

Since average brine spill volumes are estimated to be 5000 barrels, the computation of such low spill expectations reflects the remote chance of any spill occurring. Thus, there is a 78 percent change that no brine would be spilled from all pipeline uses (including operation) during the project lifetime (see Appendix E). If a pipeline rupture does occur, release of 5000 or more barrels of brine could significantly degrade water quality, especially in smaller water bodies such as Varner, Bell or Jones Creeks, or the lakes and ponds at Bryan Mound. Quantities of water required to dilute a maximum credible brine spill to concentrations near ambient are estimated in Section C.3.2.5. Prior to achieving this mixing, salt concentrations would be abnormally elevated.

A brine spill at the site or along the disposal pipeline could locally impact the water quality in the upper unit of the Chicot aquifer. The brine would tend to migrate downward within the formation and downdip along the formation due to density differences. A massive spill, although highly unlikely, could possibly impact the quality of municipal water supplies pumped from aquifers in the town of Damon Mound or the general

Brazosport area by causing increased salinities in those aquifers. As local recharge of near-surface aquifers has been found to be minimal, potential seepage from the lined brine pit or minimal pipeline spills are likely to have negligible impact on water quality.

The location of proposed SPR oil storage facilities on the elevated surface of Damon Mound precludes any dangers of possible flood induced brine spills at the site.

Alternative Facilities

Withdrawal of ground water for raw water supply is potentially feasible but it has the same potential for lowering the piezometric head, saline water intrusion, and land subsidence as described for Bryan Mound (Section C.3.1.2). Land subsidence is a particularly troublesome result of present ground water pumping in Brazoria County.

Brine disposal to salt water bearing sands at Damon Mound has the same potential for adverse impacts as at Bryan Mound and Allen dome. It is expected that proper injection methods would avoid any adverse impacts to water or mineral resources in the area. Use of the 12.5 mile diffuser would have impacts as described in Section C.3.1.2.

Impacts associated with construction of alternative oil distribution facilities are described in Section C.3.1.2.

C.6.1.3 Air Quality

Air quality impacts resulting from the development of the proposed and alternative Damon Mound facilities during site preparation and construction would be similar to those for the Allen dome alternative, which were discussed in Section C.4.1.3. It was concluded that the emissions during site preparation and construction would be short-term and confined to a relatively small area, and that air quality impacts would be minor.

Additional emissions from the construction of an 8500 bbl fuel tank for use in onsite power generation would have no significant impact upon air quality, except for short-term concentrations of paint solvents.

C.6.1.4 Noise

Similar facilities to those at Allen dome or West Columbia dome are planned for Damon Mound. The major difference is that onsite power generation is the primary alternative for power at the Damon Mound site. This would not change the type of equipment used for facility construction, as outlined in Section C.3.1.4, but could probably increase the duration of construction activity.

The zones of impact could be similar to those discussed for the Allen dome site. Table C.6-1 presents impact zone radii for the different areas developed under the SPR program for Damon Mound. Approximately 57 residences in Damon may be exposed to significantly increased noise levels during construction. Figure C.6-1 presents the noise impact contours at Damon Mound.

Alternatives

Construction of a raw water or brine disposal well field along the proposed pipeline route would contribute noise levels of a magnitude similar to the onsite drilling activities. The zone of noise impact would thus be extended further to the southwest in a sparsely populated area of coastal prairie. Construction of a marine terminal or brine diffuser system would have a measurable effect on onshore noise levels.

C.6.1.5 Ecosystems and Species

Site preparation and construction of the proposed facilities for Damon Mound would effect both terrestrial and aquatic resources in the area. Terrestrial habitats potentially affected include coastal prairie grassland and fluival woodlands (Table B.6-1). Aquatic habitats include Varner Creek, Bell Creek, Jones Creek, Brazos River Diversion Channel, ICW, several lakes and ponds at Bryan Mound, Freeport and Brazos Harbors and the near shore Gulf of Mexico.

In the following subsections, potential impacts to biological resources are treated according to specific aspects of facility development.

Raw Water Withdrawal

Impacts of raw water withdrawal from the Brazos River Diversion Channel would be identical to those discussed for the Allen dome site alternative (Section C.4.1.5).

TABLE C.6-1 Summary of Construction Noise Impact-Damon Mound Site candidate SPR storage site (alternative site)

Area	Activity	Impact Zone Radius (feet)[a]
Damon Mound Site	Drilling new shafts	4500
	Construction of support facilities	2000
Pipeline Routes	Laying of pipe	1800
	Access road construction	1400
Freeport Harbor Brazos Harbor	Construction of DOE docks	2200

[a] This is the distance within which sound levels are raised at least 3 dB by activity described. A baseline ambient day/night sound level of 54 dB is assumed for the calculations.

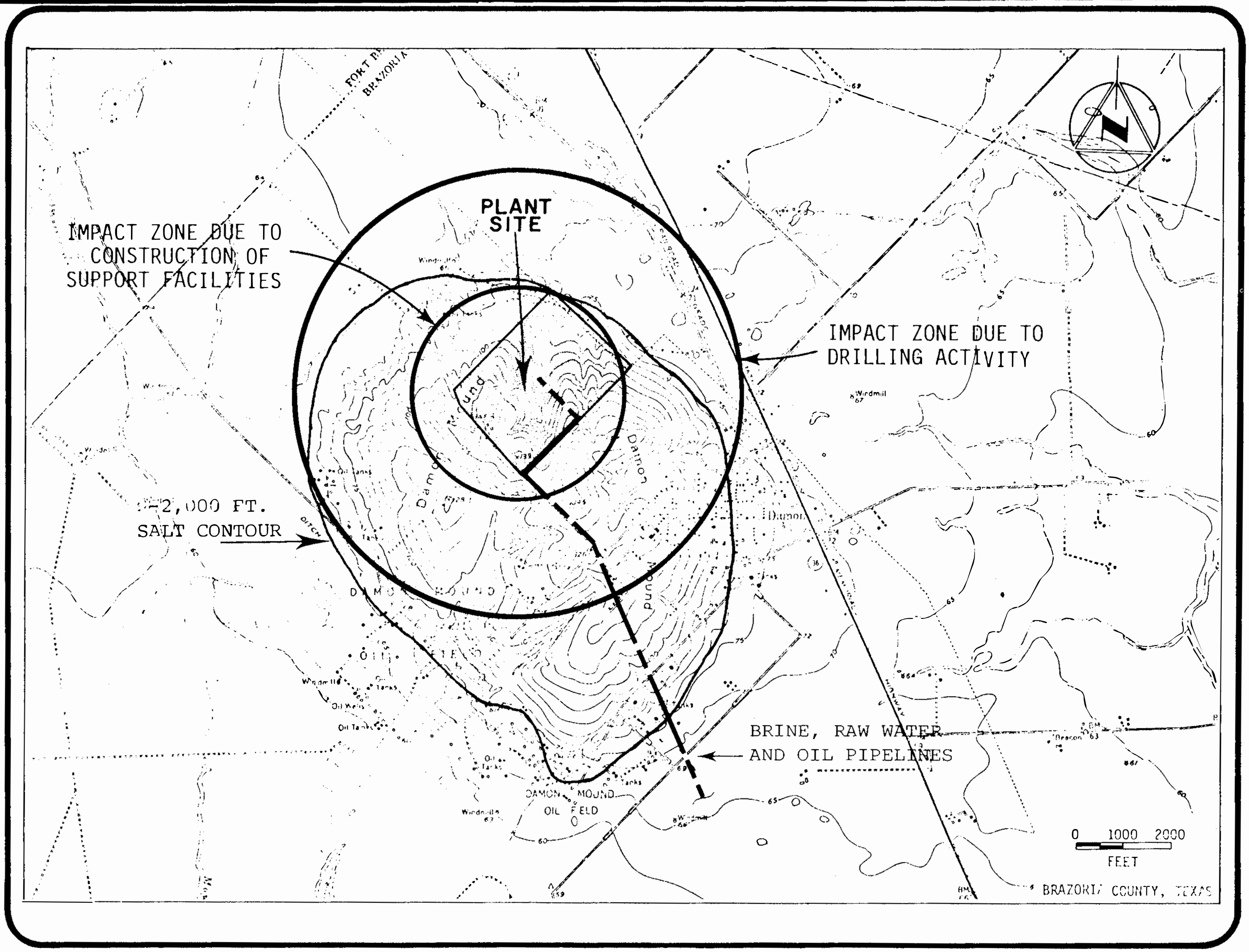

FIGURE C.6-1 Noise impact zones - Damon Mound dome candidate SPR storage site (alternative site)

FIGURE C.6-2 Air photo - Damon Mound candidate SPR storage site (alternative site)

Brine Disposal

The proposed brine diffuser 5.8 miles offshore Bryan Mound would have impacts on the ecosystems and species in the vicinity as described in Section C.3.1.5.

Dock Construction

Impacts are considered minor. They are identical to those discussed for the proposed Bryan Mound site (Section C.3.1.5).

Construction of Surface Facilities at Damon Mound

New facilities to be constructed at Damon Mound which involve potential impacts to the site ecology include the construction of 10 to 12 cavern wells, connecting pipelines, pump house, control building, brine settling pond, three brine disposal wells along the pipeline right-of-way to the west, a transformer area, and a 34,000 kilowatt gas turbine power plant.

The Damon Mound site is situated on an approximately 232 acre tract of coastal prairie. Construction at the site would impact about 30 acres of coastal prairie habitat which is used for grazing cattle. The clearing of this land would reduce primary productivity an estimated 3.03×10^8 Kcal/year (or 54,000 pounds of carbon annually). Permanent loss of this habitat would result in the loss of food, cover, nesting and breeding areas for the resident indigenous wildlife. Fencing in of the site would restrict use of the area to small animals such as rabbits, rodents, and birds. Some of the adjacent lands may be made temporarily unsuitable for certain wildlife species during construction because of the noise and activity at the site. The loss of this habitat is not significant when compared to the total acreage of similar coastal prairie habitat in Brazoria County, most of which is suitable as wildlife habitat. Indirect effects of migration to these areas and increased road kills would result in additional animal losses.

There are no known significant breeding or nesting sites on Damon Mound. No threatened or endangered, or otherwise unique species are known to occur at the site. The southern bald eagle, the perigrine falcon, prairie chicken and the Houston toad are the only threatened or endangered species which are considered to inhabit the project area. The southern bald eagle is known to nest in Brazoria County but it is not likely to be resident at the site because of the lack of suitable habitat due to area development and human activity. Because of its wide terrestrial range the peregrine falcon may also be encountered from time to time in the region but this species prefers more isolated areas than that found at Damon Mound. The Attwater's greater prairie chicken prefers open prairie lands with patches of weeds and bare ground surrounded by tall (1 to 3 feet) grasses to provide adequate roosting and nesting cover. Although colonies of this species have been observed in Brazoria County, the present development and activity at the site would preclude the site from being prime habitat for the prairie chicken. The Houston toad is closely associated with loblolly pine trees (Office of Endangered Species and International Activities, 1973) which do not occur at the site. Therefore, the occurrence of this toad at the site is unlikely.

Small populations of invertebrates, mammals and birds that reside at the site may be forced to migrate to other areas outside of the site when construction activities are taking place. These animals may experience some difficulty in locating suitable replacement habitat, but because of the large amount of coastal prairie available adjacent to Damon Mound, the potential for relocation is good.

The impact of construction on the aquatic habitat at Damon Mound would be small since the amount of this habitat is not very extensive at the site and also since clearing and excavation would be restricted to a small area. The aquatic biota could experience decreased productivity if there is sufficient precipitation to carry silt to Mound Creek by way of the small intermittent streams at the site. These impacts, if they occur, should be of short duration and minor in nature. Although eight species of fish are listed as threatened or endangered species (Texas Parks and Wildlife Department, 1976; U.S. Fish and Wildlife Department, 1976) none of these species are known to inhabit the freshwater bodies near the site.

Construction of Pipelines

A total of 397 acres of land would be required for construction of the proposed raw water, brine, and oil pipelines between Damon Mound and the SEAWAY Tank Farm. Of this total, 210 acres are prairie grassland and 182 acres are fluvial woodland (Table A.6-1). Pipeline construction between SEAWAY Tank Farm and Bryan Mound would require constructing pipelines along an already disturbed right-of-way. The entire pipeline route, except the short spur leading to Damon Mound, follows existing pipeline corridors. Between Bryan Mound and SEAWAY Tank Farm, the pipelines would be laid adjacent to the early storage phase oil line; between SEAWAY Tank Farm and Damon Mound, the pipeline would be laid adjacent to the existing SEAWAY Pipeline corridor.

Except for the increased length of pipeline rightofway, construction impacts should be basically the same as those described for West Columbia dome in Section C.5.1.5. Except in woodland areas, most impacts on wildlife habitat would be temporary.

No known threatened or endangered species are dependent on the immediate area of the Damon Mound pipeline route.

Accidental Brine Release

Expected quantities of brine and raw water spilled during cavern leaching are 410 and 355 barrels, respectively (Table C.2-3). Impacts from such quantities would be of only local importance to terrestrial or aquatic biota. However, should a pipeline spill occur, the average size is expected to be 5000 barrels, with maximum credible spills of up to 30,000 barrels, such spills could have considerable adverse impact.

As described for the West Columbia site alternative (Section C.5.1.5), brine spills are mostly likely to occur from the onshore section of the pipeline system. Spills would have significant impact, locally, on small areas of terrestrial habitat or, downstream, by release into a waterway crossed by the pipeline. In the Gulf, even a maximum credible spill should only affect organisms over a few acres of substrate and water column; recolonization would begin almost immediately.

Alternatives

Construction of a ground water well field on a brine injection field along the proposed pipeline corridor would eliminate the need for multiple pipelines to Bryan Mound but would not greatly reduce the amount of rightofway which must be cleared. It is estimated that a well supply field would require 10 wells and about 22 acres of land. Similarly a brine injection field would require 19 acres and 19 well pads. Use of the 12.5 diffuser would have impacts as described in Section C.3.1.5.

Effects of constructing alternate oil transportation facilities would be identical to those described for Bryan Mound in Section C.3.1.5.

C.6.1.6 Natural and Scenic Resources

Site preparation and construction activities at Damon Mound would have an adverse impact on surrounding natural and scenic resources. Some areas of the town of Damon would be located within view of the onsite construction activities and the proposed pipeline route. Many of the negative aesthetic impacts which result from noise, vibration, and dust would be temporary in nature and would occur over a limited area. No major recreational facilities would be affected.

Alternative brine disposal, raw water supply, and oil transport systems would have minimal additional impact on scenic and natural resources.

C.6.1.7 Archaeological and Historical and Cultural Resources

A comparison of the location of sites listed on the National Register of Historic Places and those sites identified by the Historic Preservation office for Texas and the location of the SPR facilities has been made. Based on this comparison, there are no known sites of historic significance that would be affected. Section 2(a) of Executive Order 11593, "Protection and Enhancement of the Environment" (May 13, 1971) would be complied with as detailed in Section C.3.1.7.

C.6.1.8 Socioeconomic Environment

Land Use

Land use impacts resulting from the development of the Damon Mound SPR site depend on the amount of land converted from existing uses to uses associated with underground crude oil storage. At the site, approximately 232 acres of land would be enclosed by a nine foot fence for security purposes (see Table A.6-1). Within this area, approximately 30 acres would be required for the construction of onsite roads, the plant area, and drill pads. As the site is above the floodplain, fill would not be required to elevate the structures for flood protection. Development would take place in the northwestern portion of the dome, thereby placing the storage facility approximately 3/4-mile from the town of Damon. The land overlying the storage site is presently used for cattle grazing. As the site would be enclosed, this use would terminate during the construction phase of the project.

The construction of parallel oil, brine, and raw water pipelines would disturb an additional 397 acres during the construction phase, all of which would be within the 100-foot right-of-way required for construction. The DOE right-of-way would parallel the SEAWAY Pipeline and disruption of existing land uses is expected to be minimal. Construction of the brine diffuser to the Gulf of Mexico would temporarily disturb 163 acres, 21 acres of which would be offshore.

Construction of facilities required at Freeport Harbor, on Bryan Mound, and pipelines connecting these facilities with the SEAWAY Tank Farm are treated in Section C.4.1.1.

If raw water supply or brine disposal is accomplished through the use of wells, an additional 19 to 22 acres of land may be required for drill pads.

Purchase of commercial power would require a 10-mile transmission corridor to the site and elimination of site impacts due to construction generators.

Impacts of construction of alternate oil transport facilities are the same as those discussed for development of Bryan Mound (Section C.3.1.8).

Transportation

Most of the persons employed during the project are expected to commute to the area from the urban centers in the region. This commuting traffic, along with trucks transporting materials, would have a very significant impact on traffic volumes on Route 36 and within the town of Damon. Existing traffic volumes on Route 36 near Damon average 2570 vehicles per day. Most of the project related traffic would occur during daytime hours and some of this traffic would occur along the pipeline route which parallels Route 36 to Freeport. At peak construction, almost 600 employees would be commuting to these areas each day (Table C.6-2). If half of the employees commuted to the Damon Mound site, at least a 10 percent increase in traffic on Route 36 in the area would result.

Construction of the alternative brine disposal and water supply systems would have little effect on the traffic related to project construction.

Population and Housing

As most of the project employees would commute from the larger urban areas in the region, there should be little increase in permanent population, and demand for local housing should not occur. The limited stock of housing available in Damon would also discourage workers from relocating in the vicinity of the project site.

Adoption of any of the alternative systems would not signficantly change the effect on local housing.

Economy

Construction at Damon Mound could significantly impact construction employment in the region. Peak employment would be 592 employees in the second month of construction. By the seventh month, employment would decline to about 132 and by the twentieth month only 55 workers would remain at the site (see Table C.6-2). The total wages for the construction period are estimated to be about $9.8 million. This would provide an economic stimulus to the region. Purchases of goods and supplies from regional industries would further stimulate the economy. The local economy of Damon would also be stimulated by an increased market for services such as food and gas. The employment and related income would decline as construction activities slow and finally cease after 4 years.

The water injection and brine disposal alternatives would require the same or slightly less manpower, therefore decreasing the income

TABLE C.6-2 Estimated construction employment and wages by month - Damon Mound (100 MMB) candidate SPR storage site (alternative site)

Month	Number Employed	Monthly Wages
0-1	170	$ 297,500
1-2	592	1,036,000
2-3	528	924,000
3-4	499	873,250
4-5	414	724,500
5-6	349	610,750
6-7	132	231,000
7-8	132	231,000
8-9	132	231,000
9-10	132	231,000
10-11	132	231,000
11-12	109	190,750
12-13	109	190,750
13-14	109	190,750
14-15	109	190,750
15-16	109	190,750
16-17	109	190,750
17-18	109	190,750
19-46	55	96,250
Total Construction		$9,786,000

generated. The impacts would, however, be similar in magnitude to those of the proposed facilities.

Government

The impact on government services would be the same as those expected for the other sites as discussed in Section C.4.1.8.

Adoption of the alternative water supply and brine disposal systems would decrease the project employment slightly, and therefore, the need for government services such as police and fire would be reduced.

C.6.2 Impacts from Operation and Standby Storage

Development of 100 MMB of oil storage capacity at Damon Mound would provide a total capacity of 163 MMB for the Seaway Group of SPR sites. Oil amounts would be similar to those described for Allen dome (Section C.4.2). Principal impacts of operations are expected to result from possible large oil or brine spills and from hydrocarbon emissions near the Gulf of Mexico. Impacts from Bryan Mound early storage development are included where appropriate to indicate cumulative environmental effects.

C.6.2.1 Land Features

Effects of operation and standby storage on land features are expected to be minimal. The remote possibility of cavern collapse is discussed in Section C.2.1.1. There is no recognizable danger due to seismic events. Soils would stabilize as soon as they are revegetated following construction.

Operation of alternative facilities would not affect land features.

C.6.2.2 Water Resources

Impacts to water resources as a result of operating oil storage facilities at Damon Mound would result from withdrawal of water for oil displacement, discharge of brine during oil fill, maintainance dredging at dock sites, and possible oil or brine spills.

Raw Water Withdrawal

Impacts associated with drawing water from the Brazos River Diversion Channel for oil displacement would be identical to those described for Allen dome in Section C.4.2.2.

Brine Disposal

Impacts associated with discharging brine to the Gulf of Mexico and utilizing a backup 3-well brine injection system southeast of Damon Mound would be similar to those described for Bryan Mound in Section C.3.2.2.

Maintenance Dredging

Potential impacts due to maintenance dredging at the FEA dock site would be identical to those for Bryan Mound SPR expansion (Section C.3.2.2) and Allen dome (Section C.4.2.2).

Oil Spills

During project operation, oil spills could occur in the Gulf of Mexico, in the Old Brazos River, from pipelines connecting the storage site with the former docks and with SEAWAY Tank Farm, from the well heads at Damon Mound (Releases from the underground storage caverns are not quantified, see Appendix E). A thorough description of possible modes of spills, methodology of spill calculation, and quantification of expected spill volumes and frequencies, disposal characteristics, and spill prevention and control measures is provided in Appendix E. A summary of oil spill expectations is given in Section 4.2 and in Tables C.2-1 and C.2-2. Possible effects on water resources are described in this section.

Predictable movements of spills occurring east of SEAWAY Tank Farm are identical to those for Bryan Mound (see Section C.3.2.2).

Spills from the Damon Mound storage facilities not centered on site would flow northward down slope to level ground. No significant water bodies are located in this area or on the dome. Spills from the pipeline just south of the dome would flow through intermittent stream beds toward Mound Creek, which drains to the San Bernard River. Further south, pipeline spills would enter Varner Creek which drains to the Brazos River; still further south, oil or brine would enter Bell Creek which flows to the San Bernard. Between the Bell Creek watershed divide and a State penal farm, the drainage is generally into the San Bernard River through a number of intermittent drainageways. To the east of the penal farms, the drainage is into the Brazos River south of a Dow Chemical plant, or into the Jones Creek watershed which flows through marshland to the ICW near the Gulf of Mexico.

Oil spills are most likely to reach the Gulf of Mexico as a result of a direct release from oil tankers in the Gulf.

Quantities of oil expected to be released from the early storage facilities at Bryan Mound and from SPR expansion facilities at Damon Mound are listed by source and location in Tables C.2-1 and C.2-2. Total oil spillage for five fill/withdrawal cycle is projected to be 1930 barrels for the early storage facility and an additional 3949 barrels for the Damon Mound facilities. Of the total, 73 percent is projected to occur during fill operations, 23 percent during withdrawal, and 4 percent during standby storages. The distribution of spills is projected to be 2746 barrels (47 percent) in the Gulf of Mexico (principally at the VLCC - tanker transfer operations), 1467 barrels (25 percent) at the tanker docks, 1237 barrels (21 percent) at Damon Mound, Bryan Mound, and SEAWAY Terminals, and 428 barrels from the connecting pipeline. The maximum credible spill volumes are estimated to be 60,000 barrels resulting from a tanker collision, 10,000 barrels from a pipeline rupture, 5000 barrels from storage terminals, and 500 barrels from transfer operations.

Weathering processes and dispersal characteristics of oil are given in Section C.3.2.2. Impacts expected to result from oil spills from Damon Mound facilities are basically the same as described in Section C.5.2.2 for West Columbia. Few bodies of water are crossed by the project north of SEAWAY Tank Farm and, thus, impacts are expected to be localized from spills in this area.

Brine Spills

During project operation, brine spills could occur from the brine disposal pipeline and from the brine reservoir. Saline water could be spilled from the raw water supply line and from the brine disposal line (during standby storage). A thorough description of possible modes of spills, methodology of spill calculation, and quantification of expected spill volumes and frequencies, disposal characteristics, and spill prevention and control measures is provided in Appendix E. A summary of brine spill expectations is given in Section C.2 and in Table C.2-3. Possible effects on water resources are described in this section.

Spills from the Damon Mound storage facilities not centered on site would flow northward down slope to level ground. No significant water bodies are located in this area or on the dome. Spills from the pipeline just south of the dome would flow through intermittent stream beds toward Mound Creek, which drains to the San Bernard River. Further south, pipeline spills would enter Varner Creek which drains to the Brazos River; still further south, brine would enter Bell Creek which flows to the San Bernard. Between the Bell Creek watershed divide and a State penal farm, the drainage is generally into the San Bernard River through a number of intermittent drainageways. To the east of the penal farms, the drainage is into the Brazos River south of a Dow Chemical plant, or into the Jones Creek watershed which flows through marshland to the ICW near the Gulf of Mexico.

Thus, brine spills are most likely to reach the Gulf of Mexico as a result of a direct release from a ruptured brine line in the Gulf.

Brine and salt water spills are expected to occur only from the piping system. Total spillage is estimated to be 75 barrels of brine and 115 barrels of saltwater from early storage operation and 1218 barrels of brine and 2910 barrels of saltwater from SPR expansion facilities. Of the total 210 barrels of brine and 78 barrels of saltwater would spill into the Gulf of Mexico, 1083 barrels of brine and 2948 barrels of saltwater would spill into the coastal prairie and fluvial woodlands and marshland between Bryan Beach and Damon Mound (Table C.2-3). The maximum credible spill event is estimated to be 30,000 barrels of brine.

Impacts expected to result from brine spills from Damon Mound facilities are basically the same as described in Section C.5.2.2 for West Columbia. Few bodies of water are crossed by the project north of SEAWAY Tank Farm and, thus, impacts are expected to be localized from spills in this area.

Flood Hazards

The elevated location of Damon Mound storage facilities precludes possible serious flooding hazards. Pipelines and storage tanks at Bryan Mound would be subject to the same flood hazards as previously described in Sections C.3.2.2 and C.5.2.2.

Alternative Facilities

Use of ground water to displace oil from caverns, injection of brine into deep subsurface water-bearing sands and the 12.5 mile diffuser would have the same potential for above impact as described for Bryan Mound (Section C.3.2.2).

Use of marine pipeline for oil movement would reduce the expected quantities of oil spill volume by about 60 percent. Onshore oil spillage would be essentially unaffected.

C.6.2.3 Air Quality

Air quality impacts associated with operation of the Damon Mound site alternative are essentially identical to those described for Allen dome (Section C.4.2.3 and Table C.3-6), except that onsite power generation would be an additional source of emissions.

Emissions expected to result from a 34,000 kilowatt oil-fired turbine generator at Damon Mound are listed in Table C.3-7. The results indicate that even as close as 1 km downwind, concentrations were below state and national air quality standards. However, since the 3-hour HC standard is often exceeded in Southeast Texas, hydrocarbon concentrations may cause infrequent additional exceedances near the plant (especially when interaction with brine pond emissions occurs).

Alternatives

Estimated reductions in hydrocarbon emissions which would result from use of a marine terminal are the same as those given for Allen dome in Section C.4.2.3.

Purchase of commercial power, in place of onsite generation, would eliminate the major source of gaseous pollutants at Damon Mound.

C.6.2.4 Noise

Noise impacts caused by operating SPR facilities at Damon Mound would be essentially the same as described in Section C.3.2.4 for Bryan

Mound. Though the town of Damon is about one half mile from the site, noise impacts from pumping and other operations should not be noticeable.

C.6.2.5 Ecosystems and Species

Raw Water Withdrawal

Impacts are essentially identical to those described for Bryan Mound in Section C.3.2.5 and for Allen dome in Section C.4.2-5.

Brine Disposal

Impacts are similar to those described in Section C.3.2.5 for Bryan Mound.

Tanker Transport

Impacts are essentially identical to those described in Section C.3.2.5 for Bryan Mound and in Section C.4.2.5 for Allen dome.

Maintenance of Project Lands

Type of impacts expected are the same as described for Allen dome. A greater total area (approximately 340 acres) must be maintained for Damon Mound, however, because of the longer pipeline corridor.

Accidental Oil Release

Appendix E, Section 4.2 and Tables C.2-1 and C.2-2 indicate the modes and quantities of oil spills expected for Damon Mound facilities. Expected movement, weathering processes, and potential for water quality degradation have been described in Section C.3.2.2 and C.6.2.2.

Quantities of oil expected to be spilled at various locations from Damon Mound facilities have been summarized under Water Resources (C.6.2.2). Most of the oil would spill in the Gulf. Maximum credible spill sizes are the same as for other site alternatives. Total oil spillage from Damon Mound is expected to be only slightly larger than for Allen dome SPR development (4 percent), because pipelines contribute a small fraction of the total expected oil spill volume.

As for the other sites, frequencies of spill occurrence are low - 28 per 100 MMB oil filled; 2 per 100 MMB oil withdrawn, only 0.8 for the entire lifetime for brine and saltwater. Therefore, pollution from chronic or frequently recurring spills is unlikely. Areas potentially sensitive to damage from an occasionally large oil spill include Mound, Varner, Bell and Jones Creeks, wetlands near SEAWAY Tank Farm, shallow lakes and ponds on Bryan Mound, and near-shore Gulf waters and shorelines.

Estimates made in Section C.3.2.5 of acreages which might be destroyed by maximum credible oil spills apply to the Damon Mound site alternatives. With maximum spreading, a large tanker spill could destroy 1680 acres of wetlands and as much as 7000 acres of benthos habitat in shallow coastal waters. A large pipeline spill could destroy 320 acres of wetlands (or prairie) and 1340 acres of shallow water habitat. The most sensitive acres would probably be the pipeline right-of-way near SEAWAY Tank Farm and the lakes and ponds on Bryan Mound.

In summary, except for the case of a very large oil spill (or a moderately sized spill in a sensitive area), biological impacts are not expected to be of regional significance. The expected frequency of potentially large spills is very small.

Accidental Brine Release

Appendix E, Section C.2 and Table C.2-3 indicate the modes and quantities of brine spills expected for Damon Mound facilities. Expected movement, dilution processes, and potential for water quality degradation have been described in Section C.3.2.2 and C.6.2.2.

Quantities of brine expected to be spilled at various locations from Damon Mound facilities have been summarized under Water Resources. Most brine spills would occur onshore. Maximum credible spill sizes are the same as for other site alternatives. Brine and raw water spill volume is expected to be nearly three times as large as for Allen dome, because pipeline spills are the only quantified mode of brine spills.

As for the other sites, frequencies of spill occurrence are low: only 0.8 for the entire lifetime for brine and raw water. Therefore, pollution from chronic or frequently recurring spills is unlikely. Areas potentially sensitive to damage from an occasional large oil spill include Mound, Varner, Bell and Jones Creeks, wetlands classified as critical habitat near SEAWAY Tank Farm, shallow lakes and ponds on Bryan Mound, and near shore Gulf waters and shorelines.

Estimates made in Section C.3.2.5 of acreages which might be destroyed by maximum credible brine spills apply to the Damon Mound site alternatives. With maximum spreading, a large pipeline spill could destroy 320 acres of wetlands (or prairie) and 1340 acres of shallow water habitat. Impacts of brine depend on mixing and dilution potential. The most sensitive areas would probably be the pipeline right-of-way near SEAWAY Tank Farm and the lakes and ponds on Bryan Mound.

In summary, except for the case of a very large brine spill (or a moderately sized spill in a sensitive area), biological impacts are not expected to be of regional significance. The expected frequency of potentially large spills is very small.

Alternatives

Use of a ground water supply system or a deep well brine injection system would reduce the exposure to brine or raw water spills because pipelines to the coast would not be needed. Use of the 12.5 mile diffuser would have impacts as described in Section C.3.2.5.

Use of a marine pipeline and monobuoy would substantially reduce the offshore and harbor exposure to oil spills (by about 60 percent).

C.6.2.6 Natural and Scenic Resources

Operation and maintenance activities at the project site would have a significant effect on the scenic view of some residents of the town of Damon. The project facilities would be visible from houses in the north west corner of Damon. There are no significant adverse impacts anticipated to the natural resources at the site.

Along the pipeline route there would be minimal impacts on natural and scenic resources as much of the land would be revegetated to its previous state. Also, the route parallels the SEAWAY right-of-way to the Tank Farm.

Operation of the alternative brine disposal and raw water supply systems would not have additional adverse effects on natural resources over those experienced during construction.

C.6.2.7 Archaeological, Historical and Cultural Resources

No impacts on known archaeological, historical, or cultural resources are anticipated from the operation of the Damon Mound SPR facility.

C.6.2.8 Socioeconomic Environment

Land Use

Operation and maintenance of the Damon Mound SPR site would have little additional impact on land use. The 232 acres enclosed at the site during the construction phase would eliminate the present use of the site for cattle grazing for the life of the project. Of the 817 acres required for construction offsite and within the fence, 568 acres would be needed for maintenance purposes. Some of this land could be revegetated and returned to present uses. No impact on land uses in the town of Damon is expected.

Transportation

Traffic related to project operations would have a minor impact on traffic volumes in Damon. During standby operations these impacts would be reduced to minimal levels.

Population

The effects of operation on local population would be minor. Most workers would commute to the area, while a few might relocate in or near Damon, increasing local population slightly.

Housing

Housing would be minimally effected in a manner similar to local population. A limited supply of housing is available in nearby areas.

Economy

Operation and maintenance of the proposed systems would have a minimal effect on the local Damon economy, and an insignificant effect on the region. During standby operations only 10 employees would be required; about 55 employees would be needed during filling or withdrawal. The monthly wages during these phases would be $17,500 per month and $96,000 per month, respectively. Purchases of services and supplies during these phases would have an insignificant impact on the regional economy.

Government

Demands for urban survices such as police, fire, education, and health services would be reduced during operations from those required during construction.

Alternatives

Socioeconomic effects of withdrawing ground water for oil displacement, injecting brine to deep salt water bearing sands, disposal to the 12.5 mile diffuser or using a marine terminal for oil transport are not considered to be significantly different from those resulting from the proposed facilities.

C.6.3 Impact Due to Termination and Abandonment

The impact due to termination and/or abandonment of the Damon Mound storage site as an oil storage facility would be the same as described in Section C.3.3.

C.6.4 Relationship of the Proposed Action to Land Use Plans, Policies and Controls

It is not anticipated that the Damon Mound Strategic Petroleum Reserve storage facility would conflict with any land use plans or policies. For a further discussion of the land use plans, policies and controls in the area, refer to Section C.3.4.

C.6.5 Summary of Adverse and Beneficial Impacts

Development of the Damon Mound salt dome as an oil storage facility is not likely to generate significant regional environmental impacts, except for the remote possibility of a major oil or brine spill and the release of hydrocarbon vapors during oil transport. The longtime use of the area surrounding the site for oil and gas production, for limestone mining, and for cattle grazing would tend to minimize the scope of impacts resulting from construction activities.

Site construction would require grading of about 30 acres. Fill requirements would be negligible and would be supplied from the site. Erosion of disturbed material on the site and along the pipeline would increase the potential for siltation of Mound Creek and several other tributaries of the San Bernard and Brazos Rivers. Other construction activity which would impact water quality would include dredging and construction at the two dock sites in Freeport Harbor, and installation of pipelines in a 32-mile corridor from Bryan Mound. Increased salinity in the Gulf of Mexico would result from brine disposal due to the operation of the site. Contamination of ground water supplies is unlikely.

Air quality standards are not expected to be exceeded during either construction or operation of the storage facility; however, temporary hydrocarbon standards exceedance could occur at Freeport Harbor. No significant noise impact is expected during operation of the project. However, it is estimated that up to 57 dwellings may experience increased noise levels of at least 3 dB during drilling activity on the site. The duration of this impact would be short, occurring only during a portion of the construction phase.

Land use impacts of developing this candidate site center on the amount of land required. At the dome, approximately 232 acres would be enclosed by a security fence. Within this area, approximately 30 acres would be required for construction of onsite facilities. Construction of backup injection wells and pipelines from Damon Mound to Bryan Mound to transport oil, brine, and raw water would disrupt 400 acres of previously undisturbed land. This land could be revegetated and partially returned to prior uses. Construction of systems common to each site would require 185 acres for the brine diffuser pipeline, pipeline connections to Brazos Harbor, and the new tanker docks.

The reduction of available wildlife habitat in the vicinity of the site and along the pipeline route to Bryan Mound is the most significant ecological impact associated with this site. Construction activities would force migration of many species, and reduce the amount of food, cover, and nesting area available. Many small invertebrates, birds, and mammals would be destroyed. No rare or endangered species have been identified as existing in the area. Following construction, much of the area would return to its previous state.

Although large quantities of water would be required to leach storage caverns, the withdrawal of this water from the Brazos River Diversion Channel would constitute less than one percent of its average flow. Disposal of brine in the Gulf of Mexico is expected to increase salinity in the water near the diffusers, but this increase is not expected to be significant though there may be some adverse effect on marine organisms. Pipeline construction could temporarily affect the water quality of Mound, Varner, Bell and Jones Creeks, by increasing turbidity and release of pollutants from bottom sediments. Dock construction in Freeport Harbor is not expected to have significant effects on either the ecology of the area or its water quality, as the area is frequently dredged.

During the construction phase, increases in income and employment in the Houston area are expected. These increases are not expected, however, to provide major stimulus to the economy of the region. During operation, the expected increase in income is expected to contribute about $17,500 per month in additional income during standby storage and $96,000 per month during fill and withdrawal. Temporary increases in traffic congestion in the Damon Mound area are expected. These impacts should be of short duration.

C.7 NASH DOME - ALTERNATIVE SITE

Nash salt dome is located in southern Fort Bend and northern Brazoria Counties, 32 miles northwest of Freeport (Figure A.7-1).

C.7.1 Impact of Site Preparation and Construction

C.7.1.1 Land Features

Grading and construction at the 206-acre Nash dome site would disturb about 30 acres for development of storage well pads, a central pumping station, pipelines and access roads connecting the wells to the pumps, oil and raw water tanks, a brine pond, and transformer banks.

Pipelines connecting Nash dome to SEAWAY Tank Farm for transport of raw water, crude oil, and brine would require excavation of 517,180 acres and disruption of 429 acres (Table A.7-1). An additional 3 acres would be required for pipelines and drill pads for 3 backup brine injection wells.

Construction of the two tanker docks in Freeport Harbor and the 5.8 mile offshore brine diffuser would create the impacts described in Section C.3.1.1.

Leaching of twelve storage caverns at Nash dome would involve removal of 100 MMB of salt by leaching and disposal in the Gulf of Mexico. This is equivalent to 20.8×10^6 cy of salt. Sufficient space is to be left between cavities to preserve structural integrity.

Alternatives

Feasible system alternatives at Nash dome include: (1) development of a well field for raw water supply; this will require about 22 acres for drill pads and pipeline right-of-way, located along the proposed brine and oil pipeline right-of-way; (2) disposal of brine in deep saline water bearing sands, which would require about 19 acres for drill pads and pipeline right-of-way, also located along the proposed oil line right-of-way; (3) disposal of brine through a 12.5 mile pipeline to an offshore diffuser would require an additional 163 acres for offshore construction; (4) purchase of commercial power, which would require construction of a 10 mile transmission corridor to the site; and (5) use of SEAWAY or Phillips docks by DOE or construction of a marine terminal for oil transport (see Section C.3.1.1).

C.7.1.2 Water Resources

Site preparation and construction of proposed facilities at Nash salt dome may impact several water bodies, including: ground water aquifers, the Gulf of Mexico, ICW, Freeport and Brazos Harbors, lakes and ponds on Bryan Mound, the Brazos River Diversion Channel, and Cow, Turkey, Varner, Bell, and Jones Creeks.

Raw Water Withdrawal

Potential impacts to the Brazos Diversion Channel due to raw water withdrawal are identical to those described for Allen dome in Section C.4.1.2.

Brine Disposal

Potential impacts to the Gulf of Mexico due to brine disposal are similar to those described for Bryan Mound in Section C.3.1.2.

Dock Construction

Potential impacts to the Freeport Harbor are identical to those described for Allen dome in Section C.4.1.2.

Construction of Surface Facilities at Nash Dome

The site preparation and construction activity would involve very little earth movement. Approximately 31,000 cubic yards of earth would be displaced during this process. Natural site drainage is toward Turkey Creek to the north and Cow Creek to the southeast. Standard engineering practices such as interceptor ditches, dikes, and sedimentation ponds would be utilized to prevent any significant degradation of water quality due to plant site runoff. Pollutants which would degrade the water quality are discussed in Section C.3.1.2.

Construction of Oil, Brine and Water Supply Pipelines

The proposed water supply, brine disposal, and oil pipelines would cross Cow, Varner, and Bell Creeks and several other intermittent streams in the 32.6-mile segment between the storage site and SEAWAY Tank Farm (Figure B.2-9). East of SEAWAY Tank Farm, the water supply and brine pipelines would cross Jones Creek, the Brazos River Diversion Channel and Unnamed Lake on Bryan Mound. Trench excavation through water bodies would create increased turbidity and release soluble substances from the substrate to the water column. Impacts would be temporary and local in extent.

There should be no impact on ground water supply or quality due to pipeline installation.

Accidental Brine Release

Leaching of 100 MMB of oil storage capacity from Nash dome requires transport of saline water from the Brazos River Diversion Channel and disposal of brine to the Gulf of Mexico. In addition to the impacts previously described for normal operations, a possible brine or raw water spill could affect water resources in Cow, Varner, Bell and Jones Creeks, Brazos River Diversion Channel, lakes and ponds on Bryan Mound, the ICW, and the Gulf of Mexico.

The estimated quantity of brine to be spilled during leaching of Nash dome storage cavities is 50 barrels into Gulf of Mexico waters and 360 barrels into land and water bodies between Bryan Beach and Nash dome (Table C.2-3). In addition, an estimated 355 barrels might be spilled from the raw water supply system. Maximum credible spills of up to 30,000 barrels of water are considered possible, though highly unlikely.

Since average brine spill volumes are estimated to be 5000 barrels, the computation of such low spill expectations reflects the remote chance of any spill occurring. Thus, there is a 78 percent chance that no brine would be spilled from all pipeline uses (including operation) during the project lifetime (see Appendix E). If a pipeline rupture does occur, release of 5000 or more barrels of brine could significantly degrade water quality, especially in smaller water bodies such as Cow, Varner, Bell, or Jones Creeks, or the lakes and ponds at Bryan Mound. Quantities of water required to dilute a maximum credible brine spill to concentrations near ambient are estimated in Section C.3.2.5. Prior to achieving this mixing, salt concentrations would be abnormally elevated.

A brine spill at the site or along the disposal pipeline could locally impact the water quality in the upper unit of the Chicot aquifer. The brine would tend to migrate downward within the formation and downdip along the formation due to density differences. A massive spill, although highly unlikely, could possibly impact the quality of municipal water supplies pumped from aquifers in the Brazosport area by causing increased salinities in those aquifers. As local recharge of near surface aquifers has been found to be minimal, potential seepage from the lined brine pit or minimal pipeline spills are likely to have negligible impact on water quality.

Elevation at the Nash dome site is approximately +55 feet MSL. U.S. Army Corps of Engineers preliminary Brazos River backwater studies indicate a 100-year flood elevation of 47.5 feet at Nash dome. Thus, storage facilities at Nash are not subject to a significant flood hazard.

Alternative Facilities

Withdrawal of ground water for raw water supply is potentially feasible but has the same potential for lowering the piezometric head, for saline water intrusion, and for land subsidence as described for Bryan Mound (Section C.3.1.2). Land subsidence is a particularly troublesome result of present ground water pumping in Brazoria County.

Brine disposal to saline water bearing sands at Nash dome has the same potential for adverse impacts as at Bryan Mound and Allen dome. It is expected that proper injection methods would avoid any adverse impacts to water or mineral resources in the area.

Impacts associated with construction of alternative oil distribution facilities are described in Section C.3.1.2.

C.7.1.3 Air Quality

Air quality impacts resulting from development of the proposed and alternative Nash dome facilities during site preparation and construction would be similar to those for the Allen dome alternative, which were discussed in Section C.4.1.3. It was concluded that the emissions during site preparation and construction would be short term and confined to a relatively small area, and that all air quality impacts would be minor.

Additional emissions from the construction of an 8500 bbl fuel tank for use in on-site power generation would have no significant impact upon air quality except for temporary concentrations of paint solvents.

C.7.1.4 Noise

Facilities similar to those at Allen dome or West Columbia dome are planned for Nash dome. The major difference is that onsite power generation is the primary alternative for power at the Nash dome site. This would not change the typical construction equipment types used for facility construction, as outlined in Section C.3.1.4, but would probably increase the duration of construction activity.

The zones of noise impact are larger than those of other alternative sites because background noise levels are projected to be only about 50 dB. Table C.7-1 and Figure C.7-1 present impact zone radii for the different areas which may be developed under the SPR program for Nash dome. There are no private residences in the immediate Nash dome area which would be affected by construction noise. Three residences which are within the proposed site boundary would be relocated.

Alternatives

Construction of a raw water or brine disposal well field along the proposed pipeline route would contribute noise levels of a magnitude similar to the onsite drilling activities. The zone of noise impact would thus be extended further southwest in a sparsely populated area of coastal prairie. Construction of a marine terminal would have no measurable effect on onshore noise levels.

C.7.1.5 Ecosystems and Species

Site preparation and construction of the proposed facilities for Nash dome would affect both terrestrial and aquatic resources in the area. Terrestrial habitats potentially affected include coastal prairie grassland and fluvial woodlands (Table B.7-1). Aquatic habitats include Turkey, Cow, Varner, Bell and Jones Creeks, Brazos River Diversion Channel, ICW, several lakes and ponds at Bryan Mound, Freeport and Brazos Harbors and the nearshore Gulf of Mexico.

TABLE C.7-1 Summary of Construction Noise Impact-Nash Dome Site candidate SPR storage site (alternative site)

Area	Activity	Impact Zone Radius (Feet)[a]
Nash Dome Site	Drilling new shafts	7100
	Construction of support facilities	3160
Pipeline Routes	Laying of pipe	2844
	Access road construction	2200
Freeport Harbor Brazos Harbor	Construction of DOE docks	2200

[a] This is the distance within which sound levels are raised by at least 3 dB by activity described. A baseline ambient day/night sound level of 50 dB is assumed for the calculations.

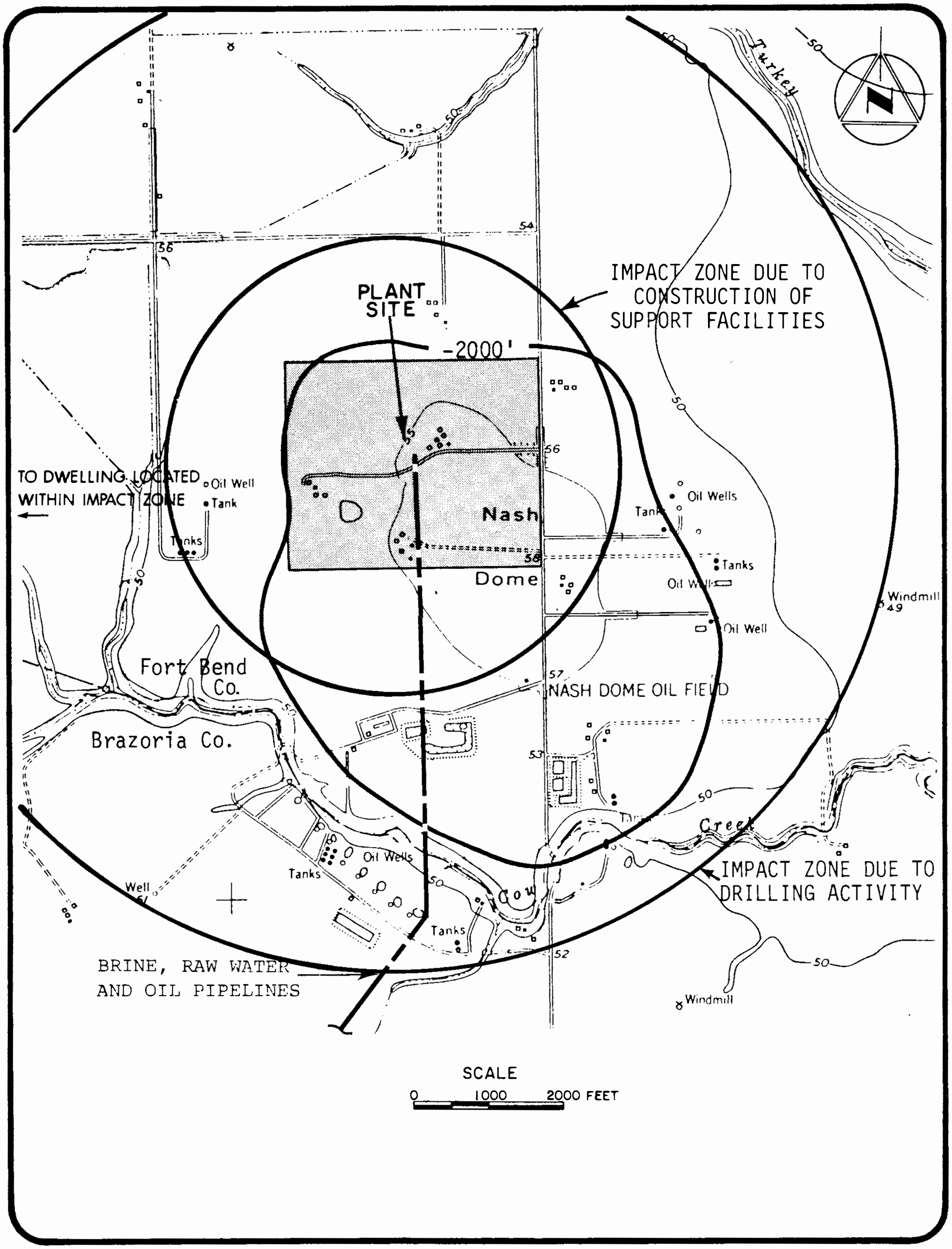

FIGURE C.7-1 Noise Impact zone - Nash dome candidate SPR storage site (alternative site)

FIGURE C.7-2 Air photo - Nash dome candidate SPR storage site (alternative site)

In the following subsections, potential impacts to biological resources are treated according to specific aspects of facility development.

Raw Water Withdrawal

Impacts of raw water withdrawal from the Brazos River Diversion Channel would be identical to those discussed for the Allen dome site alternative (Section C.4.1.5).

Brine Disposal

The proposed brine diffuser 5.8 miles offshore Bryan Mound would have impacts on the ecosystems and species in the vicinity as described in Section C.3.1.5.

Dock Construction

Impacts are considered minor. They are identical to those discussed for the proposed Bryan Mound site (Section C.3.1.5).

Construction of Surface Facilities at Nash Dome and Bryan Mound

New facilities to be constructed at Nash dome which involve potential impacts to the site ecology include the construction of 10 to 12 cavern wells, connecting pipelines, pump house, control building, a brine settling pond, three brine disposal wells along the pipeline ROW to the southwest, a transformer area, and a 34,000 kilowatt gas turbine powerplant.

The Nash dome site is situated on a 206 acre tract of land which contains mostly coastal prairie grassland. Construction at the site would impact about 30 acres of coastal prairie habitat which is used for grazing cattle. The clearing of this land would reduce primary productivity by an estimated 1.62×10^8 Kcal/year (or 28,000 pounds of carbon annually). Permanent loss of this habitat would result in the loss of food, cover, and nesting and breeding areas for the resident indigenous wildlife. Fencing in of the site would restrict use of the area to small animals such as rabbits, rodents, and birds. Some of the adjacent lands may be made temporarily unsuitable for certain wildlife species during construction because of the noise and activity at the site. The loss of this habitat is not significant when compared to the total acreage of similar coastal prairie habitat in Fort Bend and Brazoria Counties, most of which is suitable as wildlife habitat. Indirect effects of migration to these areas and increased road kills would result in additional animal losses.

There are no known significant breeding or nesting sites on Nash dome. No threatened or endangered, or otherwise unique species are known to occur at the site. The southern bald eagle, the peregrine falcon, prairie chicken and the Houston toad are the only threatened or endangered species which are considered to inhabit the project area. The southern bald eagle is known to nest in Brazoria County. But, it is not likely to be resident at the site because of the lack of suitable habitat due to area development and the level of human activity. Because of its wide terrestrial range the peregrine falcon may also be encountered from time to time in the region, but this species prefers more isolated areas than that found at Nash dome. The Attwater's greater prairie chicken prefers open prairie lands with patches of weeds and bare ground surrounded by tall (1 to 3 feet) grasses to provide adequate roosting and nesting cover. Although colonies of this species have been observed in Brazoria County, the present development and activity at the site would preclude the site from being prime habitat for the prairie chicken. The Houston toad is closely associated with loblolly pine trees which do not occur at the site (Office of Engangered Species and International Activities, 1973). Therefore, the occurrence of this toad at the site is unlikely.

Small populations of invertebrates, mammals, and birds that reside at the site may be forced to migrate to other areas outside of the site when construction activities are taking place. These animals may experience some minor difficulty in locating suitable replacement habitat, but because of the large amount of coastal prairie available adjacent to Nash dome, the potential for relocation is good.

The impact of construction on the aquatic habitat at Nash dome would be small since the amount of this habitat is not very extensive at the site and also since clearing and excavation would be restricted to a small area. The aquatic biota could experience decreased productivity if there is sufficient precipitation to carry silt to Turkey or Cow Creeks. These impacts, if they occur, should be of short duration and minor in nature. Although eight species of fish are listed as threatened or endangered species (Texas Parks and Wildlife Department, 1976; U.S. Fish and Wildlife Service, 1976) none of these species are known to inhabit the freshwater bodies near the site.

Construction of Pipelines

A total of 429 acres of land would be required for construction of the proposed raw water, brine, and oil pipelines between Nash dome and the SEAWAY Tank Farm. Of this total, 219 acres are prairie grassland and 210 acres are fluvial woodland (Table A.7-1). Much of the pipeline route, except the 6-mile spur leading to Nash dome, follows existing pipeline corridors. Between Bryan Mound and SEAWAY Tank Farm, the pipelines would be laid adjacent to the early storage phase oil pipeline; between SEAWAY Tank Farm and the spur to Nash dome, the pipeline would be laid adjacent to the existing SEAWAY Pipeline corridor.

Except for the increased length of pipeline right-of-way, construction impacts should be basically the same as those described for West Columbia dome in Section C.5.1.5. Except in woodland areas, most impacts on wildlife habitat would be temporary.

No known threatened or endangered species are dependent on the immediate area of the Nash dome pipeline route.

Accidental Brine Release

Expected quantities of brine and raw water spilled during cavern leaching are 410 and 355 barrels, respectively (Table C.2-3). Impacts from such quantities would be of only local importance to terrestrial or aquatic biota. However, should a pipeline spill occur, the average size is expected to be 5000 barrels, with maximum credible spills of up to 30,000 barrels, such spills could have considerable adverse impact.

As described for the West Columbia site alternative (Section C.5.1.5), brine spills are most likely to occur from the onshore section of the pipeline system. Spills would have significant impact, locally, on small areas of terrestrial habitat or, downstream, by release into a waterway crossed by the pipeline. In the Gulf, even a maximum credible spill should only affect organisms over a few acres of substrate and water column; recolonization would begin almost immediately.

Alternatives

Construction of a ground water well field or a brine injection field along the proposed pipeline corridor would eliminate the need for the respective pipelines to Bryan Mound, but would not greatly reduce the amount of right-of-way which must be cleared. It is estimated that a well supply field would require 10 wells and about 22 acres of land. A brine injection field would require an additional 19 acres for well pads and pipeline right-of-way. The effects of disposal at the 12.5 mile diffuser site is described in Section C.3.1.5.

Effects of constructing alternate oil transportation facilities would be identical to those described for Bryan Mound in Section C.3.1.5.

C.7.1.6 Natural and Scenic Resources

Construction activities would have a minor impact on natural and scenic resources. Most of the areas that would be disrupted have already been previously developed for pipeline routes or agricultural production. The site is visible from public roads, but these are infrequently traveled.

The alternative brine disposal, water supply, and oil distribution systems would not significantly alter the impacts anticipated.

C.7.1.7 Archaeological, Historical and Cultural Resources

A comparison of the location of sites listed on the National Register of Historic Places and those sites identified by the Historic Preservation Office for Texas and the location of the SPR facilities has been made. Based on this comparison, there are no known sites of historic significance that would be affected. Section 2(a) of Executive Order 11593, "Protection and Enhancement of the Environment" (May 13, 1971) would be complied with as detailed in Section C.3.17.

C.7.1.8 Socioeconomic Environment

Land Use

Land use impacts resulting from development of the Nash dome SPR site depend on the amount of land converted from existing uses to uses associated with underground crude oil storage. At the dome, 206 acres of land would be enclosed for the storage site (see Table A.7-1). Within this area, approximately 30 acres would be required for the construction of onsite roads, the plant area, drill pads, the brine reservoir, and the laydown yard. As the site is above the floodplain, no fill would be required to elevate onsite structures for flood protection. The existing land uses of the area in the vicinity of the dome and storage facility generally consists of pastureland, cultivated fields, and oil and gas production. During the construction phase, crop production in this area would be adversely impacted, with some acreage loss resulting from enclosure of the storage site.

Construction of parallel oil, brine, and raw water pipelines would disturb an additional 429 acres during construction. These pipelines would generally parallel the SEAWAY Pipeline. The site is, however, approximately six miles from the SEAWAY Pipeline, requiring a new pipeline corridor through range-pasture and cultivated land use areas. Construction of the 5.8 mile offshore diffuser system would require 163 acres.

Construction of facilities required at Freeport Harbor, Bryan Mound, and pipelines connecting these facilities with the SEAWAY Tank Farm are treated in Section C.4.1.8. Purchase of commercial power would require a 10-mile transmission corridor to the site and elimination of site impacts due to constructing generators.

If raw water supply or brine disposal is accomplished through the use of wells, an additional 19 to 22 acres of land may be required for pipeline construction to the well field and for drill pads. If a 12.5 mile offshore diffuser system is built, additional offshore land would be temporarily used for construction.

Impacts of the construction of alternative oil transport facilities are the same as those discussed for development of Bryan Mound (Section C.3.1.8).

Transportation

The traffic generated by this project would be similar to that at Damon Mound (Section C.6.1.8) and would also use Highway 36 for access to the site and pipeline route. The Nash site would not significantly impact the town of Damon, but rather would increase traffic on lightly traveled county roads causing little congestion. The impacts of construction activities at Nash dome SPR facility in Freeport Harbor would be the same as those discussed in Section C.4.1.8. Construction of alternative brine disposal and raw water systems would be similar or slightly reduce impacts on transportation.

Housing

The impacts on housing would be identical to those cited for Damon Mound, Section C.6.1.8 and are negligible.

Economy

The number of employees and monthly wages anticipated during construction are shown in Table C.7-2. The impacts would be about the same as those expected at Damon Mound (Section C.6.1.8).

Government

The impacts on public services would be the same as those expected at Damon Mound (Section C.6.1.8). Construction of SPR facilities at Nash dome would involve the removal of 206 acres from the tax rolls of Fort Bend County. The tax rate in the County is $1.66 per hundred dollars of assessed valuation. Assessed valuation is 20 percent of fair market value. Assuming that land at this site is valued at $1000 per acre, the loss to Fort Bend County would amount to approximately $1593 per year in property taxes for the life of the project.

C.7.2 Impacts From Operation and Standby Storage

Development of 100 MMB of oil storage capacity at Nash dome would provide a total capacity of 163 MMB for the Seaway Group of SPR sites.

TABLE C.7-2 Estimated construction employment and wages by month - Nash Dome (100 MMB) candidate SPR storage site (alternative site)

Month	Number Employed	Monthly Wages
0-1	170	$297,500
1-2	555	971,250
2-3	515	901,250
3-4	508	889,000
4-5	401	701,750
5-6	349	609,000
6-7	132	231,000
7-8	132	231,000
8-9	132	231,000
9-10	132	231,000
10-11	132	231,000
11-12	109	190,750
12-13	109	190,750
13-14	109	190,750
14-15	109	190,750
15-16	109	190,750
16-17	109	190,750
17-18	109	190,750
19-46	55	96,250
Total Construction		$ 9,458,750

Oil movements would be similar to those described for Allen dome (Section C.4.2.2). Principle impacts of operations are expected to result from possible large oil or brine spills and from hydrocarbon emissions over the Gulf of Mexico. Impacts from Bryan Mound early storage development are included where appropriate to indicate cumulative environmental effects.

C.7.2.1 Land Features

Effects of operation and standby storage on land features are expected to be minimal. The remote possiblity of cavern collapse is discussed in Section C.2. There is no recognizible danger due to seismic events. Soils would stabilize as soon as they are revegetated following construction.

Operation of alternative facilities would not affect land features.

C.7.2.2 Water Resources

Impacts to water resources on a result of operating oil storage facilities at Nash dome would result from withdrawal of water for oil displacement, discharge of brine during oil fill, maintenance dredging at dock sites, and possible oil or brine spills.

Raw Water Withdrawal

Impacts associated with drawing water from the Brazos River Diversion Channel for oil displacement would be identical to those described for Allen dome (Section C.4.2.2).

Brine Disposal

Impacts associated with discharging brine to the Gulf of Mexico and utilizing the backup 3-well brine injection system southeast of Nash dome would be similar to those described for Bryan Mound in Section C.3.2.2.

Maintenance Dredging

Potential impacts due to maintenance dredging at the DOE dock site would be identical to those for Bryan Mound SPR expansion (Section C.3.2.2) and Allen dome (Section C.4.2.2).

Oil Spills

During project operation, oil spills could occur in the Gulf of Mexico, in the Old Brazos River, from the oil pipeline connecting the storage site with the tanker docks and with SEAWAY Tank Farms, from the wellheads at Nash dome and from oil surge tanks at Bryan Mound (releases from the underground storage cavern are not quantified, see Appendix E). A thorough description of possible modes of spills, methodology of spill calculation, quantification of expected spill volume and frequencies, dispersion characteristics, and spill prevention and containment measures is provided in Appendix E. A summary of oil spill expectations is given in Section C.2 and in Table C.2-1 and C.2-2. Possible effects on water reservoirs are considered in this section.

Probable movements of spills occuring east of SEAWAY Tank Farm are identical to those for Bryan Mound (see Section C.3.2.2).

Spills at Nash dome would likely drain into Turkey or Cow Creeks which flow into the Brazos River. Line spills south of Nash may drain toward an area along the Brazos River known to contain eagle nests. A water storage project presently under consideration for development south of Eagle Lake would not be directly affected by a spill because of containment dikes there. Likewise, the Harris Reservoir would not be directly affected as long as the intakes from the Brazos River were shut off during a spill.

Near the junction point between the proposed Nash dome or Damon Mound pipelines, spills would enter Varner Creek. South of this junction, spills would affect the same drainage basins described in Section C.6.2.2.

Oil spills are most likely to reach the Gulf of Mexico as a result of a direct release from oil tankers.

Quantities of oil expected to be released from the early storage facilities at Bryan Mound and from SPR expansion facilities at Nash dome are listed by source and location in Tables C.2-1 and C.2-2. Total oil spillage for five fill/withdrawal cycles is projected to be 1930 barrels for the early storage facility and an additional 3949 barrels for the Nash dome facilities. Of the total, 73 percent is projected to occur during fill operations, 23 percent during withdrawal, and 4 percent (246 barrels) during standby storage. The distribution of spill is projected to be 2746 barrels (47 percent) in the Gulf of Mexico (principally at the VLCC-tanker transfer location), 1467 barrels (25 percent) at the tanker docks, 1237 barrels (21 percent) at Nash dome, Bryan Mound, and SEAWAY Terminals, and 428 barrels from the connecting pipelines. The maximum credible spill events are estimated to be 60,000 barrels resulting from a tanker collision, 10,000 barrels from a pipeline rupture, 5000 barrels from storage terminals and 500 barrels from transfer operations.

Weathering processes and dispersal characteristics of oil are given in Section C.3.2.2. Impacts expected to result from oil or brine spills from Nash dome facilities are basically the same as those described in Section C.5.2.2 for West Columbia. Few bodies of water are crossed by the project north of SEAWAY Tank Farm and, thus, the effects are expected to be localized from spills in this area. However, should oil get into the Brazos River southeast of the site, potentially widespread water quality degradation could occur.

Brine Spills

During project operation, brine spills could occur from the brine disposal pipeline and from the brine reservoir; fresh to saline water could be spilled from the raw water supply line and from the brine disposal line (during standby storage). A thorough description of possible modes of spills, methodology of spill calculation, quantification of expected spill volume and frequencies, dispersion characteristics, and spill prevention and containment measures is provided in Appendix E. A summary of brine spill expectations is given in Section C.2 and in Table C.2-3. Possible effects on water reservoirs are considered in this section.

Probable movements of spills occurring east of SEAWAY Tank Farm are identical to those for Bryan Mound (see Section C.3.2.2).

Spills at Nash dome would likely drain into Turkey or Cow Creeks which flow into the Brazos River. Line spills south of Nash may drain toward an area along the Brazos River known to contain eagle nests. A water storage project presently under consideration for development south of Eagle Lake would not be directly affected by a spill because of its containment dikes. Likewise, the Harris Reservoir would not be directly affected as long as the intakes from the Brazos River were shut off during a spill episode.

Near the junction point between the proposed Nash dome or Damon Mound pipelines, spills would enter Varner Creek. South of this junction, spills would affect the same drainage basins described in Section C.6.2.2.

Brine spills are most likely to reach the Gulf of Mexico as a result of a direct release from a ruptured brine disposal line.

Brine and salt water spills are expected to occur only from the piping system. Total spillage is estimated to be 205 barrels of brine and 117 barrels of saltwater from early storage operation and 2360 barrels of brine and 2988 barrels of saltwater from SPR expansion facilities. Of the total, 148 barrels of brine and 78 barrels of saltwater would spill into the Gulf of Mexico, 2210 barrels of brine and 2910 barrels of saltwater would spill into Coastal Prairie, fluvial woodlands, and marshland between Bryan Beach and Nash dome (Table C.2-3). The maximum credible spill event is estimated to be 30,000 barrels of brine.

Impacts expected to result from brine spills from Nash dome facilities are basically the same as those described in Section C.5.2.2 for West Columbia. Few bodies of water are crossed by the project north of SEAWAY Tank Farm and, thus, are expected to be localized from spills in this area.

Flood Hazards

The elevation of Nash dome storage facilities precludes any possible serious flooding hazard. Pipelines and storage tanks at Bryan Mound would be subject to the same flood hazards as previously described in Sections C.3.2.2 and C.4.2.2.

Alternative Facilities

Use of ground water to displace oil from the cavern, injection of brine into deep subsurface salt water bearing sands and use of the 12.5

mile diffuser would have the same potential for adverse impacts as described for Bryan Mound (Section C.3.2.2).

Use of a marine pipeline for oil movement would reduce the expected quantities of oil spill volume by about 60 percent. Onshore oil spillage would be essentially unaffected.

C.7.2.3 Air Quality

Air quality impacts associated with the operation of the Nash dome site alternative are essentially identical to those described for the Allen dome (Section C.4.2.3, and Table C.3-6), except that onsite power generation would be an additional source of emissions.

Emissions expected to result from a 34,000 kilowatt gas turbine generator at Nash dome are listed in Table C.3-7. The results indicate that even as close as 1 km downwind, concentrations would be below State and National air quality standards. However, since the 3-hour HC standard is often exceeded in southeast Texas, hydrocarbon concentrations may cause infrequent additional exceedances near the site (especially when interaction with brine pond emissions occur).

Alternatives

Estimated reduction of hydrocarbon emissions which would result from usage of a marine terminal are the same as those given for Allen dome in Section C.4.2.3.

Purchase of commercial power in place of on-site generation would eliminate the major source of gaseous pollutants at Nash dome.

C.7.2.4 Noise

Noise impacts caused by operating SPR facilities at Nash dome would be essentially the same as described in Section C.3.2.4 for Bryan Mound. As there are no residences near the site, impacts would be insignificant.

C.7.2.5 Ecosystems and Species

Raw Water Withdrawal

Impacts are essentially identical to those described for Bryan Mound in Section C.3.2.5 and for Allen dome in Section C.4.2.5.

Brine Disposal

Impacts are identical to those described in Section C.3.2.5 for Bryan Mound.

Tanker Transport

Impacts are essentially identical to those described in Section C.3.2.5 for Bryan Mound and in Section C.4.2.5 for Allen dome.

Maintenance of Project Lands

Types of impacts expected are the same as described for Allen dome. A greater total area (about 391 acres) must be maintained for Nash dome, however, because of the longer pipeline corridor.

Accidential Oil Release

Appendix E, Section C.2 and Tables C.2-1 and C.2-2 indicate the modes and quantities of oil spills expected for Nash dome facilities. Expected movement, weathering processes, and potential for water quality degradation have been described in Section C.3.2.2 and C.5.2.2.

Quantities of oil expected to be spilled at various locations from Nash dome facilities have been summarized under Water Resources (C.7.2.2). Most of the oil would spill in the Gulf. Maximum credible spill sizes are the same as for other site alternatives. Total oil spillage from Nash dome is expected to be only slightly larger than for Allen dome SPR development (4 percent larger), because pipelines contribute a small fraction of the total expected oil spill volume.

As for the other sites, frequencies of spill occurrence are low -- 28 per 100 MMB oil filled and 2 per 100 MMB oil withdrawn. Therefore, pollution from chronic or frequently recurring spills is unlikely. Areas potentially sensitive to drainage from an occasionally large oil spill include Turkey, Cow, Varner, Bell and Jones Creeks, wetlands near the SEAWAY Tank Farm, shallow lakes and ponds on Bryan Mound, and near shore Gulf waters and shorelines. Also, should a large oil spill reach the eagles' nesting area along the Brazos River southeast of the site, potentially serious ecological damage could occur to a broad range of vegetation and wildlife, including the endangered southern bald eagle.

Estimates made in Section C.3.2.5 of acreages which might be destroyed by maximum credible oil spill apply to the Nash dome site alternative. With maximum spreading, a large tanker spill would destroy 1680 acres of wetlands and as much as 7000 acres of benthic habitat in shallow coastal waters. A large pipeline spill could destroy 320 acres of wetlands (or prairie) and 1340 acres of shallow water habitat. The most sensitive areas would probably be the pipeline right-of-way near SEAWAY Tank Farm and the lakes and ponds on Bryan Mound.

In summary, except for the case of a very large oil spill (or a moderately sized spill in a sensitive area), biological impacts are not expected to be of regional significance. The expected frequency of potentially large spills is very small.

<u>Accidental Brine Release</u>

Appendix E, Section C.2 and Table C.2-3 indicate the modes and quantities of brine spills expected for Nash dome facilities. Expected movement, weathering processes, and potential for water quality degradation have been described in Section C.3.2.2 and C.5.2.2.

Quantities of brine expected to be spilled at various locations from Nash dome facilities have been summarized under Water Resources (Section C.7.2.2). Most brine spills would occur onshore. Maximum credible spill sizes are the same as for other site alternatives. The brine and raw water spill volume is expected to be nearly three times as large as for Allen dome, because pipeline spills are the only quantified mode of brine spills.

As for the other sites, frequencies of spill occurrence are low - only 0.8 for brine and raw water for the entire lifetime of the project. Therefore, pollution from chronic or frequently recurring spills is unlikely.

Estimates made in Section C.3.2.5 of acreages which might be destroyed by maximum credible brine spill apply to the Nash dome site alternative. A large pipeline spill could destroy 320 acres of wetlands (or prairie) and 1340 acres of shallow water habitat. Impacts of brine depend on mixing and dilution potential. The most sensitive areas would probably be the pipeline right-of-way near SEAWAY Tank Farm and the lakes and ponds on Bryan Mound.

In summary, except for the case of a very large brine spill (or a moderately sized spill in a sensitive area), biological impacts are not expected to be of regional significance. The expected frequency of potentially large spills is very small.

Alternatives

Use of a ground water supply system or a deep well brine injection system would reduce the exposure to brine or raw water spills because pipelines to the coast would not be needed.

Use of the 12.5 mile diffuser off Bryan Mound would have impacts as described in Section C.3.2.5.

Use of a marine pipeline and monobuoy would substantially reduce the offshore and harbor exposure to oil spills (by about 60 percent).

C.7.2.6 Natural and Scenic Resources

Operation and maintenance activities at the project site would have little effect on the scenic values in the area unless future development occurs along county roads. The project facilities would not be visible from any residents in the area. There are no significant adverse impacts anticipated to the natural resources at the site.

Along the pipeline route there would be minimal impacts on natural and scenic resources as much of the land would be revegetated to its previous state. Also, the route parallels the SEAWAY Right-of-Way most of the way to the Tank Farm.

Operation of the alternative brine disposal and raw water supply systems would not have additional adverse effects on natural resources over those experienced during construction.

C.7.2.7 Archaeological, Historical and Cultural Resources

There would be no impact on any known archaeological, historical, or cultural resources caused by operations at the site.

C.7.2.8 Socioeconomic Environment

Land Use

Operation and maintenance of the Nash dome SPR site would have little additional impact on land use. The 206 acres enclosed at the site during the construction phase would eliminate the present use of the site for cultivation and cattle grazing for the life of the project. Of the 823 acres required for construction offsite and within the site, 567 acres would be needed for maintenance purposes. Some of this land could be revegetated and returned to present uses.

Transportation

Traffic related to project operations would have minor impact on traffic volumes in the area. During standby operations these impacts would be reduced to minimal levels. No congestion is anticipated.

Population

The effects of operation on local population would be minor. Most workers would commute to the area, and a few might relocate in or near the town of Damon, increasing local population slightly.

Housing

Housing would be minimally affected in a manner similar to total population. A limited supply of housing is available in nearby areas.

Economy

Operation and maintenance of the proposed systems would have a minimal effect on the local economy, and an insignificant effect on the region. During standby operations only 10 employees would be required; about 55 employees would be needed during filling or withdrawal phases. The monthly wages during these phases would be $17,500 per month and $96,000 per month, respectively. Purchases of services and supplies during these phases would have an insignificant impact on the regional economy.

Government

The operational impacts on these characteristics would be the same as those experienced at Damon Mound (Section C.6.2.8). Tax base losses from removal of property at the site from the tax rolls would be similar to those discussed in Section C.4.2.8. The duration of impact would be the life of the project, or 22 years.

Alternatives

Socioeconomic effects of withdrawing ground water for oil displacement, injecting brine to deep saline water bearing sands, using a 12.5 mile offshore diffuser or using a marine terminal for oil transport are not considered to be significantly different from those resulting from the proposed facilities.

C.7.3. Impact Due to Termination and Abandonment

The impact due to termination and/or abandonment of the Nash dome storage site as an oil storage facility would be the same as described in Section C.3.3.

C.7.4 Relationship of the Proposed Action to Land Use Plans, Policies and Controls

It is not anticipated that the Nash dome Strategic Petroleum Reserve storage facility would conflict with any land use plans or policies. For a further discussion of the land use plans, policies and controls in the area, refer to Section C.3.4.

C.7.5 Summary of Adverse and Beneficial Impacts

Development of the Nash dome as an oil storage facility is not likely to generate significant regional environmental impacts, except for the remote possibility of a major oil or brine spill and the release of hydrocarbon vapors during oil transport. The longtime use of the area surrounding the site for oil and gas production and for agriculture would tend to minimize the scope of impacts resulting from construction activities.

Site construction would require grading of about 30 acres. Fill requirements would be negligible and would be supplied from the site. Erosion of disturbed material on the site and along the pipeline route would increase the potential for siltation of the several intermittent streams crossed. Other construction activity which would impact water quality would include dredging and construction at the two dock sites in Freeport Harbor, and installation of pipelines in a 32-mile corridor from Bryan Mound. Increased salinity in the Gulf of Mexico would result from brine disposal due to the operation of the site. Contamination of ground water supplies is unlikely.

Air quality standards are not expected to be exceeded during either construction or operation of the storage facility; however, temporary hydrocarbon standards exceedance could occur at Freeport Harbor. No significant noise impact is expected during construction or operation of the project.

Land use impacts of developing this candidate site center on the amount of land required. At the dome, 206 acres would be enclosed by a security fence. Within this area, approximately 30 acres would be required for construction of onsite facilities. Construction of backup injection wells and pipelines from Nash dome to Bryan Mound to transport oil, brine, and raw water would disrupt 432 acres. This land could be revegetated and partially returned to prior uses. Construction of systems common to each site would require 185 acres for the offshore brine diffuser pipeline, pipeline connections to Brazos Harbor and the new tanker docks.

The reduction of available wildlife habitat in the vicinity of the site and along the pipeline route to Bryan Mound and offshore to the diffuser are the most significant ecological impacts associated with this site. Construction activities would force migration of many species, and reduce the amount of food, cover, and nesting area available. Many small invertebrates, birds, and mammals would be destroyed. No rare or endangered species have been identified as existing in the area. Following construction, much of the area would return to its previous state.

Although large quantities of water would be required to leach storage caverns, the withdrawal of this water from the Brazos River Diversion Channel would constitute less than one percent of its average flow. Disposal of brine in the Gulf of Mexico is expected to increase salinity in the water near the diffusers, but this increase is not expected to be significant, though there may be some adverse effect on marine organisms. Pipeline construction could temporarily affect the water quality of Cow, Varner, Bell, and Jones Creeks by increasing turbidity and release of pollutants from bottom sediments. Dock construction in Freeport Harbor is not expected to have significant effects on either the ecology of the area or its water quality, as the area is frequently dredged.

During the construction phase, increases in income and employment in the Houston area are expected. These increases are not expected, however, to provide major stimulus to the economy of the region. During operation, the project is expected to contribute about $17,500 per month in additional income during standby storage and $96,000 per month during fill and withdrawal. Minor increases in traffic congestion in the Nash dome area are expected. These impacts should be of short duration.

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APPENDIX D

OIL IN BRINE MODEL STUDY

PART I GENERAL DISCUSSION AND USE OF EXISTING CAVERNS

PART II SOLUTION MINING AND USE OF NEW CAVERNS

PART III TESTIMONY OF GERARD FEDIDA: JOINT ENVIRONMENTAL PROTECTION AGENCY - CORPS OF ENGINEERS PUBLIC HEARING ON BRYAN MOUND BRINE DIFFUSER APPLICATION, MAY 2, 1978

APPENDIX D

PART I - GENERAL DISCUSSION AND USE OF EXISTING CAVERNS

D.1 INTRODUCTION

The storage of crude oil in the Strategic Petroleum Reserve Program will entail the contact of oil with brine solutions. This contact would result in the dissolving and entrainment of small concentrations of hydrocarbons in the brine through a number of physical phenomena. In order to assess the magnitude of oil concentrations discharged into the brine surface control facilities, a study was performed to determine the mechanisms of interactions between the oil and brine within a typical underground oil storage cavern. This appendix discusses the results of that study.

The primary cavern interactions which would distribute the oil into the brine are dissolution and dispersive reactions. Dispersive reactions require a physical energy input to the system to agitate the micro oil particles into the underlying brine. Dissolution occurs on the molecular level where the hydrocarbon solute dissolves into the brine solvent system. Although both of these reactions occur simultaneously during certain operational phases, the study indicates that principally dissolved components would be discharged to the surface brine control facilities.

Results of the study indicate that under a worst-case situation, the brine discharge would contain an estimated maximum 32 parts per million (ppm) of oil. However, this condition is not expected to occur. A more reasonable estimate of the dissolved oil-in-brine concentration discharged from a typical cavern during initial fill is approximately 16 ppm, and during approximately the later 10% of an individual cavern discharge and 6 ppm during the entire individual cavern discharge period for subsequent refills.

The sections which follow describe the oil/brine interactions within a storage cavern (Section D.2), dissolving reactions (Section D.3), dispersive reactions (Section D.4), expected concentration of oil-in-brine discharged to the surface brine control facilities (Section D.5), and conclusions (Section D.6).

D.2 OIL/BRINE INTERACTIONS IN A SALT SOLUTION-MINED STORAGE CAVERN

The following sections briefly describe the major interactions that occur between the oil, brine, and raw water within a salt dome storage cavern. The interactions which occur during the operational phases of the storage program are illustrated schematically in Figure D-1 and are described herein as:

The initial oil fill and discharge of brine;
The long-term storage of oil in a quiescent state;
Raw water injection to displace oil;
Storage cavern conditions after oil is displaced; and
The second and subsequent refills.

D.2.1 Initial Oil Fill

The salt dome cavern, prior to the initial oil fill, is filled with brine. As crude oil injection begins, jetting (approximately 8 feet per second) causes turbulence at the oil-brine interface which produces an emulsion of oil and brine and affects solution of various hydrocarbons into the brine. Turbulence would be confined to approximately the upper 50 feet of the cavern. As cavern filling continues, interface turbulence would decrease as the interface descends. At a depth of approximately 50 jet diameters, the oil jet momentum would be one-tenth of its initial value and interface turbulence would have ceased (American Petroleum Institute, 1969).

The lighter, more soluble hydrocarbons diffuse across the oil-brine interface, while the heavier, less soluble components slowly begin to form a relatively dense and viscous refractory layer between the oil and brine. Thus, the major oil contamination of the brine occurs during the initial period of the filling phase while turbulence is high.

Dissolved and dispersed oil is expected to remain within the uppermost 100 feet of the brine column during initial fill due to a low rate of vertical diffusion. Consequently, during the early stages of fill the oil concentration of the discharged brine would be near zero. As the oil/brine interface approaches the bottom of the brine displacement tubing, oil concentration of the discharged brine would increase and average 16 ppm during the final stages of fill (Section D.5).

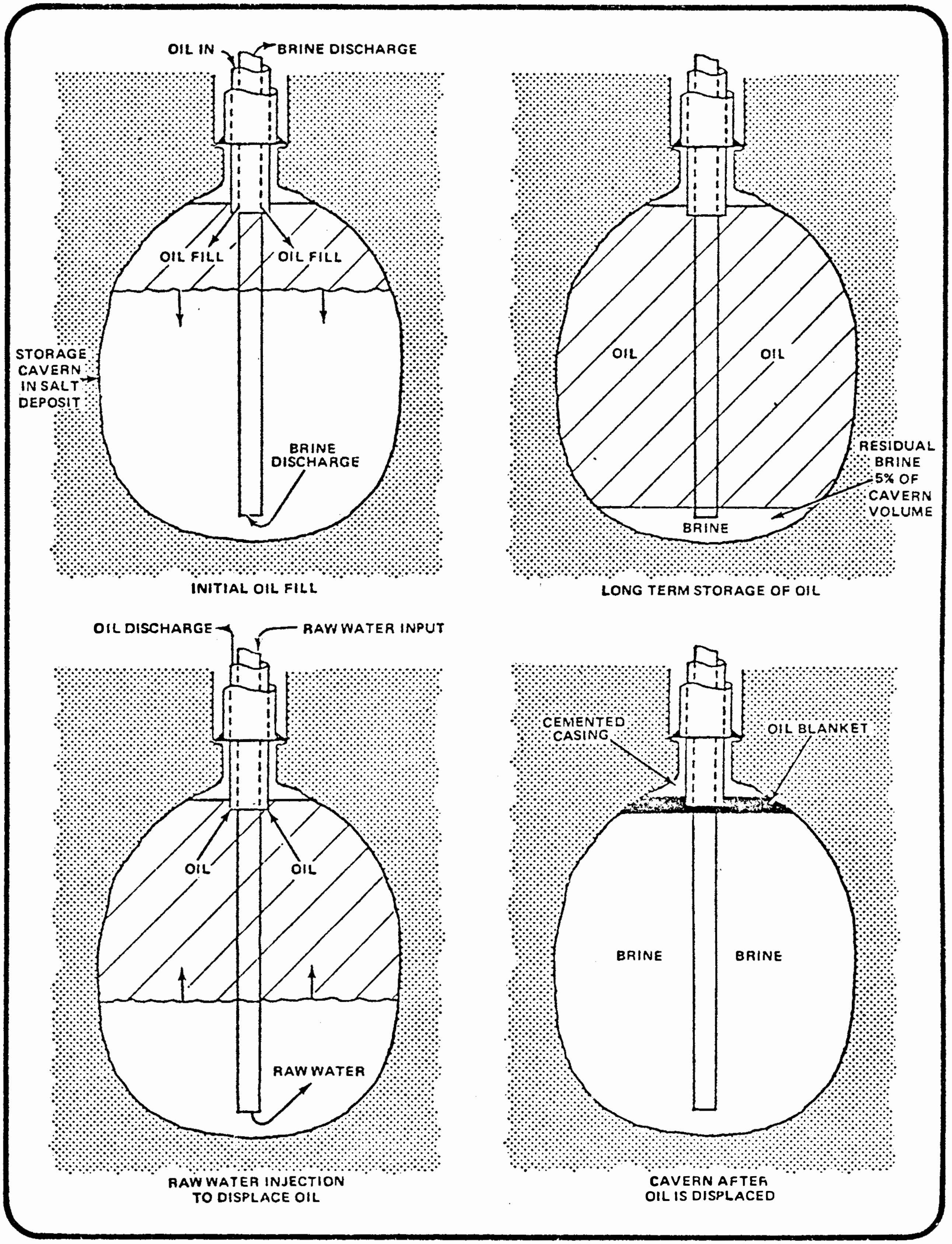


FIGURE D-1 Operational phases of oil storage program

D.2.2 Long-Term Oil Storage

During long-term oil storage, a brine layer is maintained at the bottom of the solution cavern and would amount to approximately 5 percent of the total cavern volume. The oil concentration within this brine is assumed to reach equilibrium during long-term storage. A refractory layer would form at the oil brine interface because of the loss of soluble hydrocarbons into the underlying brine and a consequent enrichment of heavier, relatively insoluble hydrocarbons. Any remaining small fraction of dispersed oil in brine would be expected to rise to the oil-brine interface contributing to the refractory layer or be absorbed by suspended particles and in turn settle to the bottom. The long-term storage is the only phase of the program where time allows the hydrocarbons to dissolve and establish equilibrium conditions with respect to the brine.

D.2.3 Injection of Raw Water and Displacement of Oil

The oil is displaced from the cavern by injection of raw water into the lower level, causing the upward displacement of oil. The raw water would dilute the residual brine solution in the bottom of the cavern and may resuspend settled particles. The resultant dilution of both the brine and dissolved oil concentration would allow further dissolution of oil into brine. Initially, there would be turbulence at the oil-brine interface which may disperse some of the oil. The refractory layer at the oil-brine interface would effectively limit diffusion and dispersion. When the crude oil is displaced from the storage cavern, an oil film would remain on the cavern walls. This oil film would, in time, partly dissolve into the brine and partly rise to the oil-brine interface as solution of the underlying salt progresses. For calculation purposes, in this report, this oil film was assumed to be totally dissolved, adding approximately 1.6 ppm to the oil-in-brine concentration.

The raw water being injected into the cavern would rise toward the surface due to its lower density and induce a circulation within the brine. This may result in an increase in the diffusion of oil into the now non-equilibrium system. As the interface rises within the cavern, the circulation would decrease in the upper brine column due to the rapid dilution of the raw water. The brine temperature within the cavern will eventually rise to approximately 150^{o}F and an increase in salinity will occur as the dissolution of the cavern walls proceeds. The net effect is a decrease in oil solubility because the salinity factor has a greater influence than that of temperature (Section D.3). The dissolved oil concentration in the brine at the end of this operation is therefore the result of:

(1) the twentyfold dilution of the residual brine which had reached equilibrium oil concentrations at the bottom of the cavern,
(2) some dissolution of the oil layer on the cavern walls, and
(3) some small additional dissolution at the oil-brine interface during displacement.

D.2.4 Storage Cavern Conditions After Oil is Displaced

After the cavern is filled with water and the crude oil removed, a small amount of the crude oil would be retained as a blanket on top of the brine column. The oil blanket acts as a barrier between the solution cavern ceiling and the brine, thereby minimizing salt dissolution around the cemented casing. The oil at the oil-brine interface will be composed of a relatively dense, viscous layer and would only allow slow diffusion of the soluble hydrocarbon components. The additional oil concentration dissolved into the brine during this operation is judged to be minimal.

D.2.5 Second and Subsequent Oil Refill Phase

The oil-brine interface would now have had sufficient time for a dense refractory layer to form. This layer would reduce the diffusion and dissolution during subsequent refills. Throughout subsequent oil refills approximately 6 ppm of oil in brine (as calculated in Section D.5) will be discharged to the surface brine control facilities, providing the dense refractory layer continues to act as a barrier. In the event that the refractory layer is penetrated by the input jet of oil, reactions similar to those of the initial fill cycle would occur.

D.3 DISSOLUTION REACTIONS DURING CAVERN OPERATIONS

The solubilities of various hydrocarbons in water and in brine have been studied by a number of workers. The data illustrated in Figure D-2 indicate that for each homologous series of hydrocarbons, the logarithm of solubility in water is a linear function of hydrocarbon molar volume. The solubility of hydrocarbons as illustrated in Figure D-2 and listed in Table D-1 increase with a decrease in molar volume and molecular weight and an increase in branching and degree of unsaturation. The most soluble hydrocarbons are the low molecular weight aromatics (Price, 1973; McAuliffe, 1976).

Review of studies which were conducted to determine the saturation concentrations for oil in seawater and in freshwater, indicate that as the hydrocarbons dissolve, solubility rates decrease before equilibrium conditions are established (Price, 1973).

Equilibrium concentrations at standard temperature and pressure for four different crudes are listed in Table D-2. Equilibrium concentrations found by other researchers for crude oil in both freshwater and saltwater, range from 7 to 40 ppm with the preponderance of data ranging from 20-30 ppm (McAuliffe, 1976; Frankenfeld, 1975; Candle, 1977; Anderson, 1974).

Selected data for the La Rosa and Murban crudes, presented in Table D-3, reveals the variations in equilibrium concentrations which can be expected. This data indicates that the hydrocarbon composition of a particular stored crude would effect the concentration of dissolved oil being discharged with the brine. For the purpose of calculating estimated oil concentrations in a brine discharge, the Middle East Murban crude was considered as a possible crude to be stored in the Strategic Oil Reserve Program.

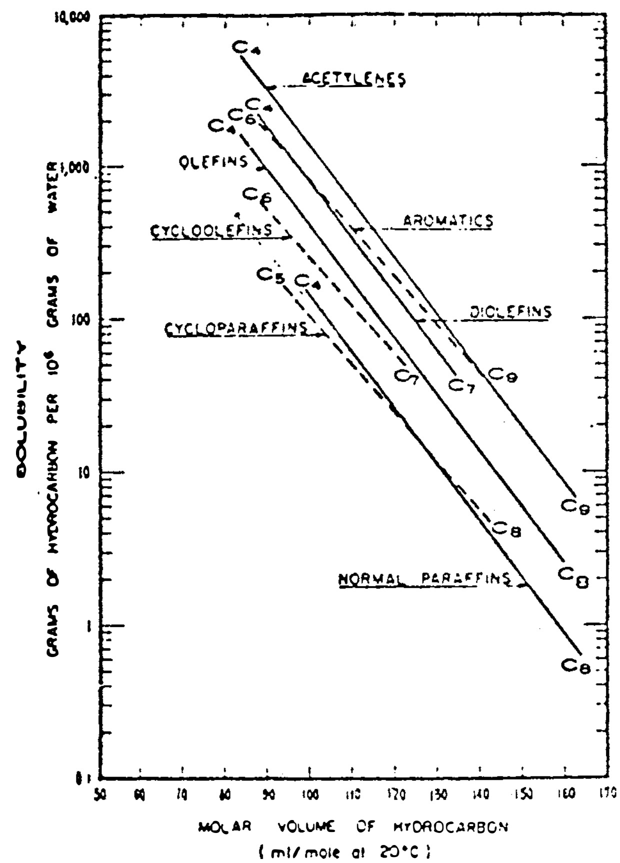
The equilibrium concentration of Murban crude in seawater with a salinity of 36 ppt is 27.9 ppm at standard temperature and pressure as shown in Table D-2.

As temperature and pressure change within the storage cavern, the resultant equilibrium concentrations can be expected to change. General hydrocarbon solubility studies indicate that as temperature and pressure increase, solubility and equilibrium concentrations increase. Increasing

TABLE D-1 Aqueous solubility values of individual compounds at 25^{O}C (ppm).

COMPOUND	PRICE	MCAULIFFE
PENTANE	39.5	38.5
HEXANE	9.47	9.5
HEPTANE	2.24	2.93
OCTANE	0.431	0.66
NONANE	0.122	0.22
ISO PARAFFINS		
2,3 – DIMETHYLBUTANE	19.1	
2,2 – DIMETHYLBUTANE	21.2	
2 – METHYLPENTANE	13.0	
3 – METHYLPENTANE	13.1	
2,4 - DIMETHYLPENTANE	4.41	
2,2 – DIMETHYLPENTANE	4.40	
2,3 – DIMETHYLPENTANE	5.25	
3,3 – DIMETHYLPENTANE	5.94	
2,2,4 – TRIMETHYLPENTANE	1.14	
2,3,4 – TRIMETHYLPENTANE	1,36	
ISOPENTANE	48.0	
2 – METHYLHEXANE	2.54	
3 – METHYLHEXANE	2.65	
3 – METHYLHEPTANE	0.792	
4 – METHYLOCTANE	0.115	
BICYCLOPARAFFIN		
(4.4.0) BICYCLODECANE	.889	
NAPTHO–AROMATIC	88.9	
CYCLOPARAFFINS		
CYCLOPENTANE	160	156
METHYLCYCLOPENTANE	41.8	42
PROPYLCYCLOPENTANE	2.04	
PENTYLCYCLOPENTANE	0.115	
1,1,3 – TRIMETHYLCYCLOPENTANE	3.73	
CYCLOHEXANE	66.5	55.2
METHYLCYCLOHEXANE	16.0	14.0
1,4 – TRANSDIMETHYLCYCLOHEXANE	3.84	
1,1,3 – TRIMETHYLCYCLOHEXANE	1.77	
AROMATICS		
BENZENE	1740	1780
TOLUENE	554	515
M – XYLENE	134	
O – XYLENE	167	175
P – XYLENE	157	
1,2,4 – TRIMETHYLBENZENE	51.9	57
1,2,4,5 – TETRAMETHYLBENZENE	3.48	
ETHYLBENZENE	131.1	152
ISOPROPYLBENZENE	48.3	50
ISOBUTYLBENZENE	10.1	

SOURCE: PRICE, 1973.
McAULIFFE, 1969



SOURCE: McAuliffe, 1969

FIGURE D-2 Comparison of the solubilities in water at 25°C of various types of hydrocarbons, as functions of their molar volumes

TABLE D-2 Hydrocarbons dissolved in sea water* equilibrated with oil samples.

COMPOUND	SOUTH LOUISIANA CRUDE (1) ppm	KUWAIT CRUDE (1) ppm	VENEZUELA LA ROSA CRUDE (2) ppm	MIDDLE EAST MURBAN CRUDE (2) ppm
ALKANES				
ETHANE	.54	.23	2.011	.23
PROPANE	3.01	3.30	3.63	2.150
n BUTANE	2.36	3.66	1.88	2.880
ISOBUTANE	1.69	.90	.76	.800
n PENTANE	.49	1.31	.60	1.340
ISOPENTANE	.70	.98		1.030
CYCLOPENTANE + 2 METHYLPENTANE	.38	.59		
METHYLCYCLOPENTANE	.23	.190	.275	.355
HEXANE	.09	.290	.65	1.35
CYCLOHEXANE			.190	.410
METHYLCYCLOHEXANE	.22	.080	.160	.235
n HEPTANE	.06	.090	.100	.330
C_{16} n PARAFFIN	.012	.0006		
C_{17} n PARAFFIN	.009	.0008		
TOTAL $C_{12} - C_{24}$ n PARAFFINS	.089	.004		
AROMATICS				
BENZENE	6.75	3.36	3.30	6.080
TOLUENE	4.13	3.62	2.80	6.160
ETHYLBENZENE	1.56	1.58	.275	.825
M – P – XYLENE			.840	1.940
O – XYLENE	.40	.67	.350	1.010
TRIMETHYLBENZENE	.76	.73	.300	.750
NAPHTHALENE	.12	.02		
1 METHYLNAPHTHALENE	.06	.02		
2 METHYLNAPHTHALENE	.05	.008		
DIMETHYLNAPHTHALENE	.06	.02		
OTHER AROMATICS	.021	.013		
TOTAL SATURATES	9.86	11.62	11.200	11.100
TOTAL AROMATICS	13.90	10.03	7.860	16.800
TOTAL DISSOLVED HYDROCARBONS	23.76	21.63	19.000	27.900

*Seawater (36 PPT) at Standard Temperature and Pressure

SOURCE: 1 ANDERSON, et. al., (1974)
2 MCAULIFFE (1976)

TABLE D-3 Relative aromatic components of crude and their effect on equilibrium concentrations*.

	MURBAN CRUDE (ABU DHABI)		LA ROSA CRUDE (VENEZUELA)	
	EQUILIBRIUM CONCENTRATIONS ppb	PERCENT COMPOSITION IN CRUDE	EQUILIBRIUM CONCENTRATIONS ppb	PERCENT COMPOSITION IN CRUDE
BENZENE	6,080	.13	3,300	.07
TOLUENE	6,160	.49	2,800	.22
TRIMETHYLBENZENE	750	.74	300	.30
TOTAL	12,990	1.36%	6,400	.59%

*In Seawater at Standard Temperature and Pressure

REF. MCAULIFFE, 1976

the salinity of the solvent yields a decrease in the hydrocarbon solubility and a reduction of the equilibrium concentrations. The following sections summarize the anticipated changes in cavern equilibrium concentrations of the oil in brine as a result of a temperature increase to 150^{O}F, an increase in pressure to approximately 1500 psi and an increase in salinity to 310 parts per thousand.

D.3.1 Increased Temperature Effects on Equilibrium Concentrations

As illustrated in Figures D-3 and D-4 the temperature/solubility relationship is non-linear and until temperatures in excess of 257^{O}F are reached significant increases in solubilities do not occur. The operating temperature for the caverns will be approximately 150^{O}F. Published data indicate that for an increase of from 70^{O}F to 150^{O}F an equilibrium concentration increase of 1.5 is the maximum that can be reasonably expected (Price, 1973; Griswold, 1942). For model calculation purposes, a temperature multiplier of 1.5 has been utilized.

D.3.2 Increased Salinity Effects on Equilibrium Concentrations

The aqueous solubility of hydrocarbons is an inverse function of salinity (Price, 1973; Candle, 1977). Within the salt dome caverns brine concentrations will be in excess of 310 parts per thousand (ppt) (McAuliffe, 1969). The results of solubility experiments on discrete hydrocarbons listed in Table D-4 indicate that large reductions in hydrocarbons solubility can be expected with increases in salinity. Recent studies on a number of domestic crude oils (Table D-5) exhibit similar decreases in hydrocarbon solubility when compared over the smaller range of salinity. Based on these studies a salinity multiplier of 0.15 is reasonable and perhaps even conservative.

D.3.3 Increased Pressure Effects on Equilibrium Concentrations

The effect of increasing pressure on the solubility of hydrocarbons is to increase their solubility. As illustrated in Figure D-5, this effects is most significant for the lighter or lower molecular weight hydrocarbons such as methane and butane. Similar effects for larger hydrocarbon molecules could not be identified. The data as listed in

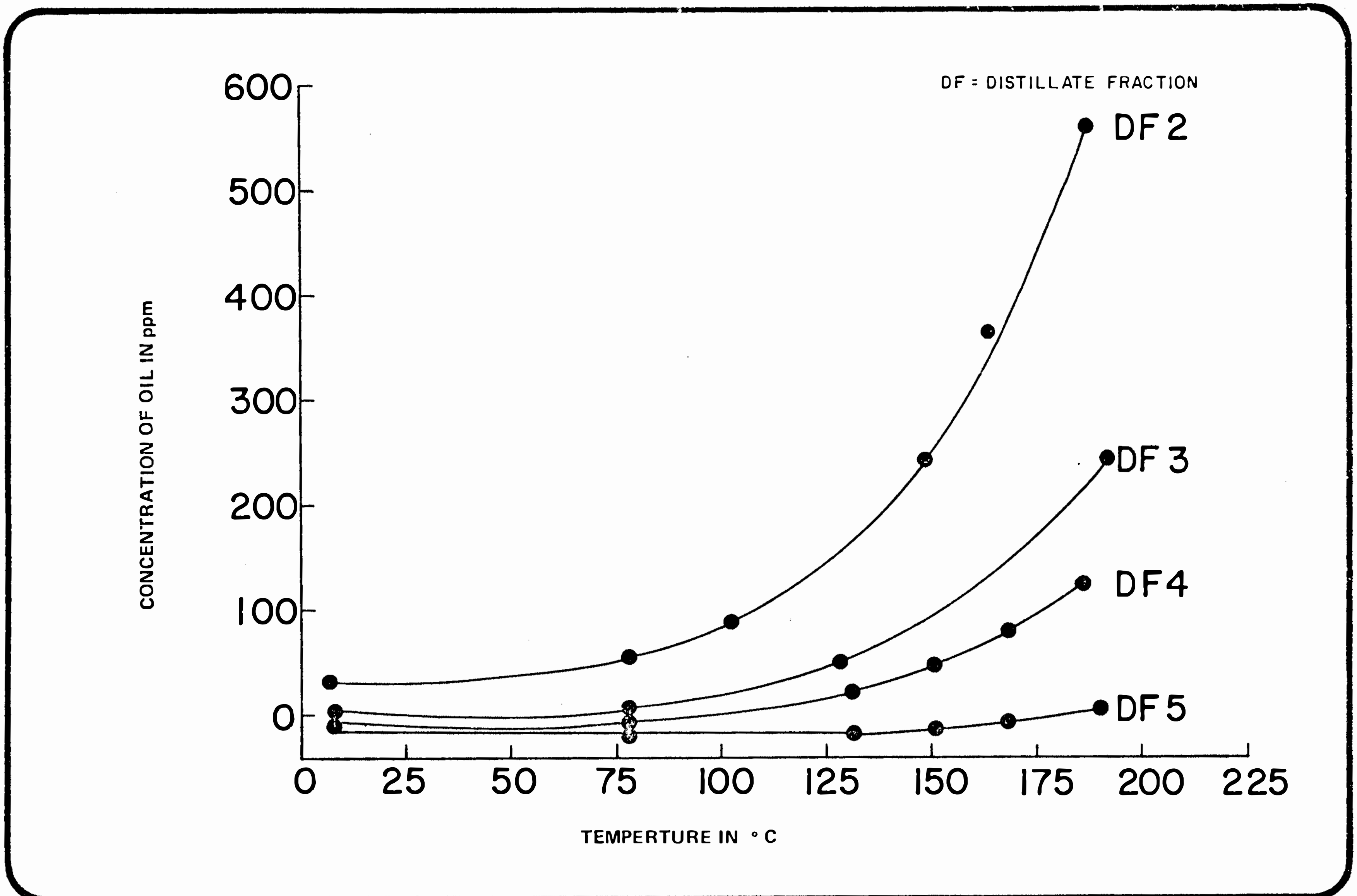
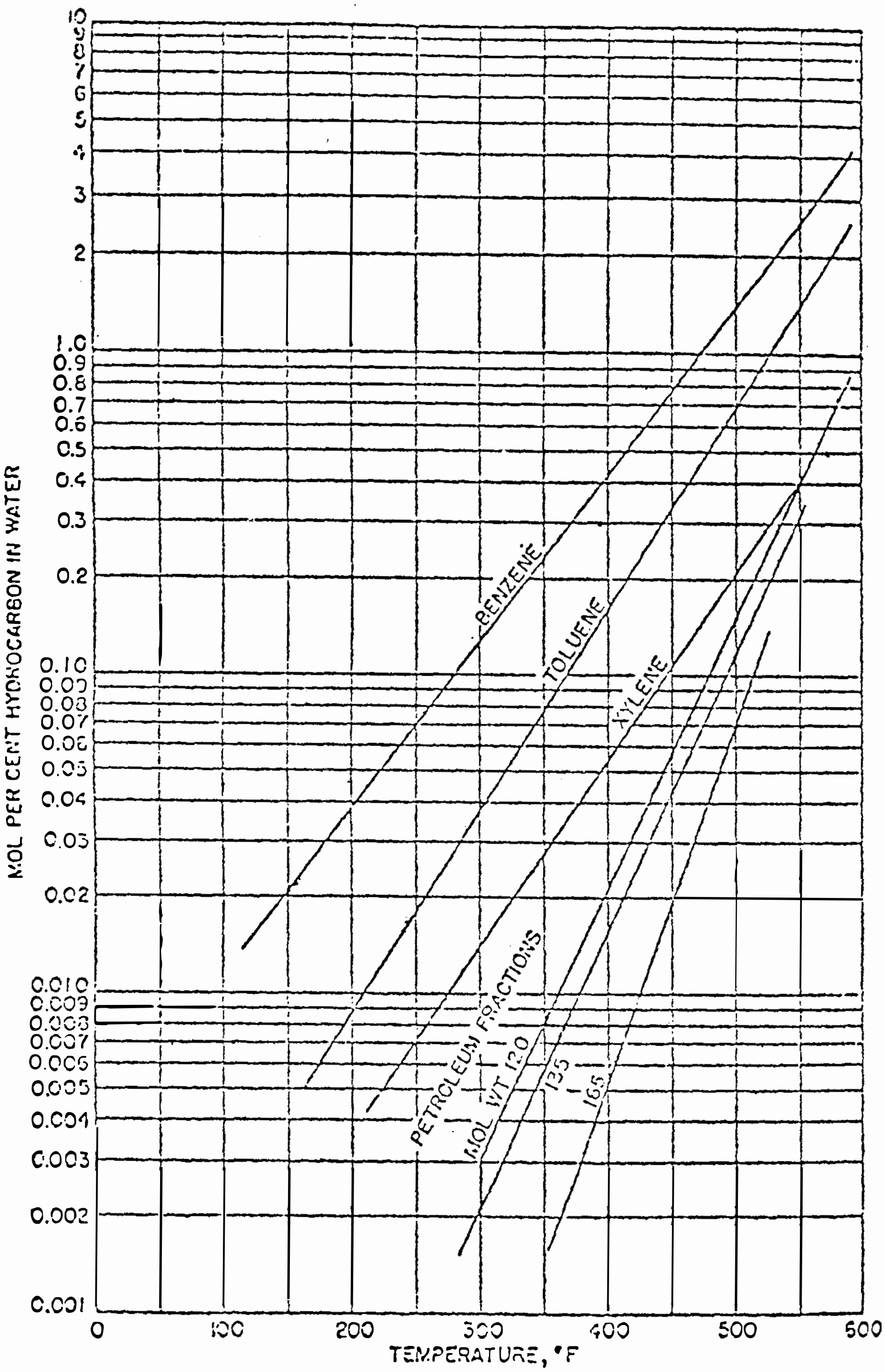


FIGURE D-3 The solubilities of the second (DF 2, 132-193°C), third (DF 3, 193-232°C), fourth (DF 4, 232-316°C) and fifth (DF 5, 316-371°C) distillation fractions of the Ghawar Arabian crude oil in water as a function of temperature at systemal pressure.



SOURCE: Griswold, 1942

FIGURE D-4 Solubilities of hydrocarbons and petroleum fractions in water at total system pressure

TABLE D-4 Solubility of individual hydrocarbons in aqueous solutions at 25°C as a function of NaCl concentration.

NaCl CONCENTRATION IN PPM	SOLUBILITY OF HYDROCARBON IN PPM			
	PENTANE	BENZENE	TOLUENE	METHYLCYCLOPENTANE
0	39.5	1740	544	41.8
1,002	36.8	1718	526	38.0
10,000	34.5	1628	490	36.3
SEA WATER * 34,472	27.6	1391	402	29.2
50,030	22.6	1194	359	27.0
125,100	10.9	593	182	12.7
199,900	5.91	388	106	5.72
279,800	2.64	214	53.8	3.36
358,700 **	2.01	134	37.2	1.89

* ARTIFICIAL SOLUTION

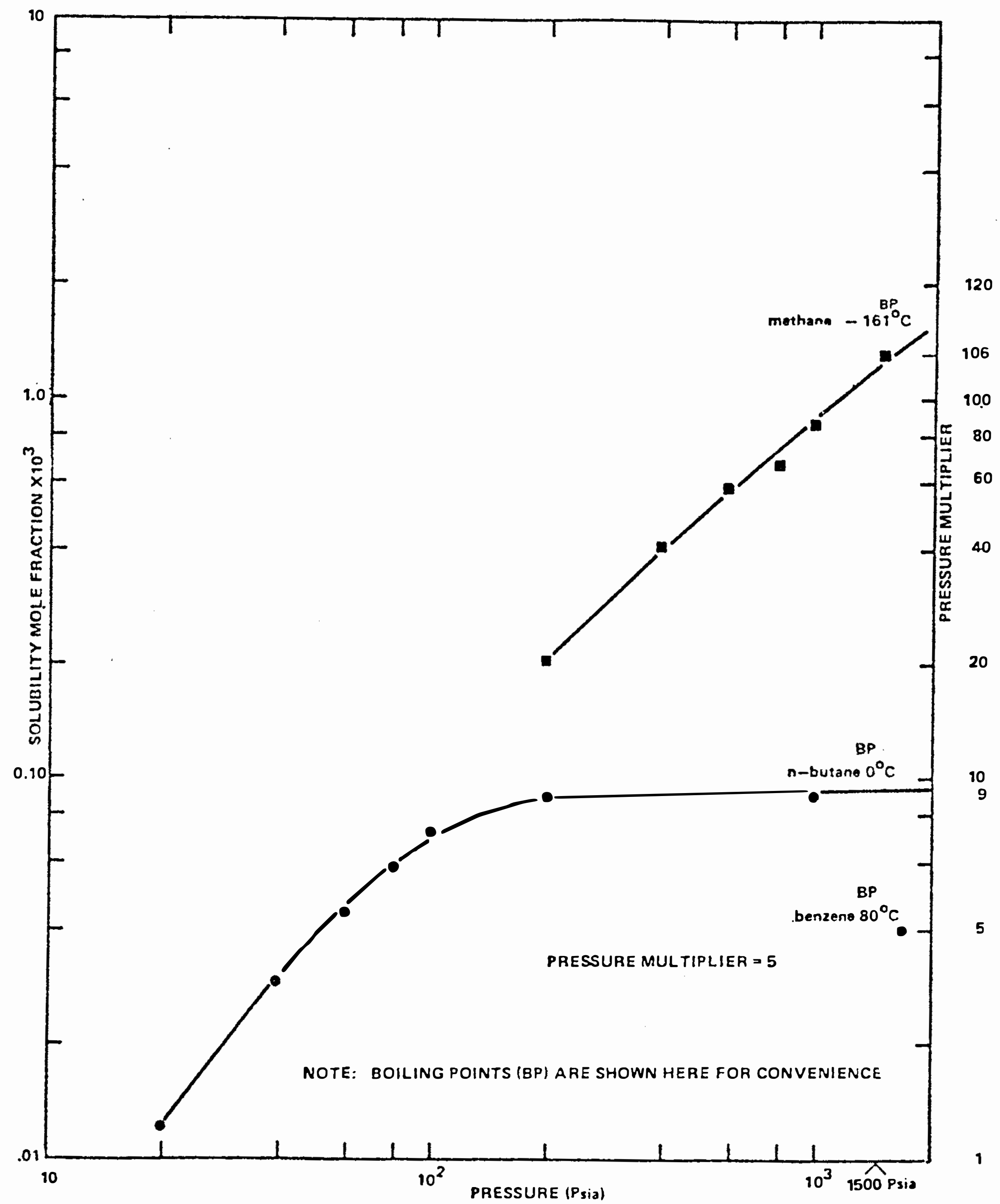
** SATURATED NaCl SOLUTION

SOURCE: Price, 1973

TABLE D-5 Dissolved oil content of brines equilibrated with various oils.

	BRINE ppt	GRAVIMETRIC mg/l
GULF COAST TEXAS CONDENSATE	1	9.64
	30	5.83
	100	2.45
GULF COAST TEXAS HIGH GRAVITY CRUDE	1	6.87
	30	4.03
	100	2.15
LOUISIANA MEDIUM GRAVITY CRUDE	1	6.16
	30	5.53
	100	3.68
EAST TEXAS MEDIUM GRAVITY CRUDE	1	11.49
	30	6.96
	100	3.11
EAST TEXAS LOW GRAVITY CRUDE	1	5.02
	30	3.96
	100	2.41
CALIFORNIA LOW GRAVITY CRUDE	1	0.40
	30	0.31
	100	0.60
CALIFORNIA MEDIUM GRAVITY CRUDE	1	9.64
	30	4.58
	100	3.87
ALASKA CRUDE	1	9.56
	30	7.83
	100	5.04
FLORIDA CRUDE	1	10.51
	30	7.51
	100	4.15

SOURCE: Caudle, 1977



SOURCE: Reference Petroleum Production Handbook

FIGURE D-5 Pressure effect on solubility

Table D-6 and shown in Figure D-5, taken at a temperature of 160°F to approximate cavern conditions, indicates a corresponding increase in solubility with pressure in addition to the importance of the hydrocarbons molecular size and boiling point. This data suggests that pressure has a diminishing effect on the solubility of the hydrocarbons as their molecular weights and boiling points increase (Price, 1973; McKelta and Wehe, 1962). For convenience, the boiling points of the hydrocarbons are also listed on Figure D-5. Since no data was located for pressure/solubility relationships for the higher boiling point hydrocarbons, a pressure multiplier of 5 was used for calculation purposes. The pressure multiplier of 5 is plotted on Figure D-5 in relation to the boiling point of benzene. The pressure multiplier factor of 5 appears to be a reasonable worst case assumption and only operating data or precise experimentation would provide closer approximations.

D.3.4 Calculations of Dissolved Oil Concentrations

Based on the preceding discussion, expected cavern equilibrium concentration for Murban crude can be computed as follows:

Seawater Equilibrium		Temperature Multiplier		Salinity Multiplier		Pressure Multiplier		
(27.9 ppm)	X	(1.5)	X	(0.15)	X	(5)	=	(31.4 ppm)

Allowing the cavern brine to reach equilibrium conditions, the concentrations of hydrocarbons will be roughly equivalent to that of seawater concentrations as determined by McAuliffe. Personal communications with McAuliffe on this subject reveals that 25-30 ppm would be a reasonable equilibrium concentration.

The equilibrium concentration would occur only during the long oil storage period. However, this concentration would ultimately be diluted by a factor of 20 by raw water during displacement of the oil (see Section 2 and 3). This dilution would lead to non-equilibrium conditions and a resumption of dissolution. During the relatively short periods between cessation of oil withdrawal and completion of cavern refill the entire volume of brine should not attain an equilibrium concentration of dissolved oil. Solution would be retarded by the refractory layer at the brine/oil interface and downward diffusion of dissolved oil will proceed very slowly.

TABLE D-6 Pressure effect on solubility.

SMOOTHED VALUES FOR THE SOLUBILITY OF METHANE IN WATER IN THE VAPOR–LIQUID REGION

PRESSURE, psia	MOLE FRACTION $CH_4 \times 10^3$ 160° F*
200	0.203
400	0.407
600	0.599
800	0.780
1,000	0.945
1,250	1.133
1,500	1.308
2,000	1.608
2,500	1.861
3,000	2.094
3,500	2.309
4,000	2.516
5,000	2.888
6,000	3.221
7,000	3.519
8,000	3.782
9,000	4.007
10,000	4.211

*Temperature of the System

SOURCE: McKetta and Wehe (1962)

SOLUBILITY OF n–BUTANE IN WATER	
PRESSURE psia	MOLE FRACTION OF n–BUTANE X 10^3 160° F *
20	0.012
40	0.029
60	0.044
80	0.058
100	0.071
200	0.088
300	0.088
400	0.088
500	0.089
600	0.089
800	0.089
1,000	0.090
5,000	0.098
10,000	0.103

*Temperature of the System

SOURCE: McKetta and Wehe (1962)

The dissolved oil concentrations contributed from the cavern wall (based on the dimentions of cavern number 4 at Bryan Mound) will be 1.6 ppm. This calculation was based on an estimated 50 micron oil film remaining on the wall during oil displacement and subsequent dissolution into the brine as the underlying salt is dissolved away. This estimate is based on smooth-wall conditions and provides an order of magnitude approximation of the contribution of the wall oil layer to the oil concentration in the brine. An irregular wall may increase the oil layer thickness slightly. The oil film adhering to the cavern wall would be thick for heavy, viscous crudes but relatively thinner for the lighter more fluid crudes. An effective film thickness was calculated by considering the largest (in molecular volume) hydrocarbon which has a measurable solubility. Under cavern operating conditions, the largest normal paraffin which would dissolve in appreciable amounts is C_{10} (decane) which has a typical layer thickness of 50 microns. A molecular layer was estimated to remain on the cavern wall.

An analysis of the wall oil layer component to the brine (based on cavern number 4) indicates that for a millimeter wall layer, the oil in brine concentration would increase to 28.6 ppm. The latter concentration is roughly equivalent to the equilibrium concentration for the entire volume.

The amount of hydrocarbons which would dissolve from the oil-brine interface during oil fill and withdrawal and during non-oil storage periods is difficult to estimate due to the lack of experimental data. The rates of solubility as determined by Price (1973) were based on studies of hydrocarbons and brine solutions in test tubes. Under these conditions, Price observed that it required 2-4 days to achieve equilibrium conditions. Under these relatively slow rates and given the infinitely larger volumes of the cavern, it is reasonable to assume that only the brine close to the oil-brine interface would be affected by dissolved oil during oil filling and withdrawal phases. The dissolution of hydrocarbons during the oil withdrawal and refill phases should be reduced with the existence of the refractory layer at the oil-brine interface. This layer will develop as a result of lighter, more soluble hydrocarbons dissolving into the underlying brine leaving the heavier, relatively insoluble hydrocarbons at the interface. The resistance of this layer to dissolution would increase with time until practically all diffusion across the interface ceases.

The hydrocarbon concentration due to dissolution occurring during the period of non-equilibrium conditioned between oil withdrawal and cavern refill will be 3 ppm. This value is based on the assumption that the time between cessation of drawdown and completion of refill will be of such short duration so that only the volume of the uppermost 50 feet of brine will approach equilibrium. Assuming a 500 foot cavern height, a ten-fold dilution of the equilibrium concentration would occur; resulting in 3 ppm of oil dispersed within the brine column. This average value would change as a function of the cavern geometry and phase within the brine discharge cycle. The addition of this component to the total hydrocarbon concentration being discharged would be minor during first quarter of a cavern's discharge cycle and increase as the oil brine interface descends toward the bottom of the brine pipe. The near equilibrium concentration close to the oil brine interface would not be discharged due to cavern enlargement and diffusion during oil withdrawal and refill phases.

The total dissolved hydrocarbon concentration expected to be discharged is derived as follows:

(1)	Long-Term Storage Equilibrium Component	= 1.6 ppm	Assumes the residual 5% volume of brine attains equilibrium of 31.4 ppm and is diluted 20 times during oil withdrawal.
(2)	Wall Oil Component	= 1.6 ppm	The solution of the 50 micron oil film from the cavern wall's surface. (cavern geometry dependent)
(3)	Oil Withdrawal, Non-Storage Period and Refill, Non-Equilibrium Component	= 3.1 ppm	Assumes the upper most fifty feet of the cavern volume attains equilibrium concentrations and is diluted by the remaining brine volume. (cavern geometry dependent)

Total dissolved hydrocarbon concentrations = 6.1 ppm or 6 ppm

D.4 DISPERSION REACTIONS

Whereas dissolution occurs on a molecular level, dispersive reactions occur on a particle level. This reaction requires a breakup of the oil into particles and dispersing them into the underlying brine. The energy for this reaction is produced during the initial oil injection where oil is jetted at a velocity of approximately 8 feet per second into the brine and micro particles dispersed into the upper area of brine. This agitation would diminish and eventually cease as the downward oil-jet momentum is balanced by the buffering force of the oil thereby limiting the depth of the turbulent zone.

Studies of the dispersion of oil in seawater under oil slick conditions indicate that the greatest amount of oil is dispersed in a particle size of 40 microns or less in diameter (Price, 1973). For illustrative purposes data for Bunker C, listed in Table D-7, show the distribution of particle sizes ranges from 10 to 80 microns.

The suspension time for oil particles in the brine would be very short because of the large density differential of the oil (sp.gr.approx. .85) versus the brine (sp.gr. 1.19). Studies of crude dispersions, Table D-8, in seawater illustrates the rate of floatation. With the greater density differential, as in saturated brine, the dispersed oil within the caverns would be expected to show even faster floatation rates.

Within the cavern, even under the most rapid fill rates, the dispersed particles would have several weeks in which to rise and coalesce at the oil/brine interface. This is believed to be sufficient time for the dispersed oil concentrations to decrease to values of less than 1 ppm. For calculation of oil in brine, a value of 1 ppm of dispersed oil is assumed to be discharged to the brine surface control facilities.

TABLE D-7 Distribution of particle size beneath an oil spill*.

	NO. AND VOL. OF PARTICLES IN 10-MICRON RANGE CENTERED AT							
	10u	20u	30u	40u	50u	60u	70u	80u
NUMBER	323	147	57	19	4	3	3	1
VOLUME	0.45	0.96	1.42	1.35	0.40	0.66	1.12	0.60

* BUNKER C OIL

SOURCE: The Fate of Oil Spilt at Sea

TABLE D-8 Settling time and dispersed oil particles*.

TIME OF SETTLING DAYS	OIL CONTENT PPM
0.01	31
0.02	10
0.04	4.5
0.33	2.5
1.0	4.6 **
1.1	1.5
2.2	2.7 **
147	0.6

SOURCE: THE FATE OF OIL SPILT AT SEA.

* TYPE OF CRUDE OIL NOT STATED
** REASONS FOR OIL CONTENT INCREASE NOT GIVEN

D.5 DISCHARGE OF THE OILY BRINE TO THE SURFACE CONTROL FACILITY

The discharge of brine containing hydrocarbons, as schematically illustrated in Figure D-6, will involve different scenarios dependent upon whether it is during initital fill or subsequent refills.

For initial fill, an assumption was made that the top 50 feet of brine became saturated with hydrocarbons (31.4 ppm) and this was diluted into the uppermost 100 feet yielding approximately 16 ppm (see Section D.2.1). This initially high hydrocarbon concentration would result from the fresh unweathered crude not having sufficient time to form a refractory layer before fill is completed. In subsequent fills the refractory layer will be present. The 16 ppm would exhibit a concentration gradient (0 to 31 ppm) when discharged; however, its average over the discharge period is expected to be about 16 ppm.

It is expected that low levels of oil averaging approximately 6 ppm would be discharged continuously during subsequent refills. Contingent upon differing cavern geometries, the oil concentration would vary from 4 to 15 ppm.

The only available data from similar operations are from the German oil storage facility at Etzel, Germany and the French oil storage facility at Manosque, France.

The Etzel data (Kavernen Bau - und Betriebs - BmbH, n.d.) indicate that the oil concentration of brine discharged from the brine control surface facility is less than 1 ppm.

The Manosque data (LOOP, Inc., 1975) indicate an oil concentration of 17 ppm in the brine discharged from the cavern to the surface facilities. Neither the duration of storage or type of crude were identified.

These data from the two operating oil storage facilities clearly indicate that with an expected eighty percent reduction of the oil concentration due to vaporization of light hydrocarbons such as butane, pentane and benzene (McAuliffe, 1969) and an additional reduction by oil skimming, the estimated oil concentration in the discharged brine of approximately 6 ppm appears reasonable for the proposed U.S. facilities.

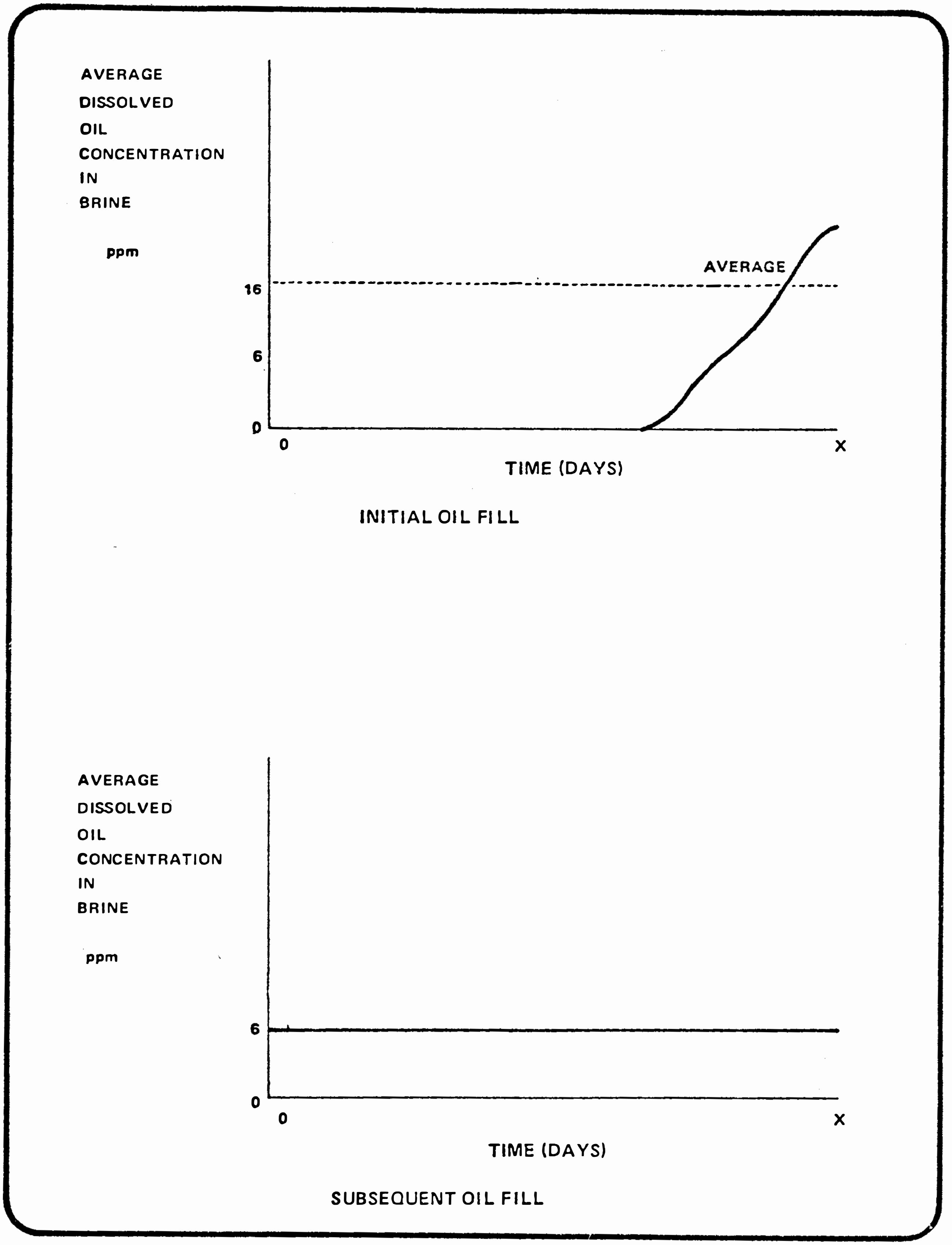


FIGURE D-6 Schematic representation of oil in brine concentrations discharged from a typical cavern

D.6 CONCLUSIONS OF THE OIL BRINE STUDY

The major conclusion of this study is that there is insufficient time, turbulence and circulation within the cavern during oil fill and withdrawal phases, to allow the dissolved oil to reach equilibrium. Practical operating experience of mines in France (Part III) have substantiated these conclusions. Equilibrium concentrations for the thirteen crudes studied will not exceed approximately 31 ppm under the cavern operating conditions. Thus, during the time when the cavern is principally filled with non-equilibrium oil-brine concentrations of less than 31 ppm, dissolution and diffusion reactions will occur in the upper brine column.

The results of the study indicate that the dissolved oil in the brine discharged to the brine surface control facility is expected to average 16 ppm for the later stages of the initial oil fill of each cavern and average approximately 6 ppm for subsequent oil refills from a cavern of specific geometry. Differing cavern geometry effects the duration of the initial oil discharge and the concentration of the dissolved oil in subsequent discharges. The oil concentration in the brine will be principally composed of dissolved hydrocarbons rather than dispersed oil as is commonly found beneath oil slicks at sea. The dispersed oil component which is created during initial turbulent oil injection is quickly and naturally removed from the brine column due to its high buoyancy and less than 1 ppm would be expected in the brine discharge.

Studies of the effects on hydrocarbon solubility as a function of increasing the temperature of $150^{o}F$, pressure to 1500 psi and salinity to 310 ppt indicate that solubility changes of: 1.5 times would occur due to temperature increase, 5.0 times for pressure and 0.15 times for salinity. The net effect of these would be an increase in solubility of only 1.125 times in comparison to seawater equilibrium concentrations. Thus, cavern oil equilibrium concentrations will be very similar to values measured for the various crudes in seawater at standard conditions of temperature and pressure.

The oil film remaining on the cavern wall is not expected to appreciably affect the net oil concentrations of the brine due to the large dilution effect within the cavern and the estimated 50 micron thickness of the wall film.

At the start of filling operations the oil jet velocities should be controlled to limit the amount of turbulence during initial fill and the possible disruption of the refractory layer during the subsequent refills.

A refractory layer is expected to form at the oil brine interface which will reduce dissolution and to a degree dispersion reactions.

D.7 REFERENCES

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PART II - SOLUTION MINING AND USE OF NEW CAVERNS

D.1 Oil-In-Brine, Cavern Construction and Operation Effects

D.1.1 Cavern Construction and Initial Fill

The caverns at the proposed SPR storage sites are to be constructed by utilizing the leach-then-fill and/or leach/fill methods. Leach-then-fill is the primary method. It requires that the cavern be leached to its design capacity before crude oil storage begins. This method has the advantage of less potential for oil-brine interactions than leach/fill does, but the disadvantage that the lengthy (2 year) leaching process must precede oil fill. The leach/fill method may be utilized to reduce the time required for initial oil storage. Leach/fill allows for storage of crude oil concurrently with all but the initial months of cavern leaching, but has a potential for higher hydrocarbon (HC) concentrations in the brine displaced from the caverns than the leach-then-fill method does. These higher HC concentrations would have a negative impact on air quality and on the brine disposal area.

D.1.1.1 Leach-Then-Fill Method

When the leach-then-fill method is utilized, caverns would be leached to their design capacity in a continuous operation. The resulting caverns would be approximately cylindrical in shape and have a maximum diameter of about 300 feet. Blanket oil (to restrict upward growth of the cavern roof) would be installed early in the leaching process and would remain in place for the duration of leaching operations.

At the conclusion of leaching of a cavern, oil fill would be initiated, displacing brine from the cavern. Initially, the displaced brine would have negligible HC concentrations. Brine with low HC concentrations would then be displaced for about two-thirds of the oil fill period. Finally, brine (near the oil-brine interface) with higher HC concentrations would be displaced. During the final stages of oil fill, HC concentrations are anticipated to average 16 ppm.

Brine displaced to the surface control facility (brine pond) would be retained for settling of insoluble material. A four hour retention time is planned, during which 50 to 100 percent of the hydrocarbons in in the brine would evaporate. The remaining hydrocarbons would be transported with the brine to the disposal area. Monitoring of HC concentrations in the brine is planned, both at the cavern wellheads and at the output of the surface control facility. Filling operations would be adjusted to maintain effluent HC concentrations below state standards (at a level of about 10 ppm). Filling would be curtailed if concentrations exceeded state standards.

D.1.1.2 Leach/Fill Method

The leach/fill procedure would permit crude oil to be stored after 1 MMB of available capacity is reached in a given cavity. With the designed cavern diameter, 1 MMB would occupy the upper 100 feet of the cavern. As with the leach-then-fill concept, the oil-in-brine would remain within the upper 100 feet of the brine column. Therefore, after a fill of 1 MMB of oil, the oil-in-brine would extend 200 feet below the top of the cavern. Additional fill would be added as space is leached.

With the leach/fill procedure the leach casings and zones of active leaching would precede oil fill by only a short vertical distance. Oil levels would be adjusted for optimum leaching configuration. The volume of brine in the cavern would be smaller than with leach-then-fill and the total elapsed time in which oil-brine activity could occur would be longer. Hence, total hydrocarbons dissolved in brine are likely to be higher for this method than leach-then-fill. Depending on casing depths and oil fill increments utilized, high concentrations of oil in brine could be released earlier using this method than for leach-then-fill. Continual monitoring of the hydrocarbon concentrations would be required to determine the appropriate criteria for leach and fill rates and schedules, to maintain concentrations below state standards.

D.1.2 Second and Subsequent Oil Refills/Withdrawals

Following displacement of stored oil during the first withdrawal, HC concentrations would be similar whether leach-then-fill or leach/fill procedures were used for cavern construction. The principal effects of subsequent fill/withdrawal cycles on the quantity of oil dissolved in brine would be 1) cavern enlargement during withdrawal, 2) the dilution of residual brine during refill, and 3) the dissolution of oil remaining on the cavern walls during withdrawal.

Assuming an initial cylindrical cavern of 10 MMB capacity, 1000 feet in height and 270 feet (average) in diameter, cavern enlargement would be experienced approximately as shown in Table D-9. Using fresh water as the displacement source, the cavern would grow from its initial 10 MMB capacity to about 18.6 MMB in size over the 5 cycles. As only 10 MMB of crude oil is planned to be stored during each fill, about 3/4 as much brine as oil would be contained in the cavern after the fifth oil fill. The cavern diameter could enlarge by as much as 50 feet and the area of the brine-oil interface would increase by 40 percent over 5 cycles. The refractory layer would then be spread over the larger area, and additional oil would be expected to enter the layer.

Cycling the cavern with 10 MMB of crude oil during each fill and withdrawal would have the effect of moving the brine-oil interface higher in the cavern with each cycle. Because brine is removed from the bottom of the cavern during oil fill, the high HC concentrations in brine (near the top of the brine) would be farther from the brine exit with each additional cycle.

Long-term storage of crude oil between withdrawals would cause increasing volumes of brine to reach equilibrium HC concentrations (31.4 ppm) prior to dilution during withdrawal. Accounting for dilution by displacement water, concentrations would increase 10-fold for 5 cycles.

Short-term dissolution would also occur in the interim between the initiation of a withdrawal and the completion of a refill; mostly occurring during the period of no activity prior to refill. Assuming the upper 50 feet of the brine reaches equilibrium HC concentration, the average HC concentration shown in Table D-9 would result. Average HC concentrations would increase in later cycles as the volume of the 50 foot thick layer becomes a greater portion of the cavern volume utilized for a 10 MMB refill.

Oil in brine resulting from residual oil on cavern walls entering solution during withdrawals is only slightly affected by cavern enlargement. As cavern volume increases, the surface area increases at a smaller rate, and the resulting average HC in brine concentrations would be less for later cycles. These concentrations are greatly affected by the thickness of the residual oil film and clingage thicker than the 50 microns assumed would greatly increase concentrations.

D.2 Summary

In summary, hydrocarbon concentrations of displaced brine during oil fill would be relatively high (due to turbulence and mixing early in the fill) during the latter stages of the initial fill. Following the initial fill, a dense refractory layer would form, lessening those effects during later fills. The later fills/withdrawals would be affected by the rate of cavern enlargement and the increasing distance from the brine withdrawal pipe to the refractory layer. The second fill would displace the least hydrocarbons due to the formation of the refractory layer and the small percentage of cavern enlargement. During subsequent fills, the effects of cavern enlargement would become more pronounced with HC concentrations approaching equilibrium conditions.

TABLE D-9 Fill/withdrawal cycle vs. cavern size relationship.

Fill Cycle	Withdrawal Cycle	Active Cavern Volume, MMB	Total Cavern Volume,[1] MMB	Residual Brine After 10 MMB Fill, MMB	Brine Dilution During Withdrawal	Long-Term Storage Equilibrium Concentration,[2] ppm	Oil Clingage on Cavern Walls,[3] bbl	Clingage Oil Concentration in Brine, ppm	Short-term Oil Dissolution[4] Ratio	Short-term Oil Dissolution[4] ppm	Total Dissolved HC Concentration ppm
1	0	10.0	10.5	0.5	-	-	-	-	-	-	-
2	1	11.7	12.2	2.2	1:20	1.6	27	2.6	1:20	1.6	5.8
3	2	13.4	13.9	3.9	1:4.5	7.0	30	2.5	1:16.0	2.0	11.5
4	3	15.1	15.6	5.6	1:2.6	12.1	32	2.3	1:13.9	2.3	16.7
5	4	16.8	17.3	7.3	1:1.8	17.4	34	2.2	1:12.2	2.6	22.2
-	5	18.6	19.1	-	1:1.4	22.4	36	2.1	1:10.9	2.9	27.4

1) Including 0.5 MMB sump
2) Equilibrium concentration ÷ dilution
3) Assuming 50 micron thickness
4) Assuming only upper 50' of cavern reaches equilibrium concentration of 31.4 PPM

PART III

COMMENTS OF GERARD FEDIDA[a] CONCERNING STUDIES OF THE OIL CONTENT OF BRINES DISCHARGED FROM SALT CAVERNS AT MANOSQUE, FRANCE

I am Gerard Fedida, Manager of Projects at GEOSTOCK (Societe Francaise De Stockage Geologique) at the time of this study and the coordinator of the group which wrote the reports on the content of oil in brines discharged from salt caverns at Manosque, France.

My professional training in engineering was obtained at the Ecole Polytechnique and Ecole Nationale Superieure des Techniques Avancees in Paris, France. I have been associated with GEOSTOCK since 1973, and was formerly associated with C.G. Doris, a French offshore engineering firm.

GEOSTOCK is a subsidiary of four oil companies in France, and has specialized in performing design and management services in the implementation of the French strategic petroleum reserve and other underground hydrocarbon storage facilities. GEOSTOCK presently is the operator for approximately 90 million barrels of a variety of hydrocarbons, including LPG, gasoline, naptha and crude oil.

In November 1977, the Department of Energy (DOE) entered into a contract with Geostorage Inc., the American subsidiary of GEOSTOCK, for the following four studies related to the storage of crude oil in salt-solution caverns at Manosque, France:

1. A compilation of selected historical data and measurements of the oil content of brines taken during several years of facility operation;
2. Sampling and measurement of the oil content of brines from caverns which had contained crude oil for prolonged periods;
3. Sampling and measurement of the oil content of brines displaced from caverns during normal fill operations; and
4. A compilation of selected historical temperature profiles made within certain caverns. This latter study has no direct bearing on my testimony and will not be discussed further.

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[a] Joint Environmental Protection Agency-Corps of Engineers Public Hearing on Bryan Mound Brine Diffuser Application, May 2, 1978.

(Transparency No. 1)[a] The Manosque storage complex is located in the south of France, 55 miles northeast of Marseille.

Between 1968 and 1973, 18 cavities were leached in a massive salt formation. In a second phase of development currently underway, 18 new cavities are being created. The volume of these cavities ranges from 700,000 to 2.5 million barrels.

The facilities include two brine surge ponds for 1.2 million barrels capacity at Manosque, two 20" pipelines linking the site to brine lakes and refineries and VLCC facilities on the Mediterranean coast near Marseille, and the necessary pumping equipment and controls. Brine samples are periodically taken at the Rognac station here. The description of this complex is analogous to the general system description of the DOE complex appearing in the Bryan Mound final Environmental Impact Statement.

The two 20" pipelines mentioned above serve to carry excess brine and petroleum between Manosque and the petrochemical industries near Marseille. One of these pipelines is dedicated to brine and the other to petroleum; they are not used interchangeably.

(Transparency No. 2)[a] Each cavity is equipped with two concentric pipes. Hydrocarbons are pumped into a cavity through the annulus and brine is displaced through the suspended tubing (Transparency No. 3)[a] to the surface brine ponds, where most dissolved and dispersed hydrocarbons separate out. This method is virtually identical to the one in which DOE will operate its facilities. Any excess brine is pumped through 20" pipeline, mentioned earlier, to the brine lakes near Marseille. During drawdown cycles, the procedure is simply reversed.

Since inception of the project at Manosque, frequent samples of the brine in the 20" pipeline have been collected in order to monitor corrosion and oil content. For Part 1 of our study a total of 40 analyses were compiled for the period January 4, 1972, through November 25, 1976. These analyses represent both leaching under a hydrocarbon blanket and actual storage operations.

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[a]Transparencies No. 1, 2 and 3 were presented as part of Mr. Fedida's testimony but have not been included in this Appendix.

As noted earlier, the brine displaced from the various caverns initially flows into one of two 600,000 barrel capacity surface ponds which act as surge pits. Any film which forms on the ponds is periodically skimmed and disposed of.

(Transparency No. 4) (Table D-10) Each of the 40 samples, selected for this compilation, was withdrawn from the 20" pipeline at the Rognac pump station, which you will recall is located near Marseille.

All samples were analyzed using an infrared spectrometric method similar to the one recommended by Michael Gruenfeld, Environmental Protection Agency, Edison, New Jersey. This method involves a liquid-liquid extract of the brine with a suitable solvent such as Freon-113 or carbon tetrachloride, followed by a measurement of the infrared absorbance of the solution. Using this method the practical limit of detection is 0.5 parts per million (ppm).

Residence time of the brine in the ponds varied from one day to more than 3 weeks depending on the scale and type of operation at the time. Differences in residence time of brine in the ponds appear to have an insignificant effect on its oil content since most hydrocarbons either volatilize, or come out of solution and form a surface film, within a short time after the brine reaches the surface, due to the decrease in pressure.

Other parameters of simultaneous movements in the caverns were also compiled, such as brine temperature and density, distances between the oil/brine interface and the shoe of the brine displacement casing, and the spacing between the shoes of the oil injection and brine displacement casings. No relationship was established between these parameters and the concentration of oil in the brine samples, the distribution of which appears in transparency no. 4 (Table D-10).

The second part of our study required the collection and analysis of brine samples from caverns which had contained crude oil in quiescent storage for prolonged periods. The purpose of this task was to obtain data on the oil content of brines which approached equilibrium with the stored oil before the samples had undergone the separation effects of the surge ponds.

We selected four cavities which we felt were appropriate for this study. Two samples were collected at the wellhead of each cavern. The first sample was collected after the volume of brine standing in the tubing had been displaced to the surface. The second sample was collected after an additional few thousand barrels had been displaced.

The results of the analysis of these samples is presented in the next transparency (No. 5) (Table D-11). As you will note, brine from cavity ET, which had contained crude oil for 13 months, contained only 12.7 parts per million oil. You will recall that these samples were collected before any settling of the brine had taken place in the ponds. All samples exhibited a strong odor of hydrocarbons and degassing when they were collected. This is consistent with what is known about the solubility of hydrocarbons in brine, namely, that the light hydrocarbons, especially those like butane and propane are the more soluble, and solubility is pressure dependent. Therefore, when brine from beneath stored crude oil is produced to the surface, the reduction in pressure will cause dissolved hydrocarbons to volatilize.

Our final study regarding oil-in-brine, called for the sampling and analysis of brines displaced from cavities during normal fill cycles. A total of 24 samples were collected from the wellheads of five cavities for the purposes of this task. The results of the analyses of these samples is presented in the next transparency (No. 6) (Table D-12). As can be seen, the maximum oil content was only 9.4 ppm, before any settling in the surge ponds, which is within the range reported earlier for historical data of operational cavities.

All of the samples exhibited a hydrocarbon odor and most were obviously degassing.

All of the oil-in-brine analyses reported were made on samples obtained from a hydrocarbon storage facility which has been in operation for ten years. The samples were obtained from origins as different as the wellheads of static storage, the wellheads of operating storage and the effluent of a brine settling pond. These analyses show that the oil concentration is below 15 parts per million even in the worst case and averages four to five ppm.

TABLE D-10 Content of oil in brines displaced from caverns at Manosque, France.

Oil Content (ppm)		
Operational Caverns (18 samples)		Leaching of New Caverns (22 samples)
0.0-13.8	Range	0-10
2.8	Median	2.6
4.6	Average	3.3

TRANSPARENCY NO. 4

TABLE D-11 Oil content of brine samples from cavities containing crude oil for prolonged periods.

(ALL SAMPLES COLLECTED AT THE WELLHEAD)

CAVITY	MINIMUM STORAGE TIME	TOTAL OIL CONTENT (PPM)	
		FIRST SAMPLE	SECOND SAMPLE
ET	13 MONTHS	12.7	9.3
A	3 WEEKS	9.4	3.8
D	3 WEEKS	6.1	1.7
F	3 WEEKS	2.2	1.6

TRANSPARENCY NO. 5

TABLE D-12 Oil content of brine displaced from cavities during normal fill operations.

(ALL SAMPLES COLLECTED AT THE WELLHEAD)

Cavity	Total Oil Content (ppm)		
	Start of Cavern Fill	End of Cavern Fill	Range
A	9.4	0.7	0.7-9.4
D	6.1	1.4	0.8-6.1
W	0.7	0.7	0.7-3
E	3	0.7	0.7-3
G	0.7	1.4	0.7-1.4

TRANSPARENCY NO. 6

APPENDIX E

OIL AND BRINE SPILL RISK ANALYSIS

APPENDIX E

OIL AND BRINE SPILL RISK ANALYSIS

E.1 Risk Analysis Introduction

This Appendix describes the oil and brine spill risks associated with development of the Seaway group of candidate SPR storage sites. Generalized environmental risks associated with facility use are described in Section E.2; calculated spill expectations associated with various facility operations are also presented. The methodology utilized in computing the spill expectations is given in Section E.3. Further description of the chance of cavern collapse and catastrophic release of oil (or brine) is provided in Appendix F.

Information presented in this Appendix, along with the description of existing environment and the expected oil or brine movements following an accidental release, is used in analyzing site specific impact potential in Sections 4.3 and 4.4 of the EIS.

E.2 Oil and Brine Spill Risks Related to the SPR Program

A significant environmental hazard associated with development of the proposed SPR oil storage facilities is the risk of crude oil or brine spills. The risk of oil spills during cavern fill begins with off-loading from VLCCs in the Gulf of Mexico and includes transport by tanker to Freeport Harbor, offloading at the DOE docks, pipeline transport to the storage site, and terminal operations (including cavern storage). During withdrawal of the oil, essentially the same transportation modes are used. However, approximately 60 percent of the oil is planned for delivery to the SEAWAY pipeline for transport to refineries in Texas and Oklahoma. The remainder would be loaded onto small tankers at Freeport Harbor for transport to other ports. Oil is expected to be left in the pipelines, and possibly in the surge tanks during standby storage, constituting a continuous exposure risk.

The risk of a brine spill is present during the cavern leaching operations when near-saturated brine is temporarily held in a reservoir at the storage site and piped to the Gulf of Mexico for disposal. During cavern fill, oil would displace brine from the caverns into the brine reservoir; subsequent disposal of the brine would be by pipeline into the Gulf of Mexico. Brine would be flushed from the reservoir and pipeline during standby storage and cavern withdrawal.

The following sections summarize oil and brine spill hazards and loss expectations due to development and operation of each of the candidate SPR storage sites (including the early storage facility at Bryan Mound). Explanation of calculation methodology is provided in Section E.3.

E.2.1 Oil Spill Risks

E.2.1.1 Oil Spill Risk from Cavern Storage

The loss of oil from cavern storage systems to the surrounding environment requires two conditions to be present. First, the storage barrier, such as the cavern enclosure or the storage tank seam, must be breached and, second, there must be a driving force to initiate oil migration. During surface storage, this force is gravity; during cavern storage the gradient would be provided by inflow from either overlying surface waters or ground water.

Since the liquid column of petroleum that is needed to hydrostatically balance a column of water is taller than the water column, the petroleum would be lifted above the head of the water column. This difference is between 10 and 20 percent and provides a 400 to 800 foot differential column height for a cavern with the salt bottom 4000 feet below the surface. Thus, diking of the storage area to protect against cavern collapse is not practical. A cavern volume of 10 million barrels represents about 1300 acre-feet of storage. Either very tall dikes or low density spacing of the caverns on the domes would be required to contain a spill associated with with collapse of a cavern.

The likelihood of a cavern collapsing has been evaluated as being a remote occurrence provided that contributory conditions are avoided or monitored (Appendix F). All four known instances of salt cavern collapse (Bayou Choctaw, Louisiana, 1954; Grand Saline, Texas, 1976; Belle Isle, Louisiana, 1973; Eminence, Mississippi, 1973) are believed to have resulted from uncontrolled or accidental leaching of the salt near the top of the dome, rather than from actual structural failure of the cavern roof. Thickness of the cavern roof in each of these occurrences was less than 300 feet.

Cavern Stability

The inherent characteristics of solution mined caverns make them one of the safest possible means for crude oil storage. The plastic nature of salt at the temperatures and pressures present in the candidate Seaway domes permits the caverns to withstand shock forces far in excess of any earthquake known to have occurred in the Gulf Coast region.

A number of factors affect the stability of cavities in salt domes, including: cavity depth, diameter, and salt temperature; dissolution; and proximity of the salt dome boundary or other cavities. These factors were considered in the selection of the cavities proposed for development in the SPR program.

For existing cavities, the major factor controlling cavern stability is changes in proximity to salt dome boundaries or to other cavities. Cavities used for product storage grow approximately 15 percent during each cycle of fill and withdrawal due to dissolution of salt by unsaturated displacement water. Solution of the salt may be controlled in the upward direction by maintenance of a blanket of oil near the cavity ceiling, and in the downward direction by the presence of relatively insoluble anhydrite in the sump.

Development of the proposed storage caverns would use a blanket of crude oil to control growth in the upward direction. The location of the oil-brine interface can be monitored by any one of several available instruments such as sonic interface detection, nuclear logging, and oil column pressure gauging. One or more of these devices would be utilized to monitor the oil-brine interface. Thus, the level of the oil-brine interface can be controlled to avoid upward leaching. The physical arrangement of the well casings, however, prohibits withdrawal of oil above the level of the oil withdrawal annulus. Thus an oil blanket would always be present in the leached space above the level of the annulus. This provides a fail-safe design which is not subject to operator error. Casing cement failures above the caverns could be easily detected and repaired using standard techniques.

The problem of internal collapse ("squeezing") of the caverns was also considered. It is planned to maintain the cavern under pressure to equalize the pressures of the salt and the cavity. Since the salt is more dense than crude oil, it is not possible to achieve total equilibrium, except at some single design depth. If the design depth is at the middle of the cavern, the fluid pressure at the cavern top will exceed the overburden stress in the salt; at the bottom, it will be less. Thus, there will always be some unequalized pressure differentials in the cavern walls. The primary purpose of balancing lithostatic pressure in the cavern is to prevent internal collapse, but the local pressure differentials may induce local creeping of the salt. This emphasizes the need to monitor the condition of the cavern.

Oil Spill Expectation

It is not possible to place meaningful quantification to the likelihood of cavern collapse. Assuming the above precautions are carried out as planned, the chance of collapse seems remote. With sonar monitoring of the cavern walls during use and following withdrawal expansion, it should be possible to detect any slabbing or cracking of the cavern roof arch, offering a further measure of protection.

In the event of collapse at any of the candidate sites, ground water is present to displace oil to the surface. The inflow rates would vary among candidate sites as aquifer conditions are not identical, and interchange of stored petroleum and fluidized rock and earth may occur.

Non-catastrophic losses from storage through a crack, loss of seal around the cavern fill pipes, or improper filling would be expected to be contained in the site diking system, so that relase to the environment should be avoided. Lateral failures between caverns should not pose any chance of oil release as long as the caverns are insulated within the dome.

The contribution of cavern collapse to expected oil spill losses is assumed to be zero under conditions of proper design, construction and monitoring.

E.2.1.2 Oil Spill Risk During Marine Transportation

Casualty and operational spills from vessels may occur during transfer between VLCC and lighter, during transfer between lighter and the docks, and in lighter transit between the VLCC and the docks (or in the case of withdrawal, between the docks and open Gulf waters). Oil spills from vessels operating in coastal waters are a function of time of exposure (Section E.2). Spills resulting from transfer operations are a function of volume handled and direction of transfer (loading or offloading). All of the oil to be stored in the caverns would be delivered by tanker to the DOE docks in Freeport Harbor for pipeline transport to the site. However, it is expected that only 40 percent of the oil in storage would be distributed by tanker, the rest going to the SEAWAY pipeline at Jones Creek. Each transport step involves a quantifiable risk of spillage into the environment, the estimation of which is based upon statistical patterns established for oil spills between 1969 and 1973 (Section E.2).

The expected quantities of oil to be spilled from Seaway group operations, is given in Tables E-1 and E-2. As shown, considerably greater volumes of oil would be spilled during cavern fill operations than during withdrawal because of the relatively clumsy tanker-VLCC transfer operation and the greater quantity of oil to be transported. For a 150 million barrel Seaway group SPR system, approximately 72 percent (4210 barrels) of the total oil spill expectation would occur from marine operations.

Spill size distributions expected to occur for the several categories of oil spill modes are presented in Table E-3. Spills greater than 1000 barrels should not occur during transfer operations. Spills greater than 1000 barrels occur 29 percent of the time from vessel casualties (average spill size of 1111 barrels); truly large spills (greater than 10,000 barrels) occur only .75 percent of the time. Thus, from Tables E-1, E-2, and E-3 operations during the lifetime of a 150 MMB storage system, is .19 percent (.27 spills expected, times .75 percent chance of large spill). This is equivalent to a recurrence interval of 11,580 years, or 2630 fill/withdrawal cycles, which is an extremely low probability.

TABLE E-1 Expected crude oil spills - cavern fill operations.

Oil Handling Mode/Location	Average Spill Size (bbl)	Bryan Mound Early Storage		Bryan Mound SPR Expansion		Allen Dome SPR Expansion		West Columbia SPR Expansion		Nash Dome SPR Expansion		Damon Mound SPR Expansion		Total Program[a] Spill Risk		Maximum Credible Spill Size (bbl)
		No. Spills	Barrels	No. Spills	Barrels	No. Spills	Barrels	No. Spills	Barrels	No. Spills	Barrels	No. Spills	Barrels	No. Spills	Barrels	
Gulf																
-Transfers	12.9	14.6	189	23.2	300	23.2	300	23.2	300	23.2	300	23.2	300	37.8	489	1,000
-Vessel Casualty	1111	0.018	20	0.029	32.2	0.029	32.2	0.029	32.2	0.029	32.2	0.029	32.2	0.047	52.2	60,000
Freeport Harbor																
-Transfers	21.7	2.9	63	4.6	100	4.6	100	4.6	100	4.6	100	4.6	100	7.5	163	500
Terminals																
-Bryan Mound	500	0.0315	15.8	0.05	25	0.05	25	0.05	25	0.05	25	0.05	25	0.0815	40.8	5,000
-SEAWAY	1100	---	---	---	---	0.05	55	0.05	55	0.05	55	0.05	55	0.05	55	5,000
-Alternative Storage Site	500	---	---	---	---	0.05	25	0.05	25	0.05	25	0.05	25	0.05	25	5,000
Pipelines																
-Pumping[b]	1100	0.0005	0.6	---	---	0.0063	6.9	0.0158	17.3	0.0252	27.7	0.0252	27.7	0.0257	28.3	10,000
Total - Single Fill	---	17.6	288.4	27.9	457.2	28.0	544.1	28.0	554.5	28.0	564.9	28.0	564.9	45.6	853.3	
Total - 5 Fills	---	87.8	1442.0	139.5	2286.0	140.0	2720.5	140.0	2772.5	140.0	2824.5	140.0	2824.5	228.0	4266.5	

[a] Totals are for worst case combination of sites having 163 MMB storage capacity, i.e., Bryan Mound early storage and Nash or Damon Mound SPR expansion.

[b] No pipeline spills are allocated to Bryan Mound SPR expansion as oil would be exposed to spillage due to standby storage with early storage facility. For other SPR sites, pipeline spill exposures occur between site and Seaway Terminal.

TABLE E-2 Oil spill expectation model projections - cavern withdrawal operations[a] and project totals.

Oil Handling Mode/Location	Average Spill Size (bbl)	Bryan Mound Early Storage		Bryan Mound SPR Expansion		Allen Dome SPR Expansion		West Columbia SPR Expansion		Nash Dome SPR Expansion		Damon Mound SPR Expansion		Total Program[b] Spill Size		Maximum Credible Spill Risk (bbl)
		No. Spills	Barrels	No. Spills	Barrels	No. Spills	Barrels	No. Spills	Barrels	No. Spills	Barrels	No. Spills	Barrels	No. Spills	Barrels	
Gulf																
-Transfers	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---
-Vessel Casualty	1111	0.0028	3.1	0.0045	5	0.0045	5	0.0045	5	0.0045	5	0.0045	5	0.0073	8.1	60,000
Freeport Harbor																
-Transfers	42	1.2	50.4	1.9	80	1.9	80	1.9	80	1.9	80	1.9	80	3.1	130.4	500
Terminals																
-Bryan Mound	500	0.0315	15.8	0.05	25	0.02	10	0.02	10	0.02	10	0.02	10	0.0515	25.8	5,000
-SEAWAY[c]	1100	0.0189	20.8	0.03	33	0.05	55	0.05	55	0.05	55	0.05	55	0.0689	75.8	5,000
-Alternative Storage Site	---	---	---	---	---	0.05	25	0.05	25	0.05	25	0.05	25	0.05	25.0	5,000
Pipelines																
-Pumping[d]	1100	0.0008	0.9	---	---	0.0016	1.8	0.0041	4.5	0.0066	7.2	0.0066	7.2	0.0074	8.1	10,000
Total - Single Withdrawal	---	1.2	91.0	1.7	124.3	2.03	176.8	2.03	179.5	2.03	182.2	2.03	182.2	3.29	273.2	
Total - 5 Withdrawals	---	6.3	455.0	8.4	621.5	10.1	884.0	10.1	897.5	10.1	911.0	10.1	911.0	16.4	1366.0	
Project Total - 5 Cycles	---	94.1	1897.0	147.9	3001.0	150.1	3604.5	150.1	3670.0	150.1	3735.5	150.1	3735.5	244.2	5632.5	
Project Total with Oil Stored in Pipeline	---	94.1	1930	147.9	3001.0	150.2	3657.7	150.2	3803.0	150.3	3948.5	150.3	3948.5	244.4	5878.5	

[a]During withdrawal it is assumed that about 40 percent of the oil is shipped by tanker to the Gulf and about 60 percent is delivered to the SEAWAY Pipeline.

[b]Totals are for worst case combination of sites having 163 MMB storage capacity, i.e., Bryan Mound early storage and Nash or Damon SPR expansion.

[c]For worst case exposure calculations, it is assumed that all oil pumped from Allen, West Columbia, Nash, and Damon Mound sites is subject to SEAWAY Terminal spill risks.

[d]No pipeline spills are allocated to Bryan Mound SPR expansion as oil would be exposed to spillage due to standby storage with early storage facility. For other SPR sites, pipeline spill exposures occur between site and SEAWAY Terminal.

E.2.1.3 Pipeline and Terminal Accidents

Oil spills from pipelines and terminals may occur while pumping oil to or from the sites and while oil is kept in lines and tanks during standby storage. Oil spills from pipelines are a function of pipeline length and time of exposure; oil spills at terminals are a function of throughput handled. Average spill sizes are larger for complex terminals, such as at the SEAWAY tank farm, than for simpler terminals such as would be constructed at the storage sites. Spills from surface oil tanks are given less weight in impact considerations since dikes would be constructed of sufficient size to contain oil from completely filled tanks.

The expected quantities of oil to be spilled from pipeline and terminal operation for the SPR program are given in Tables E-1 and E-2. There is a somewhat reduced amount of oil handling required during withdrawal, which results in lower oil spill expectation than during fill. For a 163-million barrel Seaway group SPR system, approximately 21 percent (1240 barrels) of the total oil spill expectation would occur from terminal operations; approximately 7 percent (430 barrels) would occur from pipelines, assuming they are left filled throughout the project duration.

Based on the spill size distributions in Table E-3, spills greater than 1000 barrels comprise 8.2 percent of all spills from terminals and 43 percent of all spills from pipelines. Using expected frequencies of spill occurrence from Table E-1 and E-2, the chance of a spill greater than 1000 barrels is estimated to be 14.4 percent at terminals and 11 percent from pipelines during the life of the project (calculated for a 163 MMB) storage system, and using Nash Dome or Damon Mound as the SPR expansion site for worst case pipeline spill results). This is equivalent to recurrence intervals of 153 years (35 fill/withdrawal cycles) for terminal spills and 200 years (45 fill/withdrawal cycles) for pipeline spills.

E.2.1.4 Oil Dispersion

The weathering of oil spilled into the environment involves two processes which reduce both the amount of oil and its ability to disperse. Immediately after release from confinement, the lighter fractions of oil tend to evaporate. The evaporation process reduces the fluid mass by 10-15 percent in one day, and up to 25 percent in three days under warm,

TABLE E-3 Spill size distributions.

Vessel Spills (Average, 1111 barrels)

Spill Size Range (bbl)	% Probability
0-200	23.0
200-500	23.7
500-1,000	24.0
1,000-2,000	19.0
2,000-5,000	7.0
5,000-10,000	2.6
10,000-20,000	0.6
20,000-50,000	0.14
50,000-60,000	0.006

Terminal Spills at Site (500 bbl avg)

Site Range (bbl)	% Probability
0-200	30.5
200-500	41.0
500-1,000	20.3
1,000-2,000	6.4
2,000-5,000	1.8

Pipeline Spills (1,100 bbl average)

Site Range (bbl)	% Probability
0-200	10
200-500	20
500-1,000	27
1,000-2,000	36
2,000-5,000	5.7
5,000-10,000	1.3

Transfer Spills

Site Range (bbl)	12.9 bbl avg Probability	43.2 bbl avg % Probability
0-20	85.1	45.0
20-50	11.5	30.4
50-100	2.9	17.4
100-200	0.71	5.8
200-500	0.16	1.4
500-1,000	0.03	-

Gulf coast weather conditions. Wind exposure also hastens evaporation. Weathering leaves denser, more viscous mater, until a consistency near to tar is reached. The second process is direct decomposition by bacterial, chemical, and photochemical agents. These operate quite slowly in the natural environment; some oil may be deposited in sediments and escape direct decomposition.

Spreading of floating oil on water surfaces has been reported in a wide body of literature. As the water surfaces of greatest concern for the SPR sites are irregular land drainage, marsh, and river systems, a single approach based upon average areal coverage has been utilized to estimate areas affected. An oil spill will spread until the average areal coverage is about 1-2 barrels per acre. Noting, although, that uniform coverage will not occur (the spills may be patchy with stretches of open water surface, or with sections with no more oil contamination than a surface sheen), typical coverage and average thicknesses parameters are:

100 bbl/acre - 0.16 inches - 4000 microns
10 bbl/acre - 0.02 inches - 400 microns
1 bbl/acre - 1.6×10^{-3} inches - 40 microns

For spills of 5000 barrels, 1-2 barrels/acre density may be reached in a few days. However, in spreading through an environment of small streams or marshy terrain, much of the oil may be removed as a coating at the waters' edge, and on foliage. Where tidal influences are effective, deposited coatings can be partially refloated and redeposited elsewhere, unless picked up by cleanup crews.

For spills which cannot be reached quickly (i.e. - a few minutes), motion of the water is a principal determinant in the spread of the oil. For offshore spills, wind is the principal determinant of oil slick movement, especially since it strongly influences surface currents in the Gulf offshore (5-20 mi) zone. Cleanup efforts for offshore spills, and for pipeline or vessel spills inland, in which standby equipment must be assembled, will have to be pre-planned as part of the countermeasure efforts (Section E.2.1.5).

For spills in waters with standby equipment available, it may be possible to control the spill before extensive surface spreading occurs. Such control is possible for transfer spills of 2-100 barrels where the current through the mooring does not exceed 1 knot. In stronger currents, boom underflow will likely limit full impoundment potential.

Spills which flow across the land before entering streams may be absorbed into the soil, or retained as a coating upon the vegetation. Soil pore moisture tends to retard oil absorption, so penetration can be expected to be greatest for dry, loose soils, and for gravelly soils with voids around the larger component particles. These absorptive conditions would be expected along very little of the planned pipeline right-of-way locations except at plowed, planted, or dry agricultural land. The normal drainage patterns for agricultural land provided by standard ditching would afford a strong measure of protection for lands adjacent to pipeline rights-of-way. In the event of percolation of oil into soils, the decision on whether to dispose of the soil or to permit natural degradation to restore the soil productivity will depend greatly upon the contamination of runnoff water drainage after surface removal of oil coatings was completed.

Damage parameters and spreading patterns may be utilized to estimate the general effects of oil spills from spillage expectations provided in Tables E-1 and E-2. Typical damage parameter, are as follows: (LOOP, 1975)

- 6 barrels of fresh floating oil may damage one acre of marine nursery productivity for one season.
- 25 to 60 barrels of oil may damage one year's bio-productivity of one acre of land or marsh, depending upon wetness and type.
- 60 to 120 barrels of oil may pollute one mile of beach.

E.2.1.5 Oil Spill Prevention and Control Measures

The candiate sites are planned to be diked against release of petroleum fluids to the environment from equipment failures, pipe ruptures, etc., at the pump stations, wellheads, metering forms, and surge tankage. At some locations, the salt dome surface itself will require careful design in diking, since downslope flow of leaking oil has been known to wash out diking.

Site diking can be expected to control leakage from partial cavern failures, such as loss of fill pipe integrity, internal cracking around the pipe, or overfill. However, it would not be feasible to provide diking sufficient for a total collapse of a cavern (10 million barrels or nearly 1300 acre-feet) because of the necessary height of the dikes and the remote chance of cavern collapse.

Shut-in procedures normal for terminals during hurricanes along the Texas Gulf coast involve closure of all systems, and filling all empty tanks with water. Sea water or alternative sources of water to be used for cavern filling would be readily available for tank filling. Cleaning the water afterwards would present a problem, probably requiring a field oil/water separator unit and use of the brine settling pond for primary settling separation.

At the dock area, rapid deployment booms are the primary containment defense against transfer spills. On the docks, gutters, sumps and drip pans would be used to reduce low-level water contamination. Berthing skirts are not presently specified for the dock and, because of the low current conditions in the blind channel of the old Brazos mouth, there is no indication that they would present any advantage over rapid-deployment booms.

Exposure to large vessel spills is a result of potential vessel casualties. The average fill rate during refill corresponds to less than one vessel per day. However, the mode of refill by offloading VLCCs would tend to create peak traffic levels in ports. The SEAWAY pipeline, delivering 600,000 B/D, would generate typical traffic levels of 3 to 4 vessels per day. VLCC traffic in the area would be about 1 to 2 per day generated by the proposed SEADOCK Offshore Oil Port, and about 1 per week to 10 days generated by the storage refill. Thus, VLCC traffic generated by the SPR project should not significantly increase traffic levels in coastal waters.

Along the pipeline routes, the primary spill preventive measures are regular inspection of pipeline routes, line pressure testing, and close monitoring of flow pressures and in-out volumes. In the event of line ruptures, the primary lines of containment of released oil are the affected waterways.

Prevention of spilled oil from entering the San Bernard or Brazos Rivers by response fast enough to contain the oil in the creeks and swales is unlikely, especially during periods of flood flow in those creeks. During low flow (or dry) periods, the movement of the oil could be retarded and partially absorbed along the stream bed. The generally sluggish flow of the stream is a factor helpful in the effectiveness of booms, and there are many access points to the river for wheeled transport. Some of the marshy areas would require specialized transport vehicles, and cleanup of creek areas would likely require all-terrain transport.

Oil Spill Contingency Plans

A Spill Prevention Control and Countermeasure Plan (SPCC) must be prepared by an operator of a nontransportation related oil facility that might be capable of discharging by accident, equipment failure, or operator error enough oil into navigable waters of the United States to create a visible sheen discoloration, subsurface sludge or emulsion, pursuant to the provisions of the Federal Water Pollution Control Act, Public Law 92-500. The strategic storage facilities, therefore, would be subject to the provisions of these regulations. Departments, agencies, and instrumentalities of the Federal government are subject to the regulations to the same extent as private operators. The purpose of the SPCC is to outline the method of operations, measures and equipment used to prevent spills and to describe available equipment to be used, and the planned program of response, in the event of a spill.

Loading facilities for barges and tankers must also meet Coast Guard regulations (33 CFR 154) promulgated under Public Law 92-500, for design of hose connections, necessary emergency equipment, sumps, and so forth, emergency shutoff switches, and trained personnel.

Transfer operations must meet Coast Guard rules (33 CFR 156) that define personnel requirements, lighting, communication, use of the equipment, and adherence to procedures. Barges and tankers used for oil transport must meet Coast Guard regulations for spill prevention equipment (33 CFR 155). The construction of tank vessels and their operation come under a large body of regulations, one of which is the Port and Waterway Safety Act (Public Law 92-340). This Act increases Coast Guard authority to: direct vessel movement, prescribe safety equipment requirements and safety zones, investigate accidents and environmental quality of navigable waters, and regulate vessels carrying hazardous cargo in bulk. Regulation of tankers includes the right to inspect foreign registry vessels and prescribe minimum necessary safety and navigational equipment.

The Coast Guard may specify pilotage requirements for entry to U.S. waters. Inland Rules of the Road apply to the ICW; Western River Rules of the Road apply to the Mississippi River. The Coast Guard has the primary regulatory authority for vessel licensing, inspection, and enforcement of regulations.

In the event of a spill, the Coast Guard must be notified (18 CFR 610). Under the National Oil and Hazardous Materials Pollution Contingency Plan, a Regional Response Team headed by an On-Scene Coordinator (OSC) will take steps to assure that the best and most appropriate cleanup measures are taken. The operator of the facility involved in the spill is primarily responsible for cleanup efforts. The OSC may authorize the use of various cleanup agents, sorbents, or other chemicals, if they can assist in cleanup efforts without increasing ecological stress or damage. If the parties responsible for the spill do not or cannot undertake adequate cleanup (or if the spill should be large enough to warrant widespread concern), an emergency strike force may be organized to commit available manpower and equipment resources to the containment and cleanup effort.

If wastewater or treated wastewater should be discharged from a storage facility as a result of tanker operations or pipelines, (and also barging operation), then the Procedures for the National Pollutant Discharge Elimination System (NPDES) might apply to the facility (40 CFR 125, as amended), under Public Law 92-500, Sec. 402 and 405. Specifically, if flushing of the meter lines and cavern fill lines during standby is instituted, then it will be necessary to either discharge the flushing water, or to store it in the caverns. In view of the volume of the necessary flush water supply (about 5000 barrels per typical pipeline and 500 barrels per site line) and the rust inhibiting chemicals used to protect the pipes, storage of this waste in the caverns may be preferable to discharging it.

The complete SPCC Plan does not have to be prepared until the facility begins operation. The SPCC Plan will, however, be prepared within six months and implemented no later than one year after facility operation begins, pursuant to EPA regulations (40 CFR 112) as provided by Public Law 92-500. For purposes of the Environmental Impact Statement, it is sufficient to outline the elements of such a plan and the efficacy of cleanup technology pertinent to the spill risk associated with storage. This outline is provided below.

Facility Spills

SPCC guidelines provide that where experience indicates reasonable potential for equipment failure, appropriate containment and/or diversionary structures or equipment to prevent discharged oil from reaching a navigable water course should be used, including:

1. Dikes, berms, and impervious retaining walls.
2. Curbing.
3. Culverting, gutters, or other drainage systems.
4. Weirs, booms, or other barriers.
5. Spill diversion ponds.
6. Retention ponds.
7. Sorbent materials.

In the vicinity of the sites, berms and sumps must be viewed as the primary line of defense against surface spills. The potential of heavy rain runoff filling berms and sumps make them less reliable for an unmanned facility than for this one. For sites on a waterway, a sump at water level with a boom permitting underflow of water only, can provide effective retention of floating petroleum, while releasing rain waters. At docks, effective containment of spills by rapid deployment of booms is the primary defense against dispersion of spills.

The integrity of cavern storage remains a serious concern because of the potential for large petroleum releases into the environment. The primary preventive action for cavern integrity is sonar and, other surveying; for cracks, slabbing, and other indicators of roof or wall weakening.

Loading and Unloading Spills

The SPCC plan for dock operations would involve a two-fold approach: 1) operation of the facility by a "Dock Operations Manual", which specifies the physical equipment, oil transfer procedures, emergency procedures, and inspection routine to detect faulty equipment, poor connections, errors and leaks; 2) response to a detected spill according to an "Oil Spill Contingency Manual", dealing with stopping the outflow, containment, cleanup, and guidelines for communication with local, state, and Federal response teams.

The elements of the preventive plan include:

1. Containment of Leakage - During cargo transfer, containment of leakage will be accomplished by using fiberglass spill prevention decks placed under loading manifolds, sump tanks of adequate capacity, portable drip-pans for any hose connections not over the spill prevention deck, and motor driven block valves, closed when not in use.

2. Emergency Shutdown Capability - This procedure shuts off all pumps and closes all valves. Activation switches are located at accessible locations on the dock, and a portable switch is placed on board the barge. The system must be capable of instantly stopping the barge pumps, and must also have a locked manual override to close the system during a power failure.

3. Personnel and Training - Adequate numbers of personnel must be on hand during operations to ensure safe operation, and to assist in emergency containment routines. Operators designated "persons in charge" should have at least 48 hours experience in transfer operations and pass oral qualification examinations. Any language barriers between boat and dock supervisors must be resolved.

4. Cargo Transfer Procedures - These specify the placement, linking, and hanling of hoses and/or loading arms to avoid excessive wear, pulling strain, ruptures, kinking, and so forth. Use of quick-connect devices and latches is generally limited or proscribed. Important aspects include a transfer conference between the dock operator and the boat pump operator, and use of a checklist to ensure procedure compliance. From the standpoint of spill avoidance, and especially, large spills, inspection routines of the area on a regular, frequent basis are signficant. Other regulations establish lighting standards, equipment specifications, record-keeping, and so forth.

5. Equipment Maintenance Program - Equipment service and life is documented; regular pressure and stress tests are conducted; bolt and coupling flanges, coupling seals, and gaskets, are examined for wear, abrasion, and so forth.

Staffing or having available competent, trained personnel for positions that are not permanent - i.e., which last only for a filling or emptying cycle - may be difficult. Training of personnel hired would have to be emphasized. During emptying cycles for strategic drawdown, it could be assumed that personnel would be available from the petroleum industry. Much of the regional labor pool in the area has some familiarity with petroleum-type equipment as a result of earlier drilling and oil field activities.

The elements of the cleanup plan would include:

1. Inspection for Leaks - The area must be lighted, and frequent, regular inspections of the water must be made. If reliable automatic detection devices become available, provision would be made for their use.

2. Containment of Spilled Oil - The most effective spill containment device is the rapid deployment boom. One boom should be located at each end of the dock to isolate the vessel involved; a boom or rubber air dam should be available to close off an entire slip when the site geometry permits. A skimming device, which can operate in the slip, should also be available at the site. For very small spills contained around a single vessel, sorbent material could be used, although a skimming defice would be preferable. The skimmer should be above to deliver collected materials to a sump tank, either by direct hose from the mooring slip or from a holding tank.

3. Response Mobilization - Loading and unloading mishaps may occur in river currents, protected waterways and mooring slips, and in the offshore waters of the Gulf. If oil should escape immediate booming because of current, wind, or wave conditions, guidelines for notifying and mobilizing additional response teams would be followed. Cleanup cooperatives and contractors are discussed below, since these teams are part of the regional response team for oil spills.

Transportation Spills

Spills of oil from vessels may occur as a result of casualties, i.e., collision, ground, structural or tankage failure, fire, explosion, ramming (collision with fixed objects), etc. Spills could also occur as a result of erroneous discharge - bilge, open valving, testing of discharge engines with improper valve setting, and so forth.

In the event of such mishaps or casualties, the site operator would notify the regional response team center, and the organization of the National Oil and Hazardous Materials Pollution Contingency Plan would be activated. If the site operator is unable to obtain sufficient assistance to clean up spilled oil, the On-Scene Coordinator may initiate action directly to implement spill cleanup. All vessel operators must have proof of ability to assume financial liability for cleanup costs in order to obtain an operating certificate. Most operators have prior mutual aid arrangements, either directly or through insurors, for cleanup of spills.

Cooperatives of companies involved in oil production or transportation in the Gulf coastal area, and specifically the ICW have been formed. They maintain booms and shallow draft skimmers for use in bays and the ICW. Member companies have access to the equipment, but must supply the operating labor, beyond the supervisory skeleton crew that provides operational expertise. The equipment can be leased to nonmembers as well, but manpower must be obtained elsewhere. One cooperative is located at Venice (eastern Louisiana), Intracoastal City, Cameron (western Louisiana), and locations in the Beaumont, Galveston, and Freeport area. Large equipment for cleanup in bays is located at Grande Isle, Louisiana.

Another contractor operates in the Gulf Coast and can provide both equipment and manpower for cleanup. Other contractual services available in the area include wastewater processing, and disposal of oil contaminated materials. Some of these processors may act as salvors as well to reclaim oil. The Coast Guard has oil recovery equipment on the Gulf of Mexico primarily for ocean-going vessel salvage and spill containment. The Coast Guard could supply a submersible pump to facilitate emptying of a foundering oil vessel.

Pipeline Spills

For spills from ruptured pipelines, similar procedures as those for vessel spills are followed, with one important difference. The Environmental Protection Agency has lead responsibility instead of the Coast Guard. Control measures may be land-based, focusing on drainage paths of the oil into and along streams. However, in wetlands, the control efforts may be identical to waterway spills.

An important part of contingency planning is pre-identification of all drainage paths from every pipeline route, and the planning of primary points for spill dispersion control.

E.2.2 Brine Spill Risks

Brine and saline water spills may occur from the raw water supply and brine disposal pipelines and from the brine settling ponds. The brine lines would be constructed within the same right-of-way as the oil lines.

E.2.2.1 Brine Spill Risk from Cavern Storage

The mechanisms of brine fluid release from cavern storage are equivalent to those for petroleum, except for a major difference in density between the stored fluid and the inflowing water. The lower density of petroleum permits it to be lifted above the physical height corresponding to the water inflow pressure head. The density difference is opposite for brine lift. The specific gravity of the brine, containing up to 20 lbs salt per cubic foot, would be about 1.3, and will permit the inflow water to float on top, with mixing limited to a turbulent contact zone and slow diffusion beyond that zone. The inflow itself would not be able to flow out of the collapse pit unless an artisian head were present.

In the four historical instances of cavern roof collapse referenced previously, no release of brine was involved, even though water entered the collapse sinkholes.

Lateral migration of brines between cavities does not present a migration path for major releases of either brine or petroleum into the environment. Brine overfill can lead to escape of small amounts of brine from the cavern, and could contribute to failure of the seal around the fill pipe. However, brine forced up the oil section would not be expected to excape into the environment. It can be concluded that there is no reasonable chance of major brine spills from the cavern storage.

E.2.2.2 Brine Spills from Surface Storage

Most of the sites for leaching storage are planned with a partial impoundment of the brine for settlement. Evaluation of impoundment failure on a statistical basis is not applicable, since most of the impoundment failures in U.S. statistics involve poorly engineered or unengineered farm and mine impoundments. An estimation of the chance of breaching the impoundment by flood can be made, based upon the design resistance of the structure. However, breach of a brine impoundment by flood is of little concern - the flood mitigates both the salinity and any flow which would otherwise result from impoundment losses. As a general rule, considering the flat terrain involved near the sites, the environmental context of impoundment releases should be similar to those of pipeline ruptures near the site. At sites where the impoundment may be elevated slightly, (i.e., on the side of the mound for those sites in which the salt intrusion has created an elevation) local downslope flow damage and accompanying turbidity could result from loss of impoundment waters.

Surveillance procedures for monitoring the integrity of impoundment include regular inspections of earthworks for settlement, cracking, etc., and checking ground water in the vicinity for salinity migration.

The brine settling ponds to be constructed at the storage sites have design volumes of 100,000 barrels each. Ponds at Allen dome and Bryan Mound would be exposed to hurricane floods; while ponds at West Columbia and Nash dome might be subject to floods from the San Bernard and Brazos Rivers. It is not anticipated that Damon Mound site would flood. The pond levee would be designed to withstand a 50 to 150 year flood recurrence. The chance of loss of ponded brine may be estimated to range from 4 to 50 percent in the event a greater flood should occur. Using a 50-year levee design and a 50 percent loss probability as worst case estimates, the chance of total loss of all brine would be 1 percent per year. However, brine would be in the pond only during leaching and cavern withdrawal (perhaps 6 years during the project lifetime); during standby, the ponds would be empty.

Also, during such a destructive flood, the environmental impact of a brine release would be negligible because of dilution by flood waters.

E.2.2.3 Brine Spills from Pipelines

Spills may occur from brine disposal pipelines and from raw water lines. During leaching, the environment is simultaneously exposed to spills of saline water from the water supply line and to spills of brine from the brine disposal line. During cavern fill, exposure is to brine from the brine disposal line. During cavern withdrawal, exposure is to saline water from the water supply line. Finally, during standby storage, there would be exposure to saline water in both pipeline systems.

Data for performance of brine lines in cross country fluid transport are not available except for a few specific installations. Consequently, it has been necessary to apply spill risk parameters based upon data from the entire interstate pipeline network of crude oil lines. Although concentrated brines are more corrosive to steel lines than crude oil, it may be noted that crude oils contain a small amount of brine, and much of the pipeline network is exposed to saline water on the outside of the pipe as well as the inside. Consequently, there is a basis for performance comparison, assuming that design standards for corrosion control are comparable for the two applications.

Median and maximum credible spill sizes cannot be extrapolated from petroleum data, because they are closely correlated to the detection time interval for large ruptures and the testing interval for small leaks. Petroleum transfers are closely metered for inventory control as well as for leak detection, and detection intervals are short. Brine transfers are not inventory controlled, and, in the case of ocean disposal, not reliably amenable to flow monitoring at the exit. Brine spills into the environment may go undetected for a longer period. In some cases, they may be found only by pressure tests on the line. As a result, average brine spill sizes must be projected to be much larger than oil spills.

Pressure and flow monitoring of an open disposal line extending to the ocean is not expected to be reliable for rapid detection of spills. It is unlikely that a rapid detection of ocean discharge upstream of the diffuser can be expected. The monitoring of water samples in the vicinity of the line for heavy brine plumes along the bottom would likely be the first line of ocean spill detection. However, it must be remembered that small leaks are of no concern in the ocean. The problem to be avoided is a smothering brine pool which lies on the bottom unmixed with seawater, after exit from the pipe. Diffusers are designed to set the heavy brine into the surrounding seawater for turbulent mixing. A small leak ahead of the diffuser would act in the same manner.

Calculated spill expections from pipelines for Bryan Mound early storage and for each SPR expansion site are provided in Tables E-4 and E-5. Table E-4 contains spill estimates for leaching, fill and withdrawal operations. Table E-5 contains spill estimates for standby storage and for all project operations together. Spill estimates have been summarized for both brine and for saline water, onshore and in the Gulf of Mexico. The spill risks are based on the assumption that data for petroleum pipelines are applicable, rather than data for urban waterlines.

Losses would be greatest for Damon Mound and Nash dome because of the longer pipelines required. Environmental exposure to saline water spills is more than twice as great as for brine spills. Environmental damage would be much less for saline water spills, however, brine spill exposure is greatest during the assumed five cavern fill cycles. Saline water spill exposure is greatest during the period of standby storage.

The precent chance of spills occurring during the project lifetime are, for saline water/brine:

	No Spills	One Spill	2 or More Spills
Bryan Mound early storage	97.7/98.5	2.26/1.5	.04/03
Bryan Mound SPR expansion	99.9/96.8	.1/3.2	0/.04
Allen Dome SPR expansion	83.6/90.4	15.0/9.1	1.4/0.47
West Columbia SPR expansion	68.8/84.4	26.0/14.3	5.2/1.3
Nash Dome SPR expansion	55.4/78.3	33.1/19.3	11.5/2.4
Damon Mound SPR expansion	55.4/78.3	33.1/19.3	11.5/2.4

TABLE E-4 Brine and raw water spill[a] expectation model projections during project lifetime.

Storage Facility		Leaching				Cavern Fill				Standby Storage				Oil Withdrawal				Project Lifetime			
		Brine		Raw Water		Brine		Raw Water		Brine		Raw Water		Brine		Raw Water		Brine		Raw Water	
		Gulf	Onshore	Gulf	Onshore	Gulf	Onshore	Gulf	Onshore	Gulf	Onshore	Gulf	Onshore	Gulf	Onshore	Gulf	Onshore	Gulf	Onshore	Gulf	Onshore
Bryan Mound	No. Spills	-	-	-	-	0.0125	0.0025	-	-	0.0035	0.0016	0.0078	.0035	-	-	-	0.0005	0.0160	0.0041	0.0155	0.0076
Early Storage	Barrels	-	-	-	-	62.5	12.5	-	-	18	8	39	17	-	-	-	2.5	80.5	20.5	78	37.5
Bryan Mound	No. Spills	0.01	0.002	-	0.001	0.0195	0.0040	-	-	0.0043	0.0019	b	b	-	-	-	b	0.0338	0.0079	b	0.001
SPR Expansion	Barrels	50	10	-	5	97.5	20.1	-	-	21	9	b	b	-	-	-	b	168.5	39.1	b	5
Allen Dome	No. Spills	0.01	0.024	-	0.023	0.0195	0.047	-	-	b	0.0717	b	0.0707	-	-	-	0.0115	0.0295	0.143	b	0.178
SPR Expansion	Barrels	50	120	-	120	97.5	235	-	-	b	359	b	359	-	-	-	57.5	147.5	714	b	895
West Columbia	No. Spills	0.01	0.048	-	0.047	0.0195	0.091	-	-	b	0.15	b	0.15	-	-	-	0.0235	0.0295	0.289	b	0.371
SPR Expansion	Barrels	50	240	-	235	97.5	455	-	-	b	750	b	750	-	-	-	117.5	147.5	1445	b	1853
Nash Dome	No. Spills	0.01	0.072	-	0.071	0.0195	0.142	-	-	b	0.237	b	0.237	-	-	-	0.036	0.0295	0.451	b	0.582
SPR Expansion	Barrels	50	360	-	355	97.5	710	-	-	b	1142	b	1142	-	-	-	180	147.5	2212	b	2910
Damon Mound	No. Spills	0.01	0.072	-	0.071	0.0195	0.142	-	-	b	0.237	b	0.237	-	-	-	0.036	0.0295	0.451	b	0.582
SPR Expansion	Barrels	50	360	-	355	97.5	710	-	-	b	1142	b	1142	-	-	-	180	147.5	2212	b	2910
Total Program	No. Spills	0.01	0.072	-	0.071	0.032	0.1445	-	-	0.0078	0.2410	0.0078	0.2410	-	-	-	0.0365	0.0498	0.458	0.0155	0.5896
Spill Risk[c]	Barrels	50	360	-	355	160	723	-	-	39	1160	39	1160	-	-	-	183	249	2243	78	2948

[a] Average spill from brine pipelines taken to be 5000 barrels; maximum credible spill taken to be 30,000 barrels; computed for five cavern fill/withdrawal operations.

[b] Losses from these SPR operations would occur in any case as a result of Bryan Mound early storage and are attributed to these facilities.

[c] Program totals are for worst case combination of sites having 163 MMB storage capacity, i.e., Bryan Mound early storage and Nash or Damon Mound SPR expansion.

E.2.2.4 Brine Spill Risk from Aquifer Injection and Storage

The concern for brine spillage from aquifer storage stems from the injection pressures needed to place the brine into the aquifers. The pressure increases are hypothesized as breaking the permeability barrier overlying the aquifer (hydro-fracturing), permitting the upward migration of the brine into zones of potable or agricultural water withdrawal.

Upward migration of the injected brine is unlikely because of the density involved. As the fluids percolate through the soils, they are expected to stratify in the soils according to density, rather than to undergo rapid diffusion. In the event of an upward fracture, the least concentrated brines will diffuse upward, displacing overlying waters of less salt content. Once such a process is detected, it would be arrested by cessation of injection. The build-up of pressure in the injection aquifer would dissipate as the brine migrates outward in the aquifer.

The prevailing migratory pressure for the brine is downward, in contrast to petroleum fluids which try to percolate upward in water-saturated media. Injection situations in which water supply aquifers are separated from an injection aquifer by a thin aquiclude will be avoided as a precaution. However, if the quality of supply is not sensitive in terms of changes of a few ppm of chloride content, then monitoring of the well systems for pressure and salt content could be sufficient to detect breakout migration from the injection aquifer before concentrated brine displacements into the upper aquifers can result.

The deep aquifers near the domes are highly saline, as a result of leaching of the salt domes themselves, while most of the near-surface ground waters, except where they intersect a piercement dome, are sources of fresh water, recharged by surface waters. Although in some areas, there is no longer a surplus of perennial surface water, upward migration of saline waters into ground water aquifers being withdrawn has not been a serious problem in the areas being considered for water injection.

E.2.2.5 Brine Dispersion

The motion of brine across land, in the soil, and within bodies of water, is identical to that of water in every respect except in contact with water. The mixing, or equalization of salt concentration, between brine and water by molecular diffusion alone is a very slow process. If brine flows quietly into a pond or the ocean away from shoreline turbulence, it will tend to stratify at the bottom of the water. Rapid mixing of brine and water required energy of turbulence. A small leak of brine into a flowing stream can be quickly diluted to nearly negiligible concentrations, whereas a leak into a small lake or pond may retain density stratification for several days.

The dispersion of brine in the ocean is expected to be accomplished by use of a multi-port, or multi-jet diffuser (Appendix I). Each jet has sufficient energy to provide rapid flow mixing with the surrounding water, and is separated spatially from the next port to prevent density buildup. Salinity down-current (even with sluggish currents) of a properly operated diffuser should be reduced to 5 or 10 percent above ambient within a few hundred meters. Ocean salinity is on the order of 30 parts per thousand, and brine salinity is on the order of 300 ppt. Reduction of the brine to 10 percent above ambient implies about 100 to 1 dilution with seawater.

National Oceanic and Atmospheric Administration (NOAA) studies (summarized in Appendix G) indicate that without a diffuser, a brine plume could extend for several kilometers along the Gulf floor. This would cause a potentially disruptive influence on benthos, especially shrimp. A large break in the offshore brine line could have a similar effect. It is doubtful that sufficient turbulent energies are available, even close to the surf zone, to dilute the concentrations of brine as quickly as the proposed diffuser would. A dense plume is formed by a brine spill in coastal waters and would slowly be dispersed after the source is plugged. IF natural dispersion is not sufficient to prevent the plume from impacting sensitive zones down-current, mixing could be enhanced by water jets used near the bottom. The dispersal of the plume and the location and character of sensitive zones could be seasonally variable.

Onshore, brine flows across soils would leave salt deposits in the ground, which will leach upward with upward migration of pore water during dry periods. Ruptures of buried brine lines may present an opportunity for brine to percolate into aquifers, in which the natural migration is downward. Large ruptures, however, would probably surface and flow over the land to local water courses. Partial containment of the brine in the pipeline trench by permeability limitations is not expected to occur.

For brine line spills onshore, the greatest risks would be those in which water supplies, agricultural land, or sensitive fresh water marine nursery zone, may be affected. In this context, however, salt water intrusions from hurricane surges have been experienced in much of the area which might be contacted by a brine line spill. The primary recovery mechanism after a brine spill is dilution of salt water and washout of salt deposits into the waterways, most of which can be expected to provide a flushing pathway into the Gulf of Mexico.

Intrusion of brine into ground waters underlying croplands could be more difficult to purge. During dry periods, salt is carried upward in (interstitial) soil pore water. For wet soils, the natural migration of the salt is downward. However, it may not move away, and could remain in a position to affect the root zones. One method of purging salt contamination from irrigated, or irrigable lands is downward leaching to deep drainage. A collection tile is installed at a depth of 8 to 10 feet, the land is flood irrigated, and the water in the drain tile is pumped out, carrying the leached salt with it. If a slight ground water surplus is available, recovery assistance by well point pumping may be sufficient. Otherwise, natural leachout by ground water movement toward the Gulf would be relied upon to produce eventual water quality recovery. Impacts on oil productivity could be long term.

E.2.2.6 Brine Spill Prevention and Control

Detection of brine line spills is more difficult than oil spill detection because the system is open to the ocean through a diffusor. Furthermore, a brine spill is much less readily noticed by casual observers. Primary preventive measures upstream of Bryan Mound are regular line leak checks, line inspection, and monitoring at ground water salinity. Large pressure changes accompanying major line ruptures would be readily detected, but partial losses would be very difficult to notice from operating parameter readouts. Regular line pressure checks are the only reliable method of detecting small leaks. Downstream of Bryan Mound, the system is open, and breaks would not be detectable by instrumentation. Monitoring of water salinity profiles near the diffusor and inshore of it is a possible method of detecting leaks.

The control of brine spills is opposite to that of oil; rather than containment, dispersion and dilution is desired. Dilution and flushing of saline waters to waterways discharging to the ocean is the basic mitigating measure. In some cases, this will require pumping of fresh water through affected areas to produce flushing. The drainage patterns for all portions of the line can be determined in the same manner as for oil lines, and in most instances, they will be identical. The pre-planned control points will differ, since the objective is to disperse saline brines rather than to contain them. Equipment needed for contingency action would be primarily water pumps and connecting lines, rather than booms and collection materials.

Legislative authority for action on brine spills into inland waters and lands stems from the basic Federal Water Pollution Control Act, since a saline spill alters potable water quality and affects agricultural usage. It is assumed that procedures parallel to those for oils and toxic chemicals, such as pesticides, would be followed. However, guidelines specific to brine spills may eventually be promulgated by the Environmental Protection Agency. A response and inspection team would be expected to be formed in the event of a large discharge, and would also be empowered under the levels of the Act (92-500) to undertake or require restorative actions.

For brine spills offshore, the specific procedures to be implemented in the event of determination of a brine plume are not clear. The most concerned agencies for the adverse effects on offshore fisheries and benthos conditions would be the National Oceangraphic and Atmospheric Administration and the state fisheries department. It would be necessary to determine a suitable inspection interval for offshore sampling, depending upon season, and also to evaluate methods or zones at which brine plumes might be jetted most effectively.

Other preventive measures for the brine system would include purging of the lines after use, close inspection of earthworks associated with brine impoundments (which may also serve as emergency oil sumps), and ground water monitoring in the vicinity of impoundments.

E.2.3 Related Risks

The statistical base used for projecting spill expectations includes spills from all causes, such as natural disasters and fires. Spills from the cavern storage is not covered in the statistical basis, but the petroleum in storage is well protected from natural hazards. (See Appendix H for cavern roof collapse discussion).

The natural hazards affecting petroleum operations include hurricanes, tornados, floods, earthquake (limited to subsidence faulting and related foundation problems in the area of concern), and lightning-caused fires. Additional risks include fires, and external party causes, such as aircraft crashes, vandalism, sabotage, etc. The level of risk represented by these accident modes is assumed to be accounted for with ordinary preventive measures - security, fire control spray systems, shut-in during hurricanes, and standard safe operating principles for all components. Some natural hazards are so remote that they are not perceptible in the risk bases (such as meteorite impacts).

Underground salt storage caverns which have been designed with provision for adequate cavern control, roof strength, and operating safeguards, can be projected to be inherently more hazard free than surface storage. The natural hazard which has been indicated to be a potential problem is undetected leaching of the salt cavern roof by ground water percolation around the entry passages. This particular hazard would not be caused by a sudden natural event, but rather a gradual deterioration leading to a sudden failure. Furthermore, as indicated previously, the hazard has historically occurred only where the depth to salt was less than 300 feet, and was preceeded by abnormal cavity behavior which would be detected by close monitoring.

Sudden decompression of relatively compressible oil due to shearing of the wellhead or pipeline, would be a potential driving force for oil "migration". This situation would be especially severe if it occurred during oil injection under high pressure. With adequate pipeline and wellhead design, this highly improbable (and inestimable) scenario could still result from a direct-hit airplane crash or an act of war. The latter examples are more likely to result in a fire than an oil spill.

E.3 Spill Risk Analysis Methodology

The analysis methodology used to compute expected oil (and brine) spill volumes is summarized in this section. Controlling parameters are: miles and time of exposure, for pipelines; volume of cargo and typical operation, for vessel transfers; volume throughput and facility size, for surface storage to terminals; and ton-miles (inland waterways) or travel time (coastal waters), for vessel casualties. As explained in Section E.2.1.1, data is not available to make a quantitative estimate of oil spill risks from cover storage.

The statistical bases from which the characterization of risk exposure is made and the probability procedures for projecting spill size distributions, generally define an expected incident frequency and an average spill size. The projection of risk with regard to spill sizes, however, requires that a distribution of spill sizes and frequencies be determined. The probability distribution used here is the log-normal, because of its applicability to many natural random events (earthquakes, rain falls). To complete the statistical charactization of a given mode of spill, the maximum credible spill size must be specified. The maximum credible spill is based upon extrapolation from the largest sizes of spills available in the data base and upon a realistic evaluation of program operating conditions. It presents a practical limit to the extrapolation, but does not imply that the spills larger than the credible maximum are impossible.

E.3.1 Marine Transportation

Oil spills associated with marine transportation of oil may be considered for the categories of transfer operations and vessel casualties.

E.3.1.1 Vessel Transfers

The bases for calculating spills for vessel transfer are selected mean frequency records and typical gross spillage rates for world-wide transfer of operations follows:

Frequency - 1 spill per 90 operations at docks and inland waters.
- 1 spill per 18 operations between vessels offshore.

Spill Volume - 3×10^{-6} of cargo transferred, vessel to vessel.
2×10^{-6} of cargo transferred, dock to vessel.
1×10^{-6} of cargo transferred, vessel to dock.

The above frequency rate for offshore transfers is based upon a worldwide survey of transfer operations for the period between 1966-70 (J. J. Henry, 1973). This survey included single point mooring systems (SPM), lightering and 7-point mooring facilities. The frequency rate for onshore transfers is a median of those recorded for several U.S. facilities which experienced a spill every 60 to 133 transfers. Spill volume rates recorded in U.S. facilities range from 0.5 to 3×10^{-6}; foreign ports have experienced much higher rates. The above rates were selected on the basis of U.S. experience and are consistent with other published projections.

The maximum credible spill size from transfer operations at the tanker docks is estimated to be 500 barrels. Because of higher pumping rates and less controlled docking conditions offshore, the maximum credible spill size for VLCC to tanker transfers is estimated to be 1000 barrels. Historically, a few large spills (5000 to 10,000 barrels) have occurred during transfer at terminals due to negligence. A routine of vigorous close inspection is expected to avoid spills of this type. Using a log-normal spill size distribution, the average spill sizes computed in Tables E-1 and E-2, and the maximum credible spill sizes indicated above, the chance of a spill of a particular size range occurring may be estimated as shown in Table E-3. At the docks, there is a 96.6 precent chance of a spill of less than 50 barrels; offshore, there is a 75.4 percent chance of a spill of less than 50 barrels. The mean spill size for harbor transfers doubles during the withdrawal of oil, compared to fill operations. This is because it has been found to be easier to avoid spills when going from a small container (i.e., a tanker) to a large one (i.e., a pipeline) than from the reverse operation.

E.3.1.2 Vessel Casualty

Vessel casualty rates are based on estimated selected from various casualty records to provide a spillage model dependent upon the route length. In this regard, spillage for inland waters is based upon a ton-mile cargo exposure; in offshore waters, spillage is based upon a time exposure. Very large crude carrier (VLCC) casualty exposure offshore was not included in the analysis. The following spill rate parameters were chosen:

Frequency - 1 spill per 7 billion ton-miles in inland waters.

- travel in ballast weighted 50% in inland waters (1 spill per 14 billion ton-miles)
- 1 spill per 12.8 vessel years in offshore waters.

Mean Spill Size 428 barrels in inland waters.
1111 barrels in coastal waters.

Offshore spillage rates are based upon tankship casualty rates in worldwide coastal waters. It may be reasonable to use lower rates such as might apply to a dedicated fleet for lightering operations, but the rates used here are more conservative (yield higher spill estimates). The spill frequency in inland waters is based upon the composite for all U.S. waters for barges and tankships during the period of 1968-70 (AEC, 1972). The average spill size, however, is based upon tankships for the years 1969 to 1973.

The maximum credible spill size assigned to tanker casualty losses is 60,000 barrels. Using a log normal distribution, the probability that a spill in coastal waters would be less than 500 barrels is 46.7 percent (Table G-3).

E.3.2 Pipelines

The basis for calculating pipeline spill risks is the spill rate frequency, which is 50 spills annually per 100,000 miles of pipeline. This estimate was derived in the LOOP Environmental Analysis (1975) for new crude lines. The mean spill size is considered to be 1100 barrels for the large lines involved (DOT Office of Pipeline Safety annual summaries, 1969-73).

SPR pipelines should not involve exposures unusual to Louisiana and Texas. These areas also provide a large portion of the risk exposure comprising the U.S. pipeline failure base statistics. Thus there is no reason to anticipate other than the projected pipeline failure risk. Principal pipeline hazards include soft, saturated soils, saline water and less-than-average exposure to other construction activities. The mix of pipe sizes should also be representative of the base. The basic exposure parameter for pipelines is length and time of use, rather than throughput, which is consistent with the fact that many of the causes of failure are external to the use of the line.

The maximum credible spill for the pipeline can be judged from various combined static and pumping losses. The maximum pumping rate would be about 465 barrels per minute to handle 100 million barrel in 150 days. A 36-inch line would contain 6700 barrels per mile. The leak detection capability would vary with the size of the leak. However, a state-of-the-art system has been assumed, with some allowances for operator hesitation:

Break Severity	Loss Description		Volume of Oil Loss
Total break:	1 mile of line + 10 minutes pumping	=	11,350 barrels
10 percent break:	1 mile of line + 1 hour pumping	=	9,490 barrels
2 percent break:	1 mile of line + 12 hours pumping	=	13,395 barrels

These situations are contrived by assuming worst conditions. The metering system should be able to react to a cumulative difference of 600 barrels in one hour or more, but it could be set for lower sensitivity to avoid unnecessary shutdowns due to line operating pressure surges. A maximum credible spill of 10,000 barrels has been assumed. Suction could be applied to the pipeline from the terminal to minimize oil loss after shutdown. From Table E-3 it is estimated that 30 percent of all pipeline spills would release less than 500 barrels of oil.

For brine pipeline spills, leak detection system would be substantially less sensitive. Consequently, average spill size is taken to be 5000 barrels and maximum credible spills are estimated to be 30,000 barrels. The basis for spill frequency is assumed to be the same as for oil pipelines.

E.3.3 Terminals

Average spill sizes different from the historical average are projected for the SPR terminals on the cavern sites, and at single purpose pipeline stations and docks. Where existing standard terminals (e.g., SEAWAY) are used, historical average spill size (1969-73, 1083 barrels, sometimes rounded to 1100 barrels) is applied. There are several reasons for altering the estimate for the SPR terminals. An average U.S. terminal has an exposure which could be based either on capacity or throughput. To the extent that certain types of terminals tend to have similar capacity-to-throughput ratios (i.e., from 10 days for a transportation terminal to 100 days for a storage depot), the exposure selection is not critical. An above ground SPR terminal has a ratio measured in hours, while the caverns themselves have a ratio measurable in years.

Sufficient data has not been analyzed to determine whether throughput, capacity, or a combination thereof, is the best parameter for estimating terminal spillage rates. The basis selected here is throughput, which is the most conservative estimate for terminals with minimal storage exposures such as those proposed for the storage program. The assumed basis for terminal exposure is as follows:

Frequency	-	1 spill per 2 billion barrels throughput
Spill Size	-	1100 barrels at the SEAWAY terminal
	-	500 barrels at the storage terminals.

The frequency is estimated on the basis of spill data for all U.S. terminals during the period 1969-70; the average spill size is taken from 1969-73 data. Because of the low capacity-to-throughput ratio indicated above, the throughput exposure which has been applied to SPR terminals may be conservative (high).

The maximum credible spill event selected for analysis of terminal spill expectation is 5000 barrels. Though larger spills have occurred, they have been the result of negligence and a lack of facility and monitoring. (Even if the entire contents of a storage tank should be lost, the containment levees are designed to contain all the oil released). From Table E-3, it is estimated that 71.5 percent of the spills from storage site facilties would be less than 500 barrels.

APPENDIX F

CAVERN STABILITY

APPENDIX F
CAVERN STABILITY

F.1 INTRODUCTION

Petroleum hydrocarbons have been stored in solution mined cavities in salt domes in the United States since 1951. By 1975, at least 196,298,000 barrels of hydrocarbons and products were stored in Texas, Louisiana, and Mississippi salt domes. These hydrocarbons and products include propane, butane, ethane, ethylene, burning fuel oil, natural gasoline, natural gas liquids, and crude oil condensate. Large amounts of crude oil have not been stored in the U.S. to date, but there is no reason to suppose that crude oil storage is any different from storage of other hydrocarbons, or brine with respect to cavern stability.

Solution mining of salt from domes in the U.S. has been practiced for many years. Current operations include hundreds of wells on at least 20 salt domes in Alabama, Louisiana, and Texas, run by 16 different operators.

French and German crude oil storage programs in leached caverns in salt domes were initiated in 1967 and 1970, respectively. By December 1976, at least 63 MMB of crude oil was in storage in France. German capacity stored by the same time was 22 MMB. The longest experience with storage of crude oil in a leached cavity in a salt dome is a 3 MMB cavity in Germany, which has been filled for 6 years.

There are no recorded collapses of caverns containing hydrocarbons in the storage examined to date. This includes the 25 years of experience in the United States and also includes hydrocarbons stored in cavities leached for salt mining, and thus not specifically designed for hydrocarbon storage.

F.2 STRUCTURAL STABILITY OF SALT

The use of salt domes for petroleum storage is attractive because of both the relative low cost of such bulk storage and the extreme geological stability of rock salt masses. Containment is usually very good in salt domes, because existing or incipient cracks and fissures are small and tend to seal themselves because of the plasticity of salt.

All cavities in salt exhibit some closure due to the well known characteristics of rock salt to flow under stress (Waiversik et al., 1976; U.S. Department of Interior, 1962). Overburden pressure increases with depth in any salt dome; therefore, deeper levels are more "tight" than upper levels, and leaks are less likely to occur at deeper levels. The more direct effect of cavity depth is to determine the average geostatic stress in the salt surrounding the cavity. This in turn controls the pressure difference between the cavern fluid and walls, which is a major factor in determining cavern stability (Dreyer, 1972, 1974; Albrechs and Langer, 1974; Serata and Gloyng, 1960). A room and pillar mine operated at atmospheric pressure is a far more severe test for stability of underground openings in salt than a filled storage cavity with controlled stress differences. In summary, a limited amount of creep closure or slabbing is anticipated in any dome storage cavity.

Another factor which determines cavern stability is the quality of the salt. In general, salt at shallow depths and near the top surface of domes tends to be more anisotropic and to contain zones of impurities. "Shear zone" effects tend to be minimized for relatively deep cavities in shallow domes. For example, solution cavities at shallower depths in the Bayou Choctaw dome display a preferred dissolution direction as compared to cavities at greater depth. The implication is that this domal salt has a definite anisotropic character and the tendency is toward decreasing influence as cavities are created at greater depths in the dome, probably because salt becomes more pure. At great depths in domes, the salt may again be less pure; however, storage cavities probably will never be created at such depths because of creep closure effects. The shallow levels in the room and pillar salt mines of south Louisiana also display a greater range in quality of salt (pure to impure) than deeper levels. Slabbing of salt in the room and pillar mining operations in south Louisiana domes is common, but the danger can be minimized by "scaling" off the obvious loose slabs on the mine walls and roof.

Slabbing of salt or of impurities into cavities appears to be a minor problem for properly maintained Gulf Coast dome cavities, compared to bedded salt cavities (Jaron, 1969). Gulf Coast domes contain salt that is relatively free of shale or anhydrite stringers, which are zones of weakness that could cause salt slabbing. The relatively pure salt enables the uniform dissolution of salt and the formation of regular caverns, except where occasional stringers of impurities are found.

Cavities constructed at greater depths would appear to have advantages in at least two regards as compared to cavities at shallower depths: better quality and "tighter" salt. An adequate pressure difference must be maintained for deeper cavities, otherwise collapse could become severe (Brown and Sessen, 1959).

When a storage system of multiple cavities is created in salt domes, attention must be given to the coupling effects between neighboring cavities (Chao, 1974). A primary concern is the wall thickness between cavities necessary to maintain system stability. This system design concern is somewhat similar to that involved in designing supporting pillars for room and pillar mining.

Either physical or numerical modeling of typical appropriate portions of the storage system walls can be used to obtain a measure of safe wall thickness (Dreyer, 1974). Realistic material properties again must be available before confidence can be placed in minimum wall thickness determination. In the case of Gulf Coast salt domes, we have empirical data from conventional salt mines, which span several years.

Parametric numerical studies have indicated effects of varying spacing of underground openings near the ground surface (Bank and Ottoriani, 1974). Similar studies can be readily performed for deeper storage cavities. Chao (1974) reported on measurements of long term creep closure of cavity systems, and found that his field data and "conventional" FEM predictions did not coincide. He noted that multiple cavity interaction, e.g., creep interference, increased with the passage of time.

F.3 CLOSURE OF SALT DOME CAVERNS

Three major modes of closure of caverns in salt domes are possible: "creep" closure, "slabbing," and general collapse. "Creep" closure (described above) is an active process in any salt cavity where stress differentials exist. For a fluid filled cavity under pressure, the hydrostatic pressure may equal lithostatic stress at one interval, while it exceeds lithostatic stress above and is less than lithostatic stress at greater depths. This situation would suggest that plastic "creep" of the salt would enlarge the cavern near the top, while the cavern would close slightly at depth. Total enlargement or closure due to "creep" is not expected to represent a significant fraction of the volume of the proposed cavities.

"Slabbing" has also been described above and is the result of anisotropic properties of sheared or impure salt. The proposed cavities are not expected to encounter a significant problem due to slabbing because of their designed depth and the purity of the salt at the designed cavern intervals. If slabbing is excessive in the shallow mine cavities to be converted, roof bolting of slabs may be required. This has not been a very serious problem in the previous mining oeprations.

Obviously, if "creep" closure becomes extreme, or if roof "slabbing" is excessive and continuous, then a progressive failure mode might eventually occur which could result in a partial, and eventually general, collapse of a cavern. Either of these failure modes would be detectable early, and appropriate precautionary measures could be taken to prevent more serious failure of the cavern (i.e., roof bolting to prevent slabbing in a conventionally mined cavity).

General collapse of a storage cavity is the worst case failure that is possible; however, it is not suggested in this report to be a real possibility. In the final stages of general collapse a surface sinkhole could apparently occur within a matter of several hours to a few days for a brine filled cavern. A plausible speculation of the sequence is that the salt roof over the cavity fails first, followed by the next layer of material above that, and so on until the ground surface is reached and a characteristic sinkhole develops (Terzaghi, 1970). It is also possible that this process could stop before it reaches the surface, in which case there would not be surface subsidence.

Surface subsidence in the case of all of the proposed storage sites would not be expected to directly affect any area offsite. Subsidence bowls from a "worst case" (but still not a real possibility) cavern collapse should not exceed tens of feet for the shallowest mines, and even less for deeper solution mined cavities.

The worst environmental effects of a general collapse would probably occur from the dispersion of the stored oil. The following discussion considers several possible paths of oil dispersion following a general collapse.

The general collapse of a storage cavern in salt is not analogous to debris falling into an empty hole and causing a "sinkhole" at the surface. These caverns are always full of a nearly incompressible fluid, brine or oil, which would be displaced volume for volume by falling salt caprock, and overlying sediment.

If the entire column of sediment above a cavern is lowered into the cavern in a manner analogous to a piston in a cylinder, and if the fluid in the cavern was completely displaced by percolation through the sediments of the "piston" rather than compressed, there would be a surface depression equal in volume to the original cavern filled but not overflowing with the displaced fluid.

This is a simplified case which assumes that the imperfect packing of falling particles, adsorption, absorption, dissolution, and trapping of the displaced fluid do not occur. In reality, these five mechanisms reduce the amount of oil that would continue to rise through the cone of influence and emerge on the surface. With these mechanisms, oil would probably reach the surface as small seeps, and as the sediments settles into the place formerly occupied by the oil, a small surface depression would form. Multiple depressions would appear as a wide area of shallow subsidence filled with oil.

Another possibility is that subsidence occurs without surface emergence of oil. Using the piston and cylinder model again with the assumption that the oil percolates up through water saturated sediments that have zero empty pore space, there is a volume for volume displacement of oil and the combined volume of the oil and saturated sediments remains constant. If the oil moves up from the saturated layer into the empty pores of an unsaturated layer, the volume of the unsaturated layer would remain constant as long as the oil only fills empty space. Oil would not emerge on the surface until all of the pore space near a potential seep was filled with oil. This would permit the possibility of an oil "slick" to form on top of the water table surface in the unsaturated layer.

F.4 SUMMARY

Cavern design concepts developed for the proposed cavities for the SPR program have incorporated the experience of hundreds of brine well operations, rock salt mine operations, and 25 years' experience with storing hydrocarbons in salt domes in the U.S. With use of appropriate construction techniques and constant monitoring of the caverns' integrity, the general collapse of a storage cavern is discounted as an unrealistic possibility. "Creep" closure and "slabbing" in storage cavities should present no environmental hazards, based on industrial experience with use of mined cavities in Gulf Coast salt domes.

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APPENDIX G

TECHNICAL REPORT
SEAWAY GROUP DIFFUSER SITE STUDY

EXECUTIVE SUMMARY

The Department of Energy (DOE), in implementing the Strategic Petroleum Reserve (SPR) Program, proposes to utilize for oil storage, existing caverns at the Bryan Mound salt dome, on the Gulf Coast west of Freeport, Texas. Additional storage capacity is proposed at Bryan Mound or at an alternative site in the Seaway Group by the solution mining of new caverns. The discharge into the Gulf of Mexico of salt brine produced by either the solution mining operation or cavern refills is but one of several disposal options under consideration by DOE. The brine would have salinities which range from 230 ppt to 264 ppt and temperatures which would range from near ambient to almost 120°F. Two brine disposal sites are under consideration. The proposed site is located about five nautical miles (5.8 statute miles) off the Texas coast in 50 feet of water; an alternative area is located 10.9 nautical miles (12.5 statute miles) off the coast in 68 feet of water.

This report was prepared to assist DOE's examination and assessment of potential environmental impacts associated with the option of brine disposal in the Gulf and to support the application for a discharge permit. This report is based on both historical data and site-specific investigations undertaken in the Gulf of Mexico.

The continental shelf at the proposed diffuser site is covered by a relatively thin blanket of sand, silt, and clay. Isolated coral heads lie to the south and southwest of the proposed site. Water close to the shore is cooler than that offshore, except during the summer months when the shelf waters become nearly isothermal. Surface currents in the area are wind-driven and generally flow at speeds less than 50 cm/sec. Circulation generally parallels the Texas coastline; the nearshore currents flow northeast during the summer, but reverse direction in late fall to the southwest. This change results in the introduction of fresh, cool but less dense waters from the northeast.

Predictive modeling for the proposed diffuser indicates that the discharged brine plume would remain near the bottom, thus minimizing its effect on mid-depth and surface waters. One series of model runs was performed using estimated magnitudes and directions of tidal and wind-driven currents based on historical data. Under conditions of moderate wind and current, modeling indicated that a plume with salinities greater than 1.0 ppt above ambient at the bottom would cover less than 500 acres. Under stagnant conditions, such salinities would cover up to 2000 acres, and an area of about 25 acres would experience a salinity increase of 5 ppt or greater.

Approximately 13 days of observed currents collected in the vicinity of the diffuser site were used as input in a second series of model runs. Outputs were taken on the 13th day at the four quarters of the tidal cycle. The plume patterns closely followed the patterns predicted using estimated currents.

At the 5 ppt isohaline, 1000 feet or less from the diffuser, the water temperature was found to be increased by less than $1^{o}F$, resulting in only minor impacts. Variations in brine temperature at the diffuser and the ambient sea water temperature would have only a small effect on temperature rise outside the 5 ppt isohaline. In contrast, higher temperatures would be found in the immediate area of the diffuser.

Discharge of brine at the alternative disposal site would be expected to have plume characteristics similar to the proposed site. Monitoring at the alternative site indicates that density stratification occurs there. This condition could affect vertical brine dispersion, causing the plume to spread over a larger area.

At both the proposed and alternative sites, BOD, pH, COD, alkalinity and heavy metal levels are within the range of expected values for coastal waters. Nutrient (NH_3, NO_2, and PO_4) levels are low. Dissolved oxygen is usually above 5 mg/l; however, low values are found during the summer in bottom waters. Oxidation-reduction potentials of the sediment change from oxidizing in the winter to reducing in the summer. Transparency in the water column increases between spring and summer. Because of lesser riverine influences, the offshore water is clearer than that at the proposed site. Oil and grease levels are 25 percent higher at the offshore site compared to the proposed site because of its proximity to shipping fairways.

Chemical impacts would be similar for both sites. Within the discharge plume, increased salinity would result mainly from the high levels of sodium and chloride discharged. Discharged heavy metals would have negligible impacts if compensation water is taken from the Brazos River during normal flow periods. But if the water is taken during either low flow or flood periods, heavy metal levels could be above EPA guidelines. Increased salinity and temperature levels could result in altered solubilities of oxygen and other elements. Hydrocarbons (6 ppm) in the discharge would exceed ambient oil and grease levels in the Gulf (2.4 ppm). However, since ambient oil and grease concentrations are higher at the offshore site (3.2 ppm), hydrocarbons could have less impact at the offshore site. Because of the better water clarity at the offshore site, turbidity attributed to brine discharge could have a greater impact at the offshore site.

The biological assemblages at both the proposed and alternative sites are diverse and productive, but their components differ in several aspects. The phytoplankton communities at the sites are very similar, but the composition at the proposed site is strongly influenced by the freshwater input to the Gulf from the nearby Brazos and San Bernard Rivers; the phytoplankton at the alternative site has a greater proportion of marine species. Cell density and productivity at the proposed site is relatively higher than at the offshore site. Both sites attain maximum values for biomass, productivity and chlorophyll _a_ in the early spring; distinct minima occur during the summer months.

Bioassay studies have indicated that plankton entrained in the brine plume would be subjected to severe physiological (mainly osmotic) and temperature stress and therefore these plankton would undergo a temporary reduction in productivity and standing stock. Since the residence time of the plankton in the plume area would be in terms of only a few hours, it is expected that no long-term or major impacts would be reflected in the plankton community for either of the two sites. Since the plume will remain near the bottom, only those organisms associated with this lower portion of the water column or the benthic sediments would be affected.

The mean density of benthic macroinvertebrates at the proposed site (902 organisms per square meter) in December was low compared to that at the offshore site (2092 organisms per square meter); however, the number of taxa at the nearshore site (107 taxa) was high compared to the alternative site (59 taxa). Polychaetes were the dominant benthic organisms at both sites.

Bioassay studies of a polychaete species indicate that it is able to withstand brine concentrations of 40 to 53.3 ppt. At the proposed site approximately 3.2×10^8 benthic organisms would be eliminated within the 25 acres covered by the plume under worst case conditions, and 7.4×10^8 organisms would be similarly destroyed at the alternative site. Under these conditions more than twice as many benthic invertebrates would be killed in the offshore area.

A large white shrimp fishery and spawning area is associated with the proposed disposal site area. This area is also fished for Atlantic croaker, Gulf butterfish, silver seatrout, and star drum. Sport fishing is important in the area of the proposed site, particularly around reefs, wrecks, and oil rigs where catches include seatrout, red drum, flounder, sheepshead, and members of the jack fish family. The most significant impact of the brine to the nekton at the proposed site will be the loss and damage to white shrimp eggs and/or larvae entrained in the brine plume. Bioassays reveal that brine is lethal to white shrimp larvae at concentrations between 36.5 and 38.0 ppt and may inhibit larval metamorphosis at 39 ppt. Because of their high mobility, most adult nektonic organisms could avoid the high salinity impact area near the diffuser.

Brown shrimp characterize the offshore alternative site. This site is dominated by longspine porgy, silver seatrout, and Atlantic croaker, and is a transitional area between the white and brown shrimp fishing grounds. This offshore area is not considered to be a prime shrimping area, a major white shrimp spawning area, or an important fish spawning area.

At either site, trawling operations would not be hindered by the diffuser ports. By the use of an anti-snag port design, their potential to catch or tear trawling nets would be minimized.

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APPENDIX G

TECHNICAL REPORT

SEAWAY GROUP DIFFUSER SITE STUDY

G.1 INTRODUCTION

G.1.1 BACKGROUND

This appendix presents an analysis of the physical, chemical, and biological effects of brine disposal in the Gulf of Mexico. The brine results from the leaching of cavern storage capacity in salt domes, and from the subsequent use of that capacity for crude oil storage, thereby displacing the remaining brine. At Bryan Mound, the initial filling of existing storage caverns with crude oil as part of the early storage phase will displace brine to be sold as chemical feedstock. Displaced brine discharged offshore will result from crude oil refills of Bryan Mound early storage phase and from construction and filling of new leached caverns at Bryan Mound or at an alternative site in the Seaway Group.

Brine would be transported from the Bryan Mound site through a pipeline to a diffuser located 5 nautical miles offshore, where it would be discharged at a rate of up to 45 cubic feet per second (cfs). An alternative diffuser location 10.9 nautical miles offshore is also addressed.

G.1.2 OPERATIONAL BRINE DISPOSAL REQUIREMENTS

Offshore brine disposal for the early storage phase at Bryan Mound was initially addressed in the Draft Supplement to the Bryan Mound Final Environmental Impact Statement (EIS) (FEA, 1977b). In that report two alternatives to sale of the brine were presented: Disposal of brine by deep-well injection and disposal in the Gulf. Due to program considerations, deep-well injection and sale of brine will be utilized for the initial 63 million barrels (MMB) fill of the existing caverns utilized for early storage phase capacity and was so addressed in the Final Supplement (USDOE, 1977).

The Seaway Group is proposed for a Strategic Petroleum Reserve (SPR) program expanded storage capacity of 163 MMB, an increase of 100 MMB over the early storage phase. This capacity would be obtained by constructing new leached caverns, for which each barrel of space created requires the introduction of seven barrels of water and the disposal of a like amount of brine. Technical studies have also determined that new leached space (per cavern) can be created at the rate of about 15,000 barrels per day. Therefore, development and initial fill of 100 MMB of new capacity in the Seaway Group may require the disposal of as much as 800 MMB of brine over a period of 4 to 5 years. This period includes the construction of the caverns by leaching and the initial fill period when crude oil is pumped into the newly formed caverns, displacing the remaining brine to the surface for disposal.

After the initial fill of new caverns, early storage phase capacity (63 MMB) and new capacity (100 MMB) will be operated as a single system. Once the caverns are filled with oil, however, no further brine disposal or water supply will be required unless a foreign oil supply interruption occurs. Then, according to SPR program requirements, the oil will be withdrawn from the caverns by displacement with raw water within approximately a 150-day period. Resumption of normal foreign oil supplies would then initiate a second cycle; that is, the caverns would be refilled with oil, and this oil would displace the saturated brine. The refill period and its associated brine disposal will require from 12 to 24 months. Subsequent crude oil withdrawals and refills of the Seaway Group capacity could each displace an additional 163 MMB of brine to the Gulf.

The range of projected disposal rates, durations, and total brine disposal volumes for the expansion of Bryan Mound or an alternative site by 100 MMB beyond the initial 63 MMB of the early storage phase to bring the total storage to 163 MMB in the Seaway Group is presented in Table G.1-1. The maximum value of discharge (534 thousand barrels per calendar day (MBCD)) in this table represents leaching of the enlarged cavity for a duration of 36 to 44 months. During refill periods, up to 240 MBCD of brine would be discharged into the Gulf from the Bryan Mound diffuser. Over the projected 22-year life of the SPR, a total of five fill/withdrawals could potentially occur, displacing up to 1400 MMB of brine.

TABLE G.1-1 Projected brine disposal data by modes for the Bryan Mound salt dome.

Site	Capacity (MMB)	Mode	Disposal Rate (MBCD)	Duration (months)	Brine Volume (MMB)	Salt Mass (millions of short tons)
Bryan Mound: (early storage facility)	63	Initial Fill	100[a]	20	63	3.4
Seaway Group (100 MMB expansion)	100	Leach	534	50-60	700	37.9
	100	Initial Fill	240[b]	24	100	5.7
	163	Refills	240	24	163	8.7

[a]Use of onshore injection wells and sale of brine to industry only.

[b]Maximum rate, average rate 150 MBCD.

G.1.3 OBJECT OF STUDY

Since large quantities of water will be required for solution mining and large quantities of brine will be produced and must be subsequently disposed of, the impact of this disposal on water quality in the marine environment is one of the most critical issues identified in the programmatic Environmental Impact Statement (FEA DES 76-2).

The main objective of this appendix, therefore, is to augment the Seaway Group Final Environmental Impact Report with an assessment of the environmental effects of the offshore brine disposal operation at the Bryan Mound salt dome. This assessment is based on field studies which were conducted at the brine diffuser site during the months of September 1977 through January 1978. Because of the limited time period involved, these studies are more appropriately termed a preliminary baseline characterization. The baseline studies will be continued until June 1978, after which an operational monitoring study will be initiated at the diffuser site.

Another objective of this study is to provide DOE with information that, along with other studies, can be used to select an environmentally appropriate size, configuration, and location for a brine disposal diffuser system for the Texas offshore region which is within a reasonable distance of the dome storage site under consideration. The information contained in this appendix will also be used as partial documentation to support applications by DOE to the Environmental Protection Agency for brine disposal permits in the Gulf of Mexico.

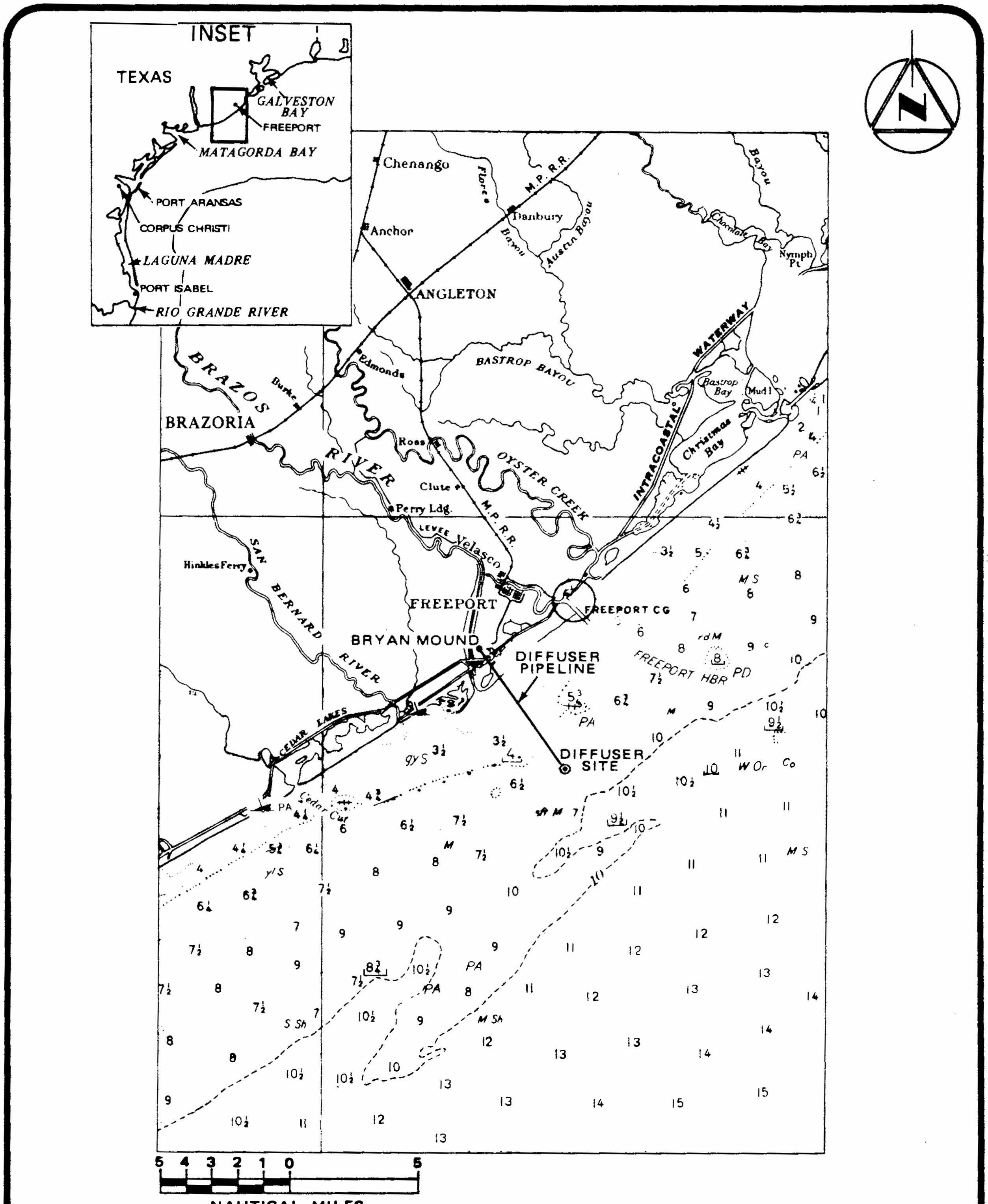
G.1.4 SCOPE OF WORK

In order to assess the environmental impacts of the Seaway Group brine discharge on the Gulf of Mexico, an investigation of the diffuser site was initiated in July 1977. This study was composed of seven project components. A detailed description of the methods and materials used in this study is presented in Section G.1.7. With the exception of the bioassay tests, the components consist of two phases each. Phase I, the preoperational phase, began on July 1, 1977, and will continue until the disposal of brine from the diffuser is initiated. It was initially estimated that brine discharge would begin on March 1, 1978; this estimate has been revised, and as a result Phase I will be continued through October 1978. Phase II, the monitoring study, will provide a comparison with preoperational Phase I data to help assess the impact of the brine discharge on the Gulf of Mexico environment.

This appendix is a report of the Phase I investigation to date. The data presented represents five monthly cruises conducted between September 1977 and January 1978. The proposed Seaway Group diffuser site is located 5 nautical miles offshore from Bryan Mound; this area was sampled from September through December 1977. An alternate site, located 10.9 nautical miles from shore, was sampled in December 1977 and January 1978.

G.1.5 GEOGRAPHIC AREA OF STUDY

The proposed diffuser site for the Seaway Group is located 5 nautical miles offshore of the Freeport, Texas, coast in the Gulf of Mexico, at latitude 28°49.4'N and longitude 95°18.1'W (Figure G.1-1). The area of primary interest is bounded on its northern edge by the Texas coastline and extends south into the Gulf almost 10 nautical miles. The study area extends approximately 7 nautical miles to the east and approximately 7 nautical miles to the west of Bryan Beach. Major features of the coastline include the Brazos and San Bernard Rivers to the west and Freeport Harbor to the east. The total offshore area under discussion covers almost 140 square nautical miles. The water depth in the study area ranges from less than 5 feet to almost 70 feet.



SOURCE: Texas A & M, 1978.

FIGURE G.1-1. Regional map of the Bryan Mound Strategic Petroleum Reserve site (soundings in fathoms.)

G.1.6 BRINE DIFFUSER DESIGN CRITERIA AND PLUME CHARACTERISTICS

The design criteria for the offshore brine diffuser proposed by DOE (U.S. Dept. of Commerce, 1977) were based upon consideration of various environmental conditions in the area, together with selected operational requirements. The proposed diffuser characteristics are as follows: length - 2000 feet; orientation - normal to the coast; number of ports - 34; length between ports - 60 feet; port diameter - 3 inches; orientation of port riser - 90° to bottom; and exit velocity - 25 feet/sec.

Brine plumes would occur from two activities, fill and refill of existing caverns and solution mining of new caverns. For each case, the brine at the ports is expected to have a salinity of about 260 ± 5 parts per thousand (ppt) and a temperature near ambient.

Based on a brine plume model (U.S. Dept. of Commerce, 1977), developed at the Massachusetts Institute of Technology (MIT), representative conditions would be approximated by a scenario assuming tidal currents plus a 4-day winddriven current cycle. For the 4-day winddriven cycle, upcoast currents of 0.5 foot per second (ft/s) would be followed by a downcoast current of 1.0 ft/s for 1 day each, then by 2 days of slack water. Under this scenario, a bottom area of approximately 2100 acres would experience a 0.5 ppt or greater salinity increase above ambient conditions, of which about 800 acres would be impacted by a salinity increase of 1 ppt or greater. A small area in the immediate vicinity of the diffuser would experience excess salinity of 3.5 ppt or greater. Under a worst case scenario assuming slack water conditions for eight days, a bottom area of approximately 25 acres surrounding the exposed diffuser would experience a 5 ppt or higher salinity increase above ambient conditions after a 16-day slack period. About 2800 acres would experience a 1 ppt or higher salinity increase.

G.1.7 METHODS AND MATERIALS

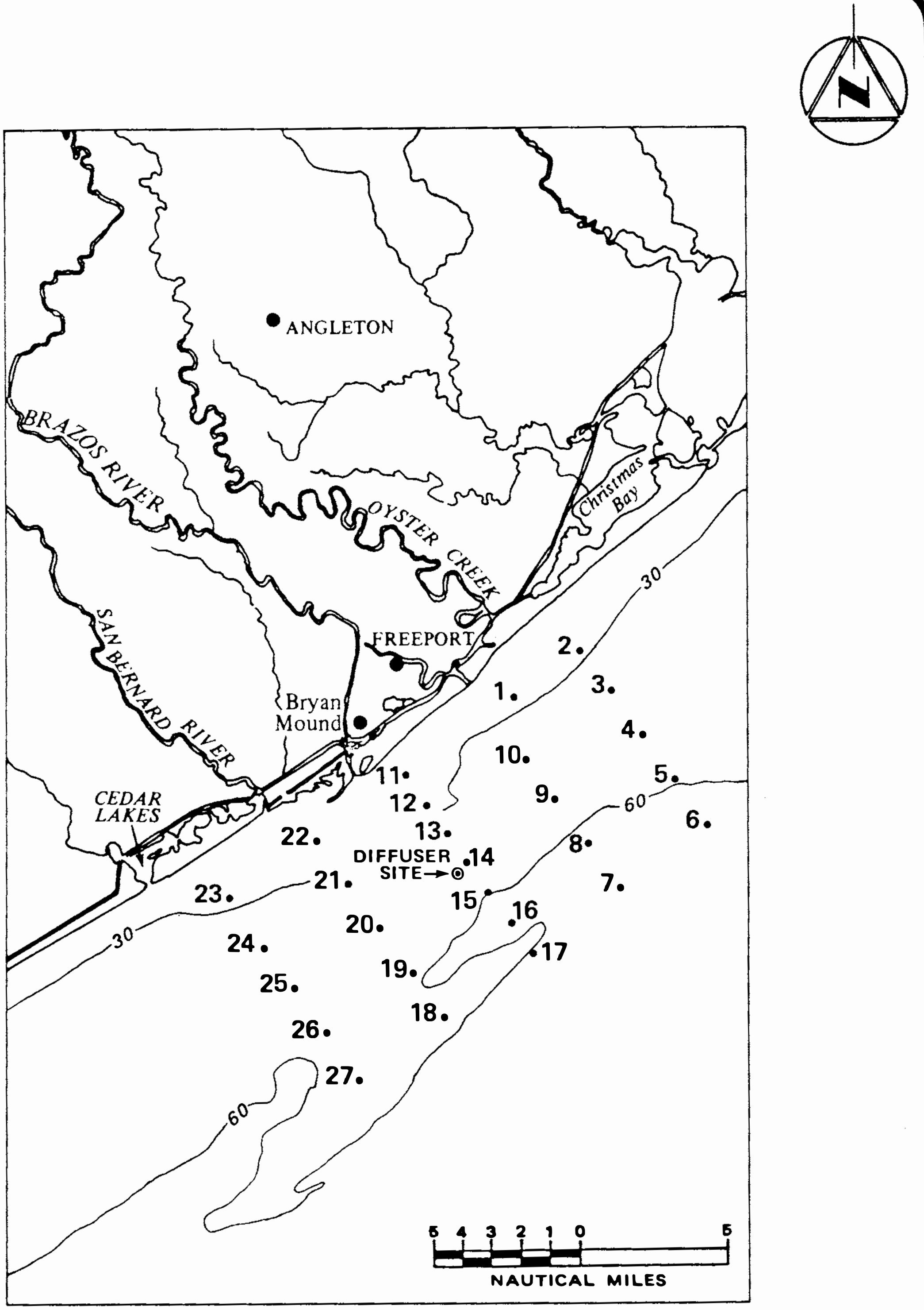
To assess the environmental impact of the proposed Bryan Mound brine discharge, a study was undertaken consisting of six component parts: (1) bioassay tests, (2) physical oceanography, (3) water and sediment quality, (4) benthic community, (5) nekton community, and (6) prediction of the discharge plume extent and distribution. Oceanographic cruises have been conducted monthly since September 1977, to study components (2) through (6). The data for this report extends through January 1978, although the effort is ongoing and monthly cruises will continue at least through September 1978. The following discussion presents the methods, materials, and approach taken.

G.1.7.1 Bioassay Tests

Bioassay tolerance studies were undertaken in the laboratory to determine the acute toxicity of increased salinity on selected life stages of fauna and flora typical of the biological community expected at the proposed Bryan Mound diffuser site. These species were selected because they are representative of key parts of the food web at the site. Laboratory observations were made on the relationship between brine concentration and species mortality and to assess any sublethal effects indicating physiological stress. The test species incorporated into these bioassays included: spotted seatrout, Cynoscion nebulosus (eggs and larvae); white shrimp, Penaeus setiferus (eggs and postlarvae); phytoplankton, Skeletonema costatum, Tetraselmis chuii and Hymenomonas carterae, and polychaetes Neanthes arenaceodentata and Nereis limbata. Each of these test organisms were exposed to brine dilutions ranging from 0.0 percent to 40.0 percent on a volume to volume basis for brine diluted with natural seawater obtained from the site. Details concerning both methodology and results of these bioassays will be presented in a forthcoming report (U.S. Department of Commerce, 1978a).

G.1.7.2 Physical oceanographic Measurements

Over-the-side current measurements were made in the proposed Bryan Mound diffuser study area (Figure G.1-2) in order to assess cross-shelf currents at the surface and near the bottom. The field data were obtained



SOURCE: Texas A & M, 1978.

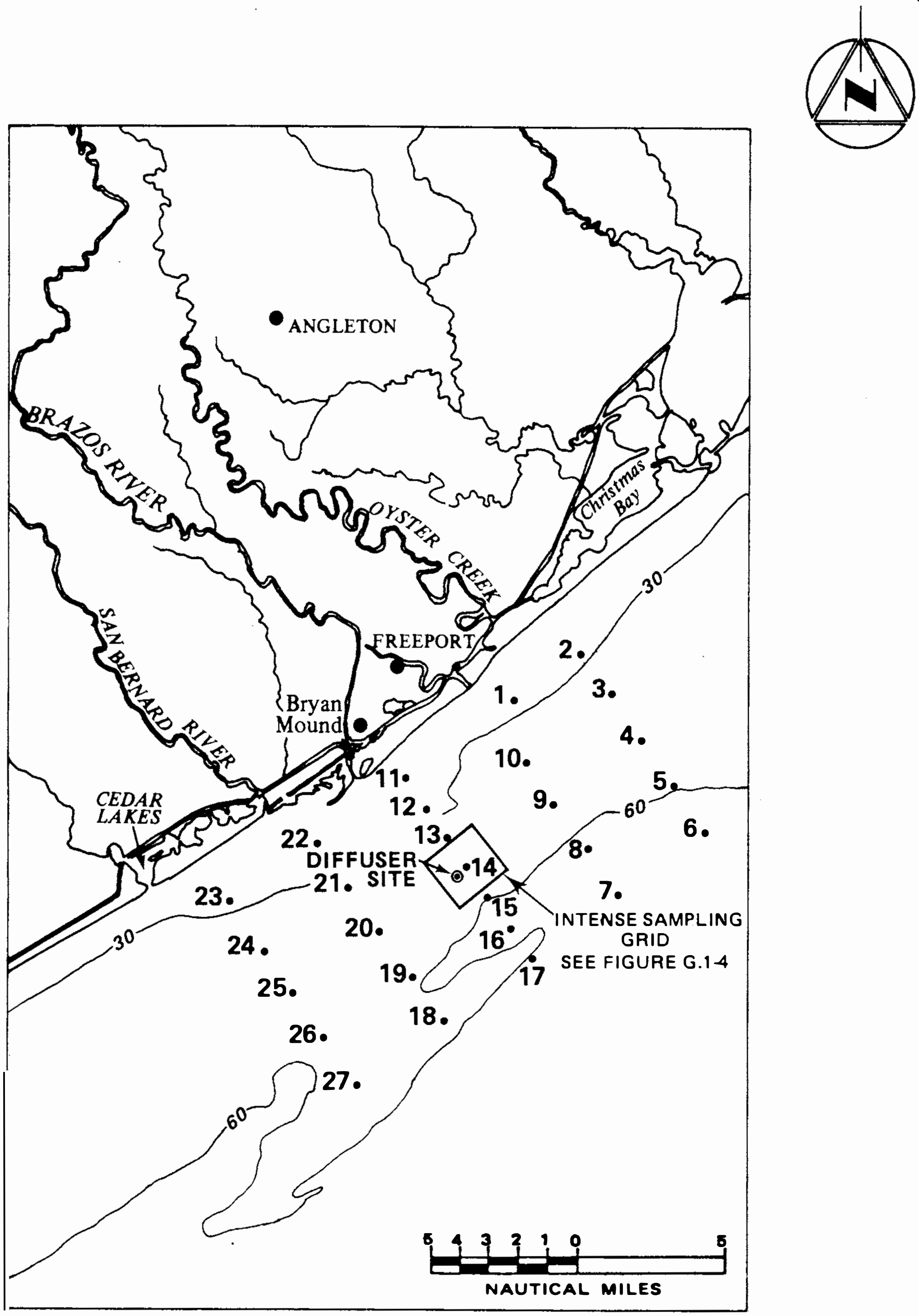
FIGURE G.1-2. Station locations for over-the-side current, temperature, and salinity measurements (depth contours in feet).

on 15, 16, and 17 September, 20 and 21 October, 17 and 18 November and 18 and 19 December, 1977. Only current speeds were recorded during September, October, and November, whereas both current speed and direction were measured during the December observations. Surface currents were recorded at depths of from 7 to 10 feet below the water surface, while bottom currents were measured about 7 feet above the bottom sediments. On December 15, a single ENDECO-type 105 current meter was deployed at the brine diffuser site to continuously monitor in situ bottom current velocities. This meter was approximately 7 feet above the bottom and was tethered to a wire rope suspended by a subsurface float; the current meter array was marked by a surface buoy. A similar deployment mode was used for two current meters located about 10.9 nautical miles offshore in about 68 feet of water. These meters were set in place on December 22, 1977; one meter was 7 feet below the surface, the other meter was several feet above the bottom. These offshore meters were recovered on January 5, 1978. The offshore current data were utilized to refine the brine plume patterns predicted by the Transient Plume Model developed at the Massachusetts Institute of Technology (U.S. Department of Commerce, 1978a).

Temperature and salinity measurements were also collected at the proposed diffuser site (Figure G.1-2) during each month of the sampling program. Surface, mid-depth, and bottom salinity values were taken with a Beckman model RS5 salinometer. Continuous temperature data were collected with a thermograph from December 22, 1977, to January 5, 1978, about 10.9 nautical miles offshore in 68 feet of water. One thermograph was tethered about 7 feet below the surface while the second was placed approximately 6 feet above the bottom. These temperature and salinity measurements were used to identify the density patterns of the study area. Densities were calculated using the equations of LaFond (1951).

G.1.7.3 Water and Sediment Quality

Fifty-two sediment cores were taken with a Phleger gravity corer in the vicinity of the proposed diffuser site (Figures G.1-3 and G.1-4). Four duplicate samples were taken at Stations L, N, 9, and 20 and analyzed



SOURCE: Texas A & M, 1978.

FIGURE G.1-3. Sediment core stations (depth contours in feet).

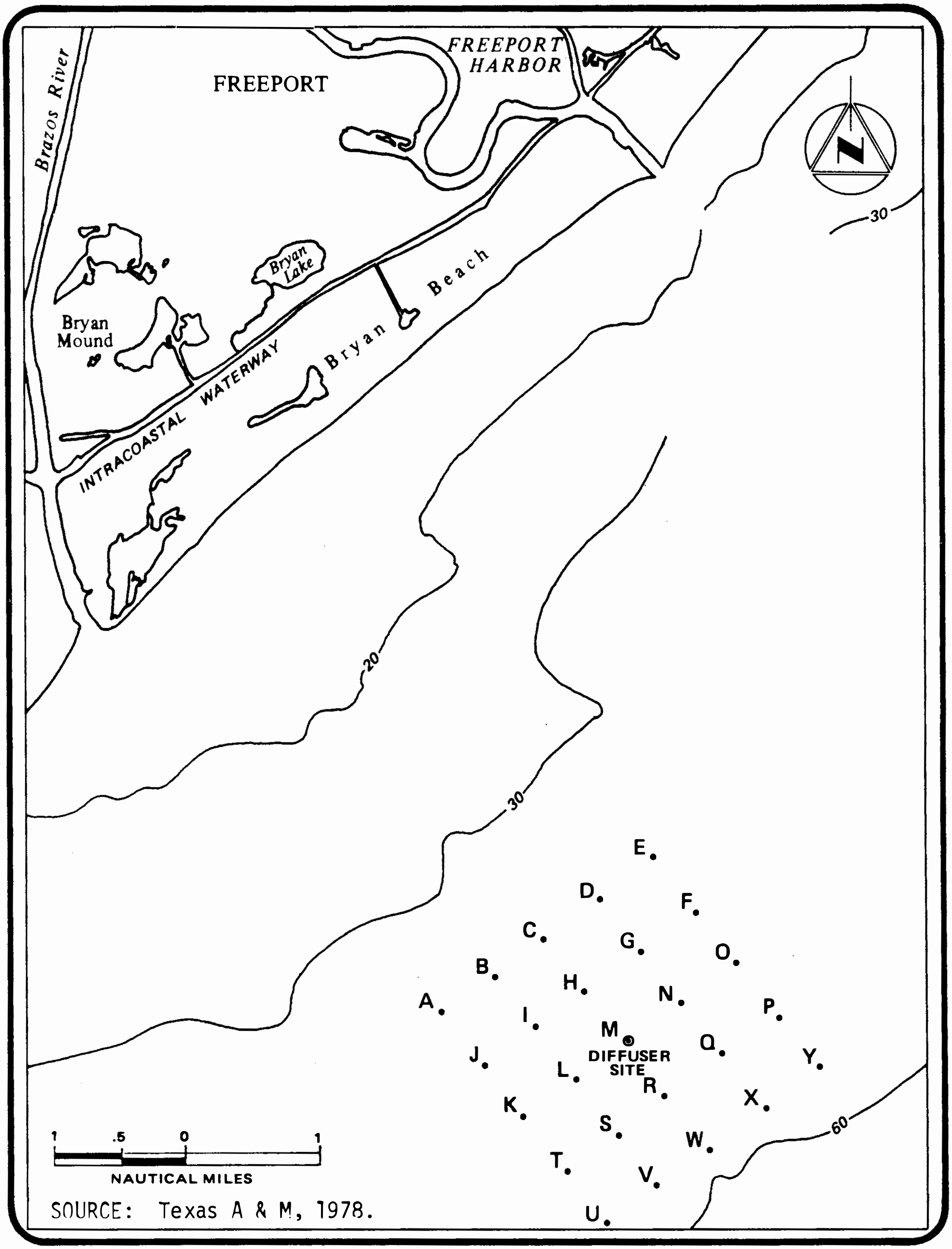


FIGURE G.1-4. Sediment core stations in the immediate vicinity of the proposed Bryan Mound brine diffuser (depth contours in feet).

in the laboratory for heavy metal concentrations and general sediment characteristics, as described in Chemistry Laboratory Manual for Bottom Sediments (EPA, 1969) and Standard Methods for the Examination of Water and Wastewater, 14th Edition (U.S. Department of Commerce, 1976). The remaining sediment samples were stored for later analysis and comparison in the event potentially harmful water quality characteristics should be found in the discharge brine. The sediment parameters measured for the duplicate samples included cadmium, copper, iron, manganese, lead, zinc, chromium, nickel, mercury, calcium, magnesium, pH, percent solids, percent oil and grease, and percent organic carbons.

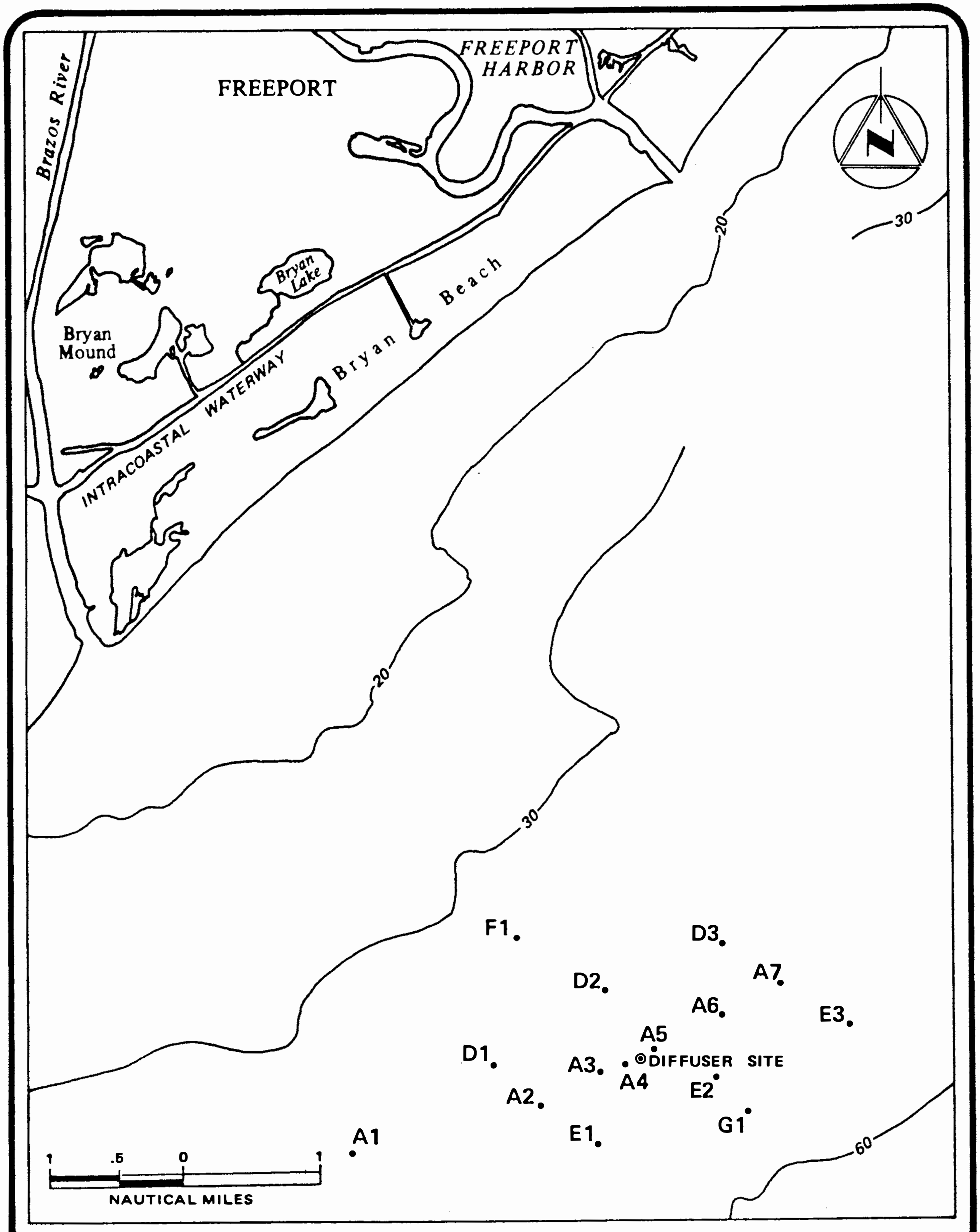
G.1.7.4 Biological Oceanography Sampling

G.1.7.4.1 Benthos

Benthic samples were obtained at stations (Figure G.1-5) that were sampled on a monthly basis from September through December, 1977. The January 1978 sampling was terminated after only four stations had been occupied, due to severe weather in the Gulf. Benthic sampling was conducted utilizing three Ekman grabs (each with a sample area of 232 cm^2). The grabs were dropped overboard, and subsequently triggered and secured by scuba divers. Visual examination of the substrate was conducted by the divers whenever water transparency conditions allowed it. After the grabs were brought aboard, temperature of the sediment was measured and the samples were washed through a 0.5 mm mesh sieve. The portion of the sample remaining on the screen was preserved in a 5 percent seawater-formalin solution.

A single water sample was collected by the divers while on the bottom at each of these stations. The temperature and salinity of these bottom water samples were recorded aboard the research vessel. Surface water temperature and salinity measurements were also taken at each station.

In the laboratory the benthic samples were washed in freshwater, and preserved in 70 percent ethanol stained with rose Bengal. The stained organisms were identified to the lowest possible taxon, counted, and classified as either a young or adult stage. Species diversity, in



SOURCE: Texas A & M, 1978.

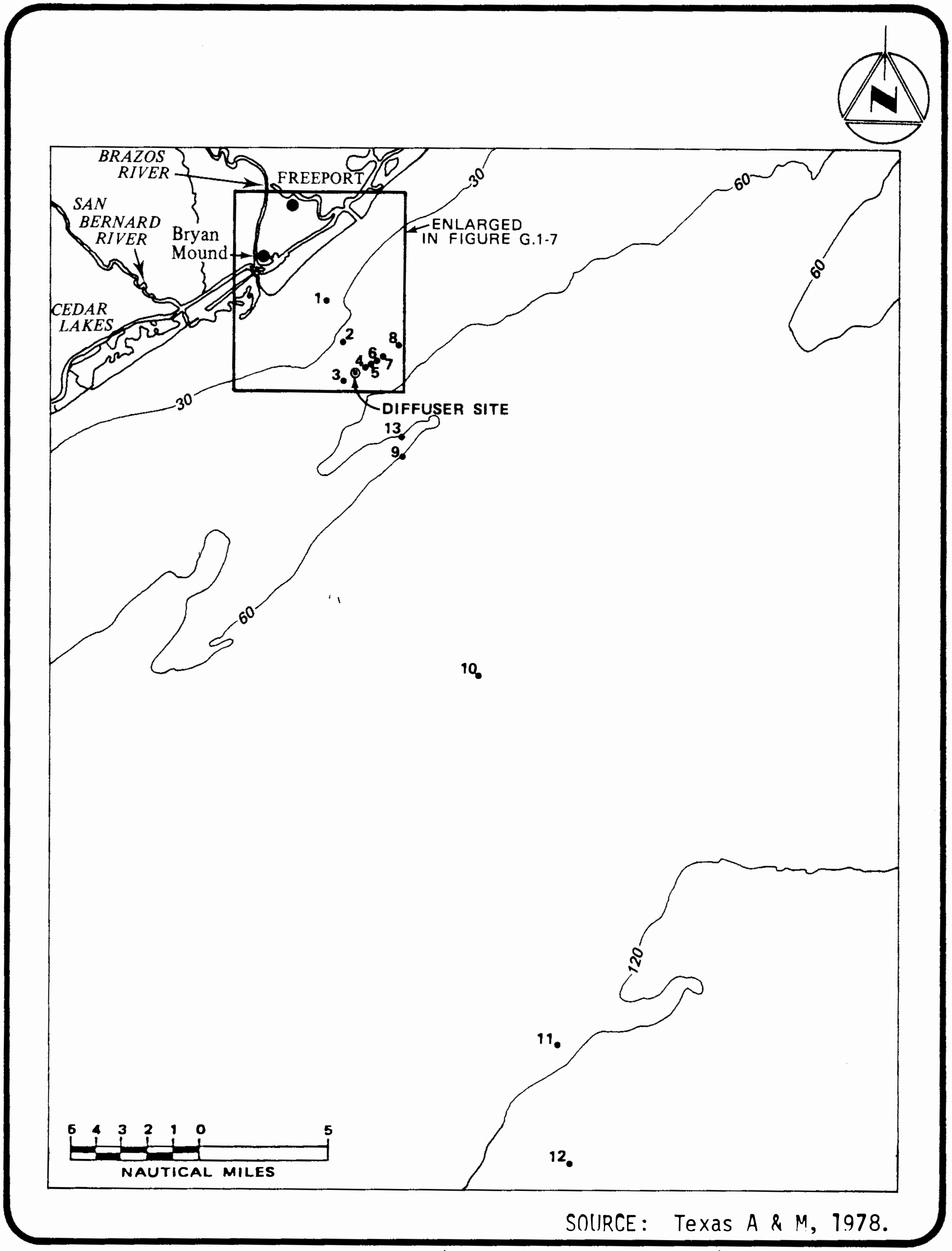
FIGURE G.1-5. Benthic survey stations (depth contours in feet).

terms of the total number of species at all stations, and the seasonal population, in terms of average number of individuals per station, was determined for the samples. Cluster analysis was determined (for dominant organisms) in the samples to evaluate the major benthic invertebrate assemblages.

G.1.7.4.2 Nekton

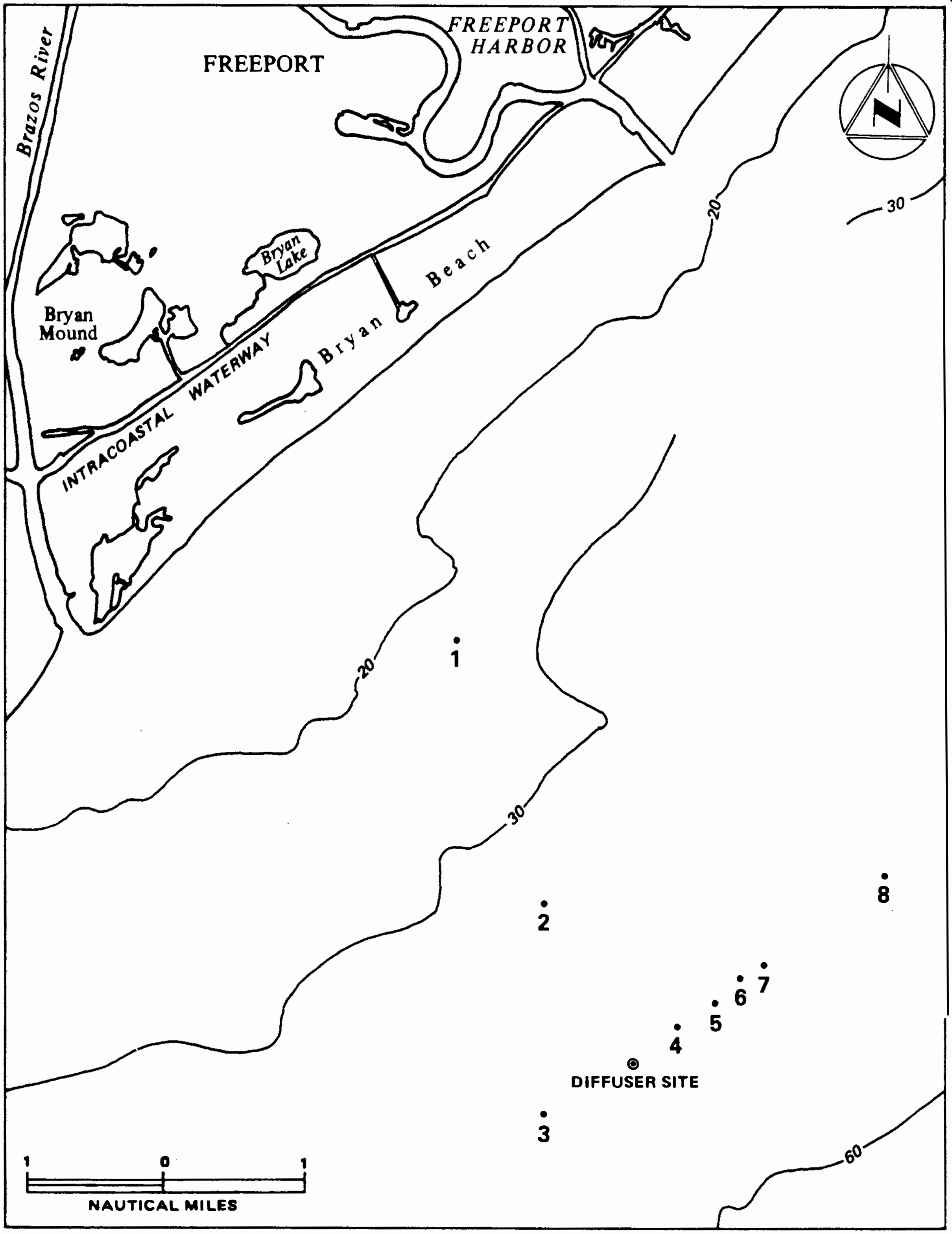
Nekton were sampled (Figures G.1-6 and G.1-7) in October, November, and December with four 34-foot, 2-seam modified-balloon trawls equipped with tickler chains and 1-3/4-inch stretch mesh netting in the cod end. Nets were towed in a circular pattern around the station locations at about 2-3/4 knots. Two nets were fished on each side of the boat (total of four nets), for a period of 10 minutes (bottom time); but only the catches collected on the port side were used to compile the baseline data. The catches from the two nets on the port side were pooled to one common statistical catch base. Catches from the starboard side were retained temporarily as a backup. Upon verification of the catch from the port side, the starboard catch was disposed of at sea. One trawl was made at Stations 1, 2, 9, 10, 11, 12, and 13. At stations 3, 4, 5, 6, 7, and 8, two tows were made.

The nekton catch was processed in the following manner: the target species of shrimp and fish (Section G.2.4.4) were segregated from each catch for quantitative and qualitative analysis. A representative number of the other organisms collected in each catch were sorted out and these organisms preserved in a 10 percent borax-buffered formalin solution for laboratory analysis. With the exception of seatrout (*Cynoscion* spp.), the species of interest obtained from the first tow at each station were identified, counted, and measured onboard. Seatrout were returned to the laboratory for processing. Catch collected from the second tow were treated similarly, however, length was not determined. Species of interest from both trawls (except for shrimp) were also returned to the laboratory. As no additional taxonomic identification of shrimp was required, they were disposed of at sea.



SOURCE: Texas A & M, 1978.

FIGURE G.1-6. Trawl survey stations (depth contours in feet).



SOURCE: Texas A & M, 1978.

FIGURE G.1-7. Inshore trawl survey stations (depth contours in feet).

G.2 PHYSIOGRAPHY OF PROPOSED DIFFUSER SITE

G.2.1 CLIMATE AND METEOROLOGY

G.2.1.1 General Climatology

The subtropical climate of the diffuser site is influenced by the relatively warm waters of the Gulf of Mexico and by the large continental landmass to the north and west of the study area. Rainfall and humidity are typically high throughout the year.

Spring and summer in the proposed diffuser site area are dominated by the Bermuda high, an extensive semipermanent high pressure cell centered in the Atlantic Ocean, which creates a southeasterly wind flow. Generally, there is little daily variation in weather: the average diurnal temperature range is small; humidities are high; and shower activity, mostly associated with thunderstorms, occurs almost daily. Coastal circulation is affected by sea breezes during the afternoon and evening hours.

In August, easterly winds and tropical cyclones (a generic name used to describe storms of tropical origin) increase in the Gulf of Mexico, reaching a peak in September. Most of these storms come into the Gulf through the Straits of Florida or the Yucatan Channel. More than one-half of the tropical cyclones become hurricanes, that is, storms with sustained wind speeds exceeding 74 miles per hour (mph) (64 knots).

Winters are generally short and mild, with persistent low stratus ceilings and rain; tropical airmasses alternate with periods of colder continental air associated with cold fronts. Although the study area is south of the normal winter storm track, and subfreezing air temperatures and snowfall are rare, occasional intrusions of polar air can bring about sudden and sometimes large temperature drops. The colder airmasses also tend to lower sea-surface temperatures and are important in the formation of advection-radiation fogs, which are common in the coastal area from November through March.

G.2.1.2 Meteorology

Over 100 years of meteorological data have been recorded at Galveston, Texas (U.S. Department of Commerce, 1971). These data are regionally applicable to the proposed diffuser site and are discussed in the following subsections.

G.2.1.2.1 Air Temperature

Due to the moderating effects of the prevailing southeasterly winds, air temperatures in the Gulf of Mexico do not usually exhibit extreme variation. These winds generally produce warm humid summers and mild winters. Summer temperatures around the site average in the mid-80's; winter temperatures are in the 50's, although these temperatures depend on the frequency and intensity of penetration of cold polar airmasses or "northers", which may occur in the region 15 to 20 times between the months of November and March.

Table G.2-1 presents long-term, monthly average and extreme temperatures for Galveston, Texas. The annual mean temperature at Galveston is 69.9^{O}F; average annual diurnal variation is 10^{O}F. The highest mean daily maximum, 87.5^{O}F, occurs in August, and the lowest mean daily minimum, 49.3^{O}F, occurs in January. Throughout the period of record (101 years), the highest and lowest recorded temperatures at Galveston were 101^{O}F (July, 1932) and 8^{O}F (February, 1899), respectively.

G.2.1.2.2 Precipitation

Table G.2-2 summarizes long-term mean monthly precipitation amounts measured at Galveston, Texas. Although these data show that total rainfall is evenly distributed throughout the year, the type and frequency of occurrence show a large seasonal variation. The largest amount of rainfall usually occurs in the summer and is typically associated with either local thunderstorm activity or an occasional tropical storm. In winter, the frequency of precipitation increases with increased frontal activity; low stratus clouds produce slow, steady rainfall. This precipitation may occur at any time of day and continue intermittently for several days.

TABLE G.2-1 Long-term, monthly average and extreme air temperatures for Galveston, Texas.

Month	Temperature: Normal[a] Average Daily Maximum (°F)	Average Daily Minimum (°F)	Average Monthly (°F)	Extremes[b] Record Highest	Year	Record Lowest	Year
J	60.5	49.3	54.9	77	1969	11	1886
F	62.4	51.2	56.8	83	1932	8	1899
M	66.6	56.2	61.4	85	1879	27	1943
A	73.0	64.0	68.5	92	1953	38	1938
M	80.1	71.5	75.8	93	1911	52	1954
J	85.6	77.7	81.7	99	1918	57	1903
J	87.3	78.9	83.1	101	1932	66	1910
A	87.5	79.0	83.3	100	1924	67	1966
S	84.6	75.5	80.1	96	1927	52	1942
O	78.5	68.4	73.5	94	1952	41	1925
N	68.6	57.4	63.0	85	1886	26	1911
D	62.7	51.6	57.2	80	1918	18	1880
YR	74.8	65.1	69.9	101	JUL. 1932	8	FEB. 1899

Source: U.S. Department of Commerce, 1971.

[a]1931 through 1960

[b]Period of record: 101 years (1870 - 1971).

TABLE G.2-2 Long-term, mean monthly precipitation amounts measured at Galveston, Texas.

	Precipitation				
Month	Normal Total[a] (inches)	Maximum Monthly[b] (inches)	Year	Minimum Monthly (inches)	Year
J	3.46	10.39	1899	0.02	1909
F	2.88	8.29	1881	0.09	1954
M	2.86	9.39	1926	0.06	1953
A	2.59	11.04	1904	0.01	1887
M	2.79	10.50	1929	T[c]	1889
J	2.65	15.49	1919	T[c]	1907
J	4.79	18.74	1900	T[c]	1962
A	4.39	19.08	1915	0.00	1902
S	5.09	26.01	1885	0.04	1924
O	2.86	17.78	1871	T[c]	1952
N	3.56	16.18	1940	0.03	1903
D	3.89	10.28	1887	0.23	1889
YR	41.81	26.01	SEP. 1885	0.00	AUG. 1902

Source: U.S. Department of Commerce, 1971.

[a]1931 through 1960

[b]Period of record: 101 years (1870 - 1971).

[c]T = Trace, an amount too small to measure.

The records show that Galveston has a mean annual rainfall of 42 inches. The highest recorded monthly precipitation was 26 inches (September, 1885); the lowest was no rainfall at all (August 1902).

In the study area, any form of frozen precipitation is rare, and over the 101-year period of record the mean annual snowfall was 0.2 inches. In February 1895, however, an unusual storm dumped 15.4 inches of snow on the Galveston area.

G.2.1.2.3 Wind Speed and Direction

Surface Winds

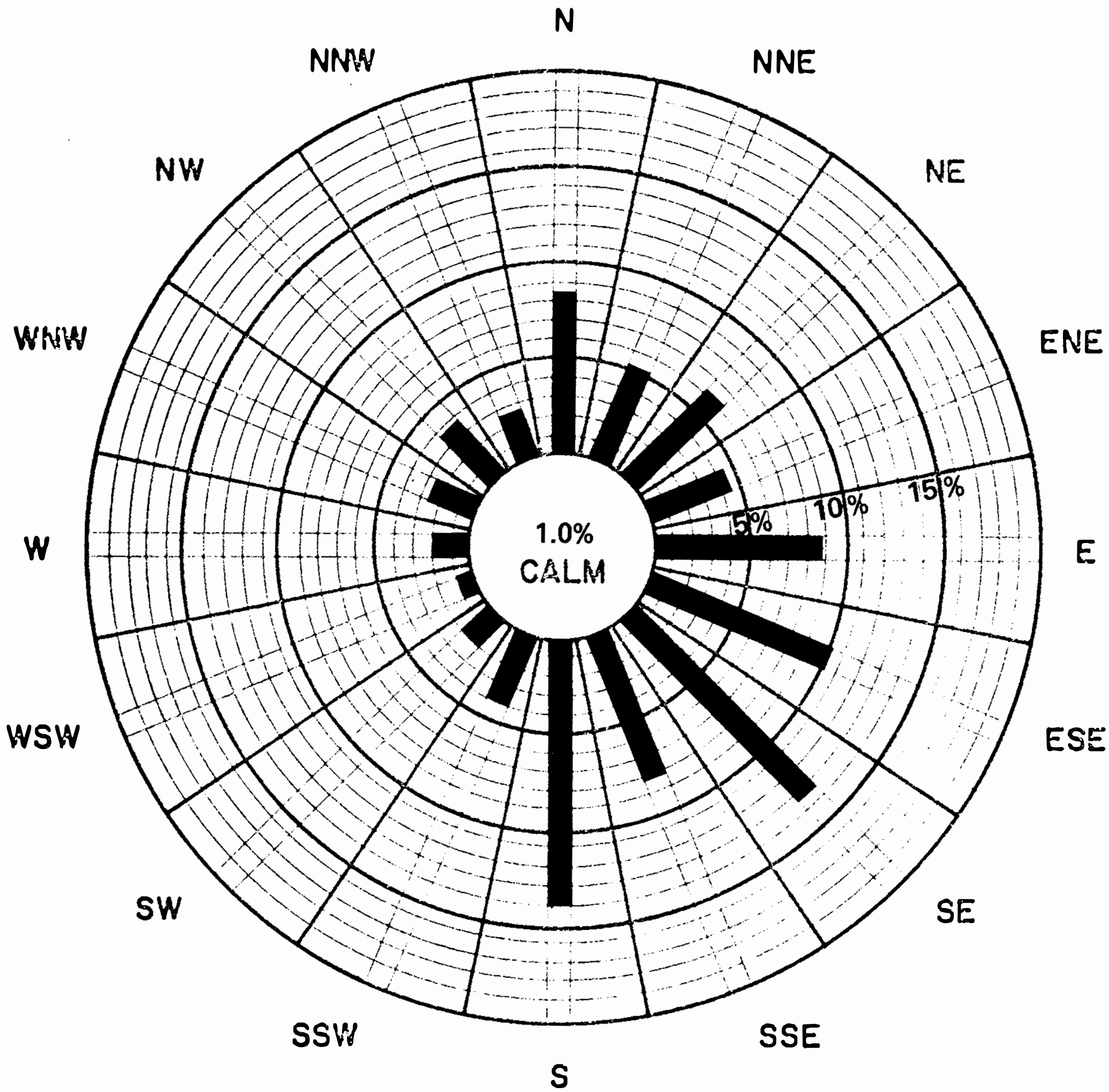
Surface winds along the Gulf Coast are dominated throughout most of the year by the Bermuda high; thus the prevailing wind direction from January through June is southeasterly. The wind shifts to a more southerly direction during July and August and then easterly until late November. During December the winds persist from the north.

The mean annual wind speed was 12.7 mph at a monitoring site approximately 28 miles offshore southeast of Freeport (11 knots) (Table G.2-3). The winds have their highest average speeds in December. Between March and September the winds have lower average speeds. Figure G.2-1 presents an annual wind percent frequency distribution for the period 1958-1962.

Extreme Winds

Table G.2-4a summarizes the "fastest-mile" recorded wind speeds for a 100-year period. These extreme winds are sustained (1-minute average) winds, normalized to 30 feet above the ground and include all meteorological phenomena (thunderstorms, extratropical storms, tropical cyclones including hurricanes) except tornadoes.

Estimated extreme winds for return periods (an estimate of frequency of occurrence) from 2 to 500 years are given in Table G.2-4b. The maximum recorded wind speed of 100 mph (120 mph estimated maximum) agrees well with the estimated 100-year return period wind speed of 121 mph (105 knots).



SOURCE: SEADOCK, 1975.

FIGURE G.2-1. Annual wind frequency distribution for Galveston, Texas, 1958-1962.

TABLE G.2-3 Mean monthly wind speed and direction for Galveston - Freeport offshore site (28° 30'N 95° 01'W)[a].

Month	Speed (knots)	Direction
J	12.2	SE
F	12.0	SE
M	11.8	SE
A	11.7	SE
M	10.8	SE
J	9.8	SE
J	8.7	S
A	8.5	S
S	11.0	E
O	11.9	E
N	12.8	E
D	12.9	N
YR	11.1	SE

SOURCE: U.S. Department of Commerce, 1972.

[a] Period of record: 1952-1971.

TABLE G.2-4a Monthly variation of extreme "fastest-mile" winds for Galveston, Texas (1872-1971).

Month	Speed (mph)	Direction[a]	Year
J	53	S	1915
F	60	N	1927
M	50	SE	1952
A	57	NW	1961
M	66	W	1959
J	62	SE	1921
J	68	NW	1943
A	91	E	1915
S	100[b]	NE	1900
O	66	SE	1949
N	54	N	1950
D	50	NW	1954
YR	100	NE	SEP. 1900

[a]Recorded for only 8 compass points.

[b]Highest speed recorded before anemometer blew away. Maximum velocity estimated to be 120 mph.

SOURCE: SEADOCK, 1975.

TABLE G.2-4b Estimated annual "fastest-mile" return period for the Galveston area.

Return Period (yrs)	Wind Speed (mph)
2	52
5	63
10	72
20	81
50	95
100	108
200	122
500	143

SOURCE: SEADOCK, 1975.

Slack Wind and Persistence

Winds in the Texas coastal region have their greatest variability in speed and direction in December. The most persistent winds occur between March and September; these winds are from the southeast and are associated with the presence of the Bermuda high. Figure G.2-2 is a climatological record of wind persistence produced from a 15-year (1948-1963) record of hourly wind data observed at Galveston, Texas.

The frequency of occurrence of slack wind periods (wind speeds $\leq$ 5 knots) lasting for more than 12 hours is low. More than half of the slack wind observations had a duration of less than five hours indicating that slack periods can often occur but in most cases these slack periods prevail for only a short time.

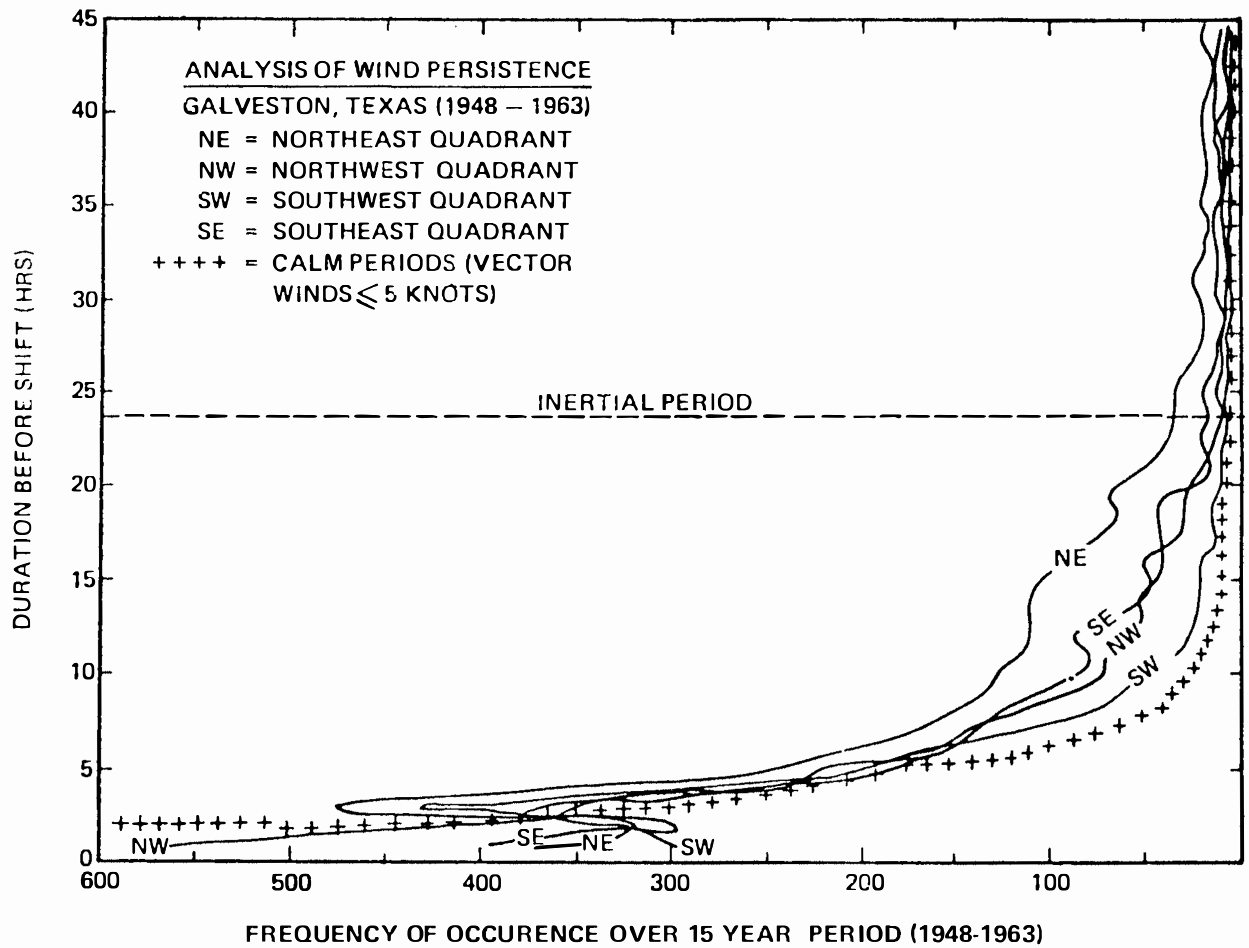
Table G.2-6 presents a monthly percent frequency distribution of wind speed categories based on marine observations in the Galveston-Freeport area between 1952-1971. Winds with speeds of 3 knots or less occur most frequently between the months of May and September.

The table below shows monthly frequency categories and wind speed for the Bryan Mound diffuser area:

MONTH	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	AVG
Frequency of Occurrence	Windspeed (knots)												
01% $\leq$	0	0	0	0	0	0	0	0	0	0	0	0	0
05% $\leq$	1	1	1	2	1	1	1	1	1	1	2	2	1
25% $\leq$	6	6	6	6	5	5	4	4	5	6	6	6	5
50% $\leq$	12	10	10	11	9	8	7	7	9	10	11	11	9
75% $\leq$	17	17	16	16	15	14	11	11	15	16	17	18	16
95% $\leq$	28	27	25	23	21	20	19	19	22	25	28	29	24
99% $\leq$	33	30	30	30	28	25	21	22	35	30	30	32	29

Of the total observations, only 25 percent of the record were of wind speeds 5 knots or less with the greatest frequency of their occurrence between May and September.

A summary analysis of 1010 observations for wind distribution by speed and sector (Table G.2-5) taken between October 18 and December 3,



SOURCE: U.S. Department of Commerce, 1977f.

FIGURE G.2-2. Climatological record of wind persistence for Galveston, Texas.

TABLE G.2-5 Wind distribution by speed and sector observed between October 18 and December 3, 1977 at Latitude 28.75°; Longitude 95.30°.

Wind Distribution by Speed Categories:
(wind speed in knots)

	0 - 3	4 - 10	11 - 21	22 - 33	34+
Number of Observations	146	170	417	275	2
Percent	14.4	16.8	41.3	27.2	0.2

Wind Distribution by Sector:

	N	NE	E	SE	S	SW	W	NW
Number of Observations	115	57	117	277	236	61	49	98
Percent	11.4	5.6	11.6	27.4	23.4	6.0	4.8	9.7

SOURCE: Texas A & M, 1978.

TABLE G.2-6 Monthly percent frequency of observed wind speeds, Galveston - Freeport area, 1952-1971.

Month	Wind Speed (knots) 0 - 3	4 - 10
January	9.2	39.5
February	9.8	40.5
March	8.1	43.6
April	7.7	41.9
May	10.6	44.9
June	11.7	51.6
July	13.6	58.8
August	14.8	59.6
September	10.6	46.6
October	7.9	42.4
November	6.6	38.6
December	7.3	38.5

SOURCE: U.S. Department of Commerce, 1972.

1977 at Latitude 28.75 and Longitude 95.30 shows that during this period slack winds of less than 3 knots occurred 14 percent of the time while 41 percent of the winds were in the range of 11 to 12 knots. During this same period more than 50 percent of the winds were from the south to southeast. The longest period when wind speeds of less than 3 knots were recorded was 11 hours.

G.2.1.2.4 Hurricanes

Hurricanes of tropical cyclones are the largest and most destructive storms affecting the Bryan Mound diffuser site and adjacent coastal areas. Hurricanes usually enter the diffuser area from the south or southeast; these storms have their origins over the warm tropical waters of the central Atlantic Ocean, the Caribbean Sea or the southeastern Gulf of Mexico. Hurricane season extends from June through October, with the greatest frequency of occurrence during July and August.

Tropical cyclone and hurricane frequencies recorded in the Galveston area between 1899-1971 (U.S Department of Commerce, 1977f) are as follows:

	Total Number	Average Number of Years Between Occurrences
Tropical Cyclones (Winds $\geq$ 34 knots)	35	2.1
Hurricanes (Winds $\geq$ 64 knots)	23	3.2

Damage from hurricanes results both from high winds and storm surges produced during the storm. Storm surges in the Gulf of Mexcio can cause water to pile up on the northeast-southwest oriented coast as much as 10 to 25 feet above normal. These flood tides can carry large loads of sediment from deep offshore waters and spread a layer of these deposits over the beaches and marsh areas. In 1900, more than 6000 people were drowned on Galveston Island during a storm surge.

In recent Gulf history, Camille (August 1969) was the most severe hurricane. During this storm the highest winds were estimated at 201.5 mph and barometric pressure in the eye of the storm was recorded at 26.61 inches of mercury.

G.2.2 PHYSICAL OCEANOGRAPHY

G.2.2.1 Nearshore Features

G.2.2.1.1 Regional Description

Except for a string of isolated coral heads off the mouth of the Brazos River in 36 to 48 feet of water (Mattison, 1948), 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 statute miles just north of the Rio Grande River and 86 miles off the Brazos River to a maximum of 130 statute miles at the Texas-Louisiana border. The inner shelf has a very gentle gradient with the "shelf break" (line of the greatest change in gradient) occurring at approximately 65 fathoms (Curray, 1960).

G.2.2.1.2 Freeport Nearshore Area

Bathymetry at the proposed diffuser area shows that the region consists of a relatively smooth bottom and that bottom contours off Bryan Beach generally parallel the shore. Distances between bottom contours increase offshore; typical distances from shore for the 30 foot, 60 foot and 90 foot isobaths are 2.5, 6.5 and 19.5 miles, respectively. Bottom depths within a 5 mile radius of the proposed diffuser site range from about 16 feet nearshore to 65 feet offshore. The proposed 2000 foot diffuser is located in about 50 feet of water.

Uncertainties exist regarding the apparent erosional bottom environment in the area; this is reflected in the recommended height of the brine diffuser riser ports above the sea bottom (0 to 5 foot range). Bathymetric charts provided by NOAA are a composite of a survey from the 1930's superimposed by a 1966 survey. The two surveys show discrepancies of up to ten feet within the 40-foot contour. Offshore depths increased over this period, while Bryan Beach accreted through deposition several hundred feet seaward. On the bathymetric charts the earlier survey shows soundings considerably onshore of the present shoreline; the intersection of the brine line with the shoreline appears to be half a mile at sea. These discrepancies are most likely the result of a stepwise function related to storms. Therefore, additional surveys along the proposed brine line route would be required to confirm the bathymetry, to assess changes over the past decade, and to assimilate this information in making allowances for deposition or storm scour in selecting the port riser height.

The most prominent nearshore features of the area off Bryan Mound include shallow bays, barrier islands, sand dunes, and relatively flat marshland which is dissected by man-made flood control structures. Texas bays are generally shallow and have relatively smooth shorelines. The barrier islands range in width from several hundred feet to three miles. These islands are separated from the mainland by shallow coastal lagoons.

The Brazos and San Bernard Rivers comprise the main source of sediment and freshwater inflow to the diffuser area (See Figure G.1-1). Sediment discharge from the rivers contribute most of the coarse sediment necessary to maintain the coastal beaches and barrier islands. Unlike most other Gulf Coast rivers that flow into estuaries, the Brazos and San Bernard Rivers have built up deltaic plains directly into the Gulf of Mexico. Peak water flow in the area usually occurs in the winter and spring; minimum flows occur in the late summer and early fall. Discharge from the Brazos and San Bernard Rivers is summarized in Tables B.2-4 and B.2-9, respectively.

G.2.2.2 Water Temperature, Salinity, and Density

G.2.2.2.1 Regional

G.2.2.2.1.1 Introduction

The most complete and up-to-date review of seawater properties has been compiled by the National Oceanic and Atmospheric Administration (NOAA) in their environmental assessment of the South Texas continental shelf (U.S. Dept. of Commerce, 1976). Most of the accumulated data was provided by Texas A&M University (TAMU) and the National Oceanographic Data Center (NODC). Additional major contributors were the University of Texas Marine Sciences Institute, the U.S. Geological Survey (USGS), and the National Marine Fisheries Service (NMFS). Although there are a large number of oceanographic observations in the Gulf, their overall geographic distribution is poor, especially in the vicinity of the proposed diffuser.

G.2.2.2.1.2 Surface Water

Temperature

Monthly distribution of surface temperature is presented in Figures G.2-3 and G.2-4. The range of temperatures (54° to 72°F) at the surface is the greatest during January. From February to May, temperatures begin to rise due to solar heating, and the surface waters become nearly isothermal from June (82°F) through September (82° to 85°F). During October, November, and December seasonal cooling reestablishes a thermal gradient.

During all but the three summer months of June, July, and August, the isotherms are parallel to the shoreline with the cool water found inshore. Shallow water temperatures generally increase in a southerly direction along the coast except during June, July, and August, when the opposite is true.

A minimum average temperature of 54°F occurs in the nearshore zone in January; the maximum average temperature of 85°F is found in August.

Salinity

Similar to surface isotherms, the monthly isohalines parallel the shoreline during most of the year except from May to August when large quantities of freshwater inflow to the Gulf from the coastal Texas rivers and the Mississippi and Atchafalaya Rivers (Figures G.2-5 and G.2-6). During the rainy season the isohalines progressively align normal to the shoreline, and surface salinities increase along the coast and in the offshore direction. Over the shelf, southwest of Galveston, salinity values are markedly depressed as a result of the freshwater inflow. By September the isohalines are again parallel to the coast and remain so until the following spring.

Density

Monthly distributions of surface density (specific gravity) are presented in Figures G.2-7 and G.2-8. Density is given in terms of sigma-t (σ_t) values where $\sigma_t = (\rho - 1) \times 10^3$; ρ is the specific gravity of seawater at the particular temperature and salinity. Density patterns

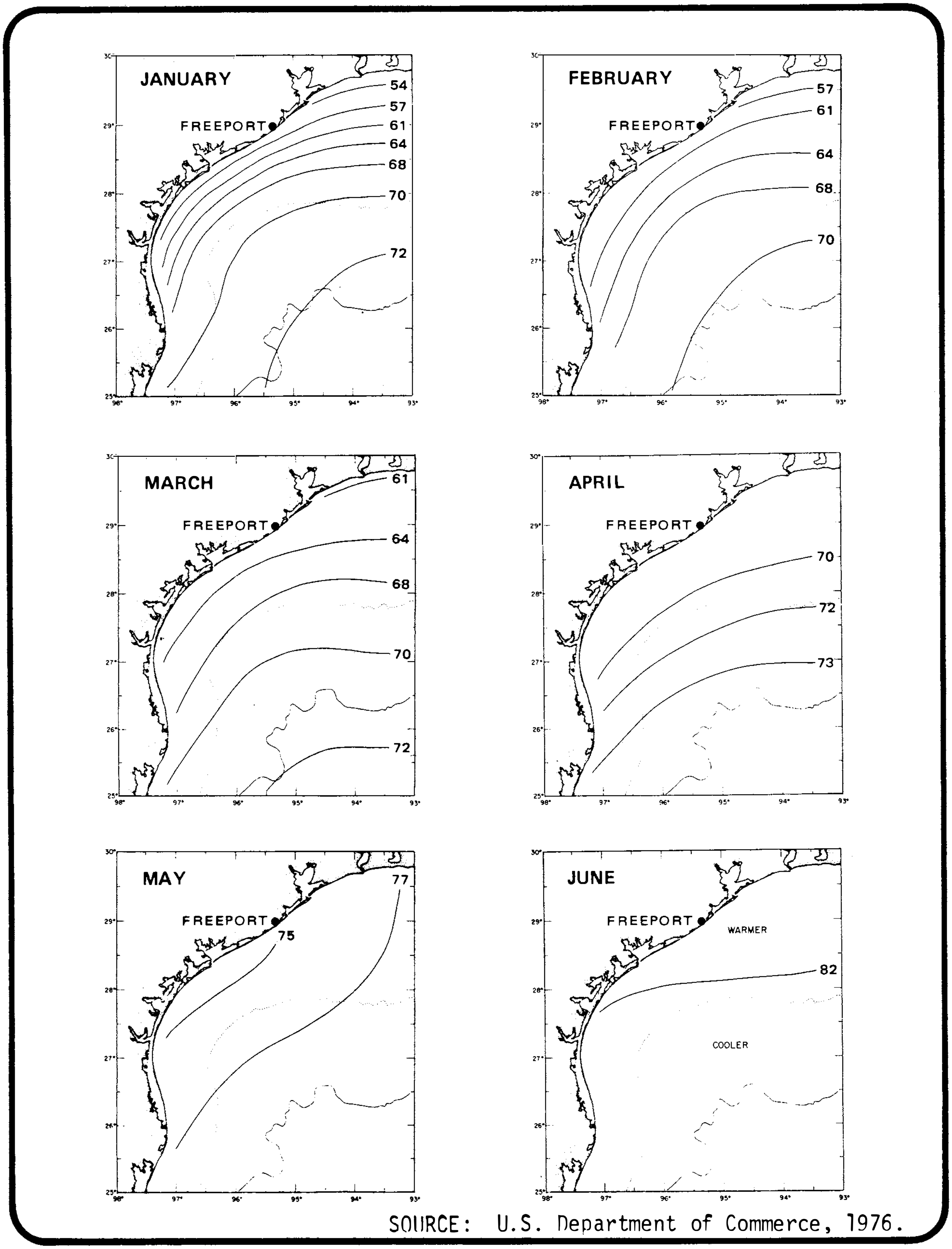


FIGURE G.2-3. Monthly sea surface temperature, $^{\circ}F$, January-June.

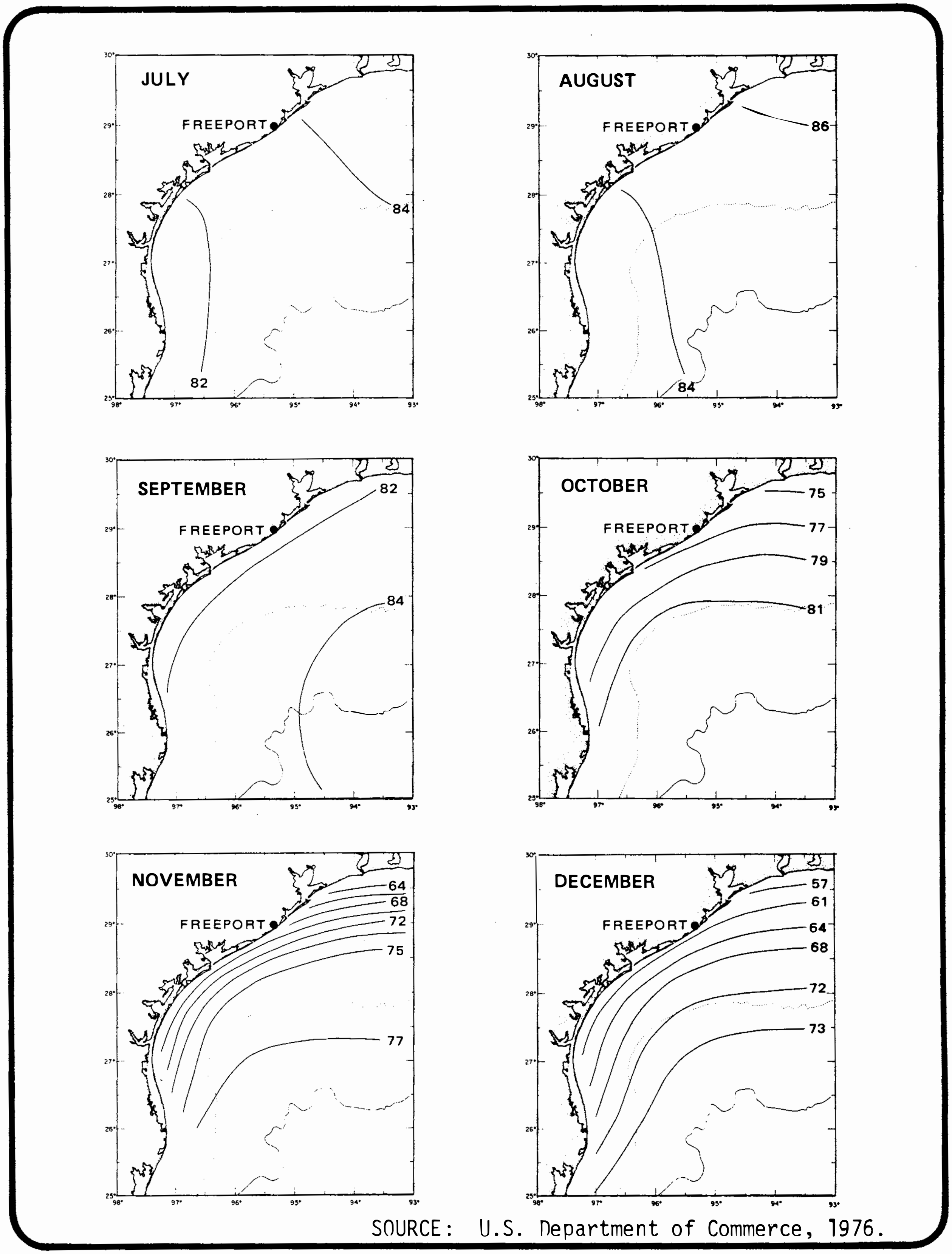
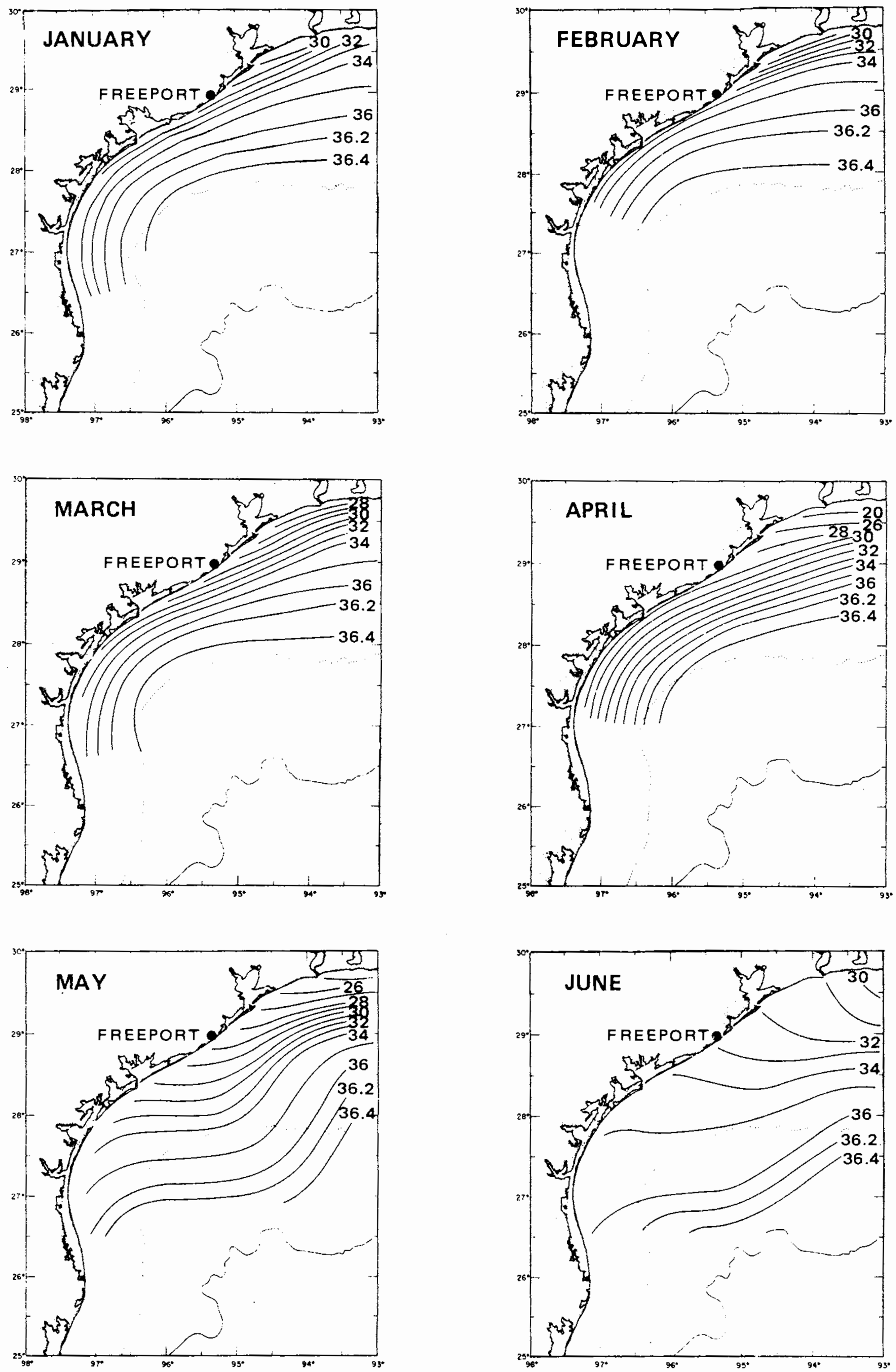
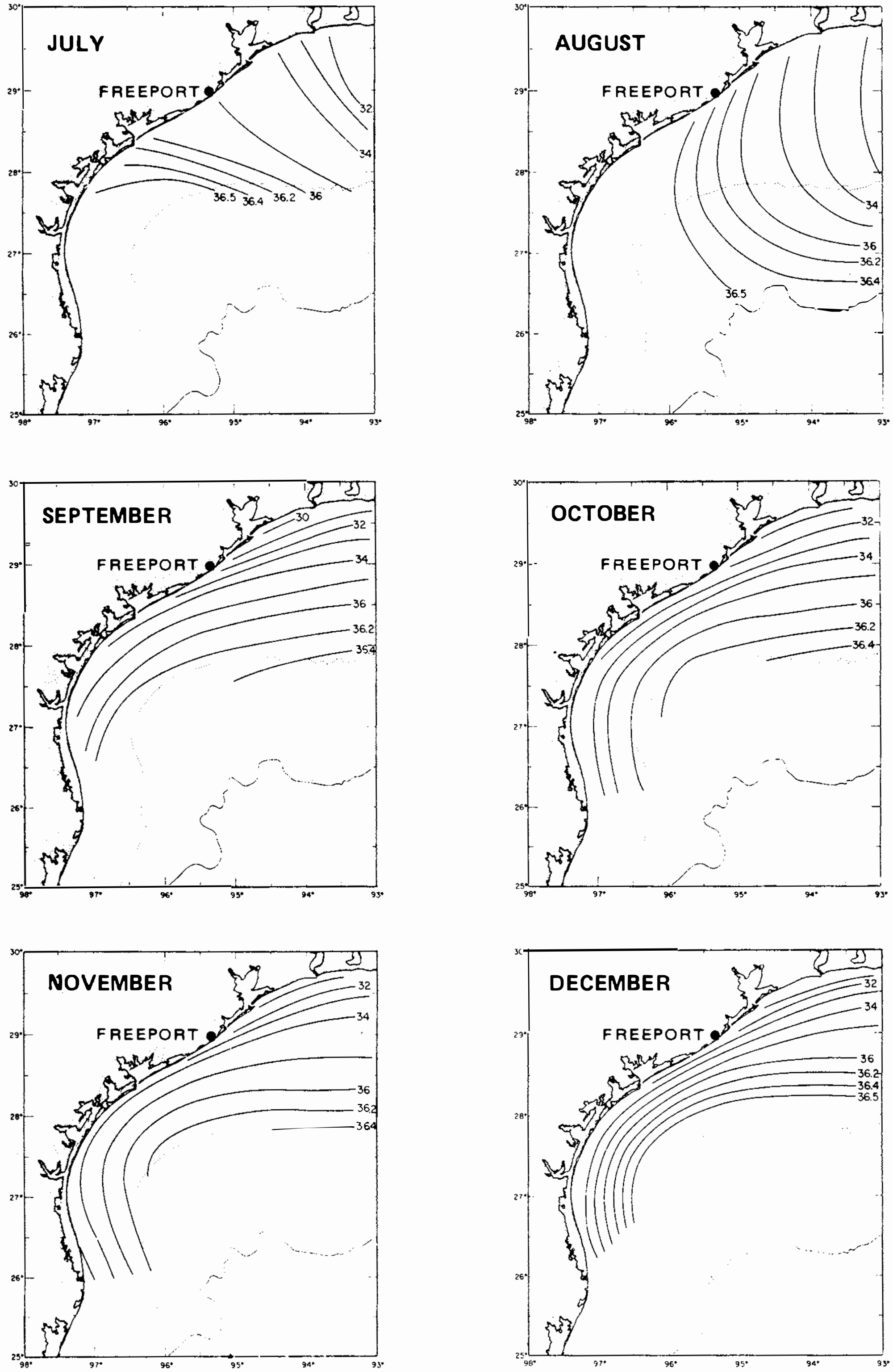


FIGURE G.2-4. Monthly sea surface temperature, ^{o}F, July-December.



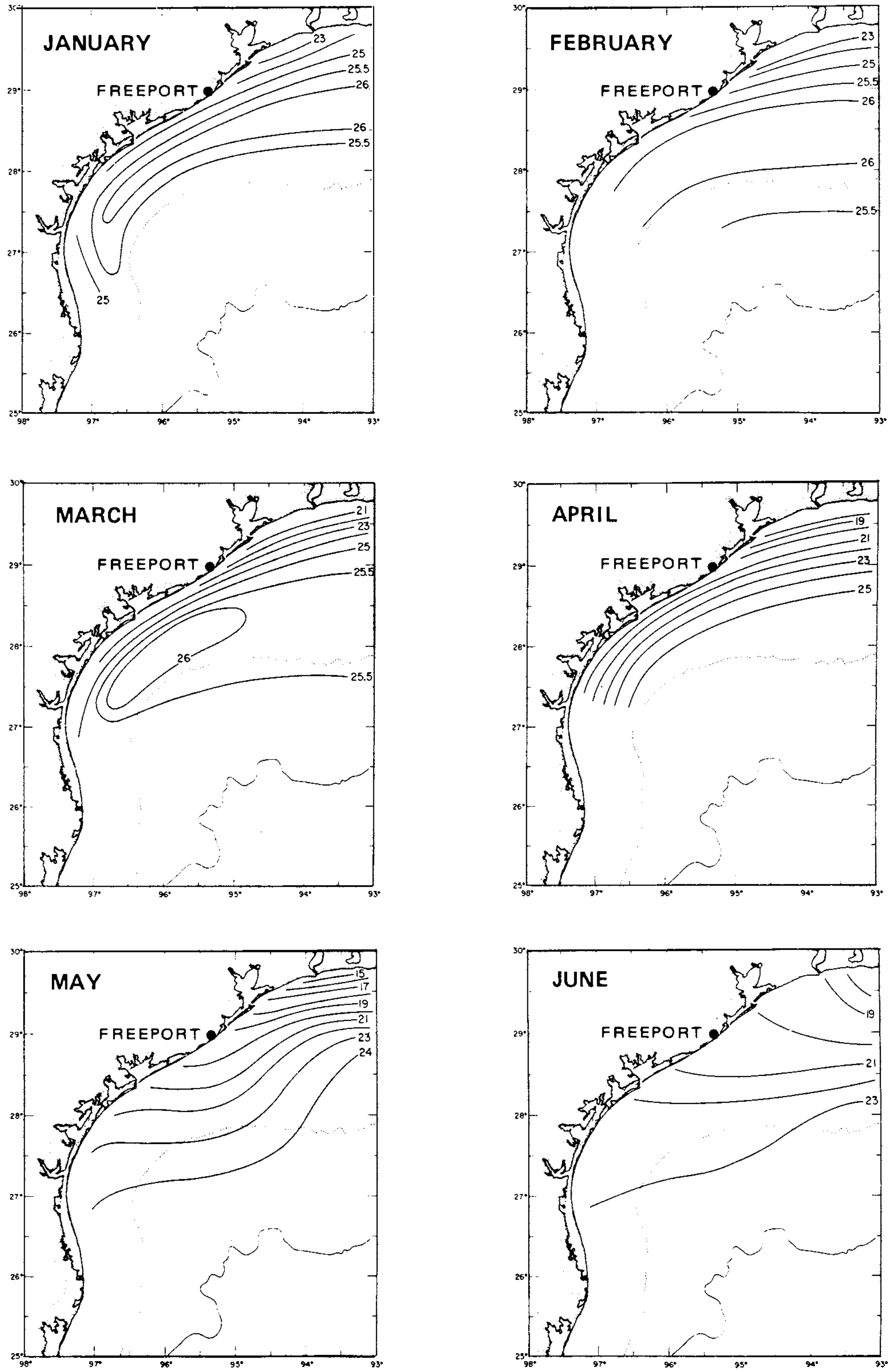
SOURCE: U.S. Department of Commerce, 1976.

FIGURE G.2-5. Monthly sea surface salinity, ppt, January-June.



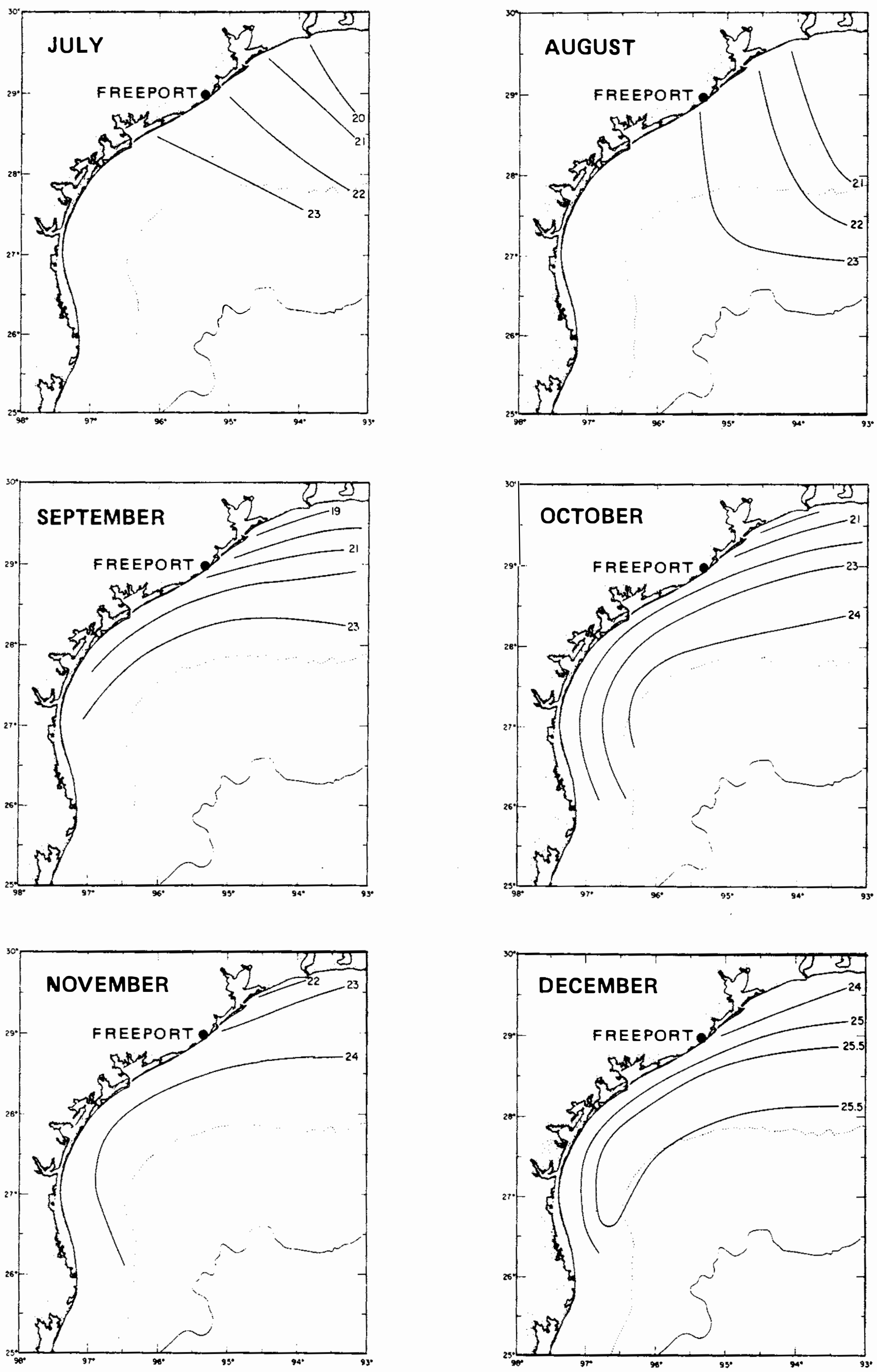
SOURCE: U.S. Department of Commerce, 1976.

FIGURE G.2-6. Monthly sea surface salinity, ppt, July-December.



SOURCE: U.S. Department of Commerce, 1976.

FIGURE G.2-7. Monthly sea surface density, σ_t, January-June.



SOURCE: U.S. Department of Commerce, 1976.

FIGURE G.2-8. Monthly sea surface density, σ_t, July-December.

generally follow the patterns of temperature and salinity, and horizontal gradients are usually strongest from September through March, but deteriorate during the spring and summer (April through August).

Throughout the year, the lowest σ_t values are found east and southeast of Galveston. The minimum density (σ_t = 15) levels occur in May and reflect the freshwater inflow from the Mississippi and Atchafalaya Rivers.

G.2.2.2.1.3 Vertical Sections

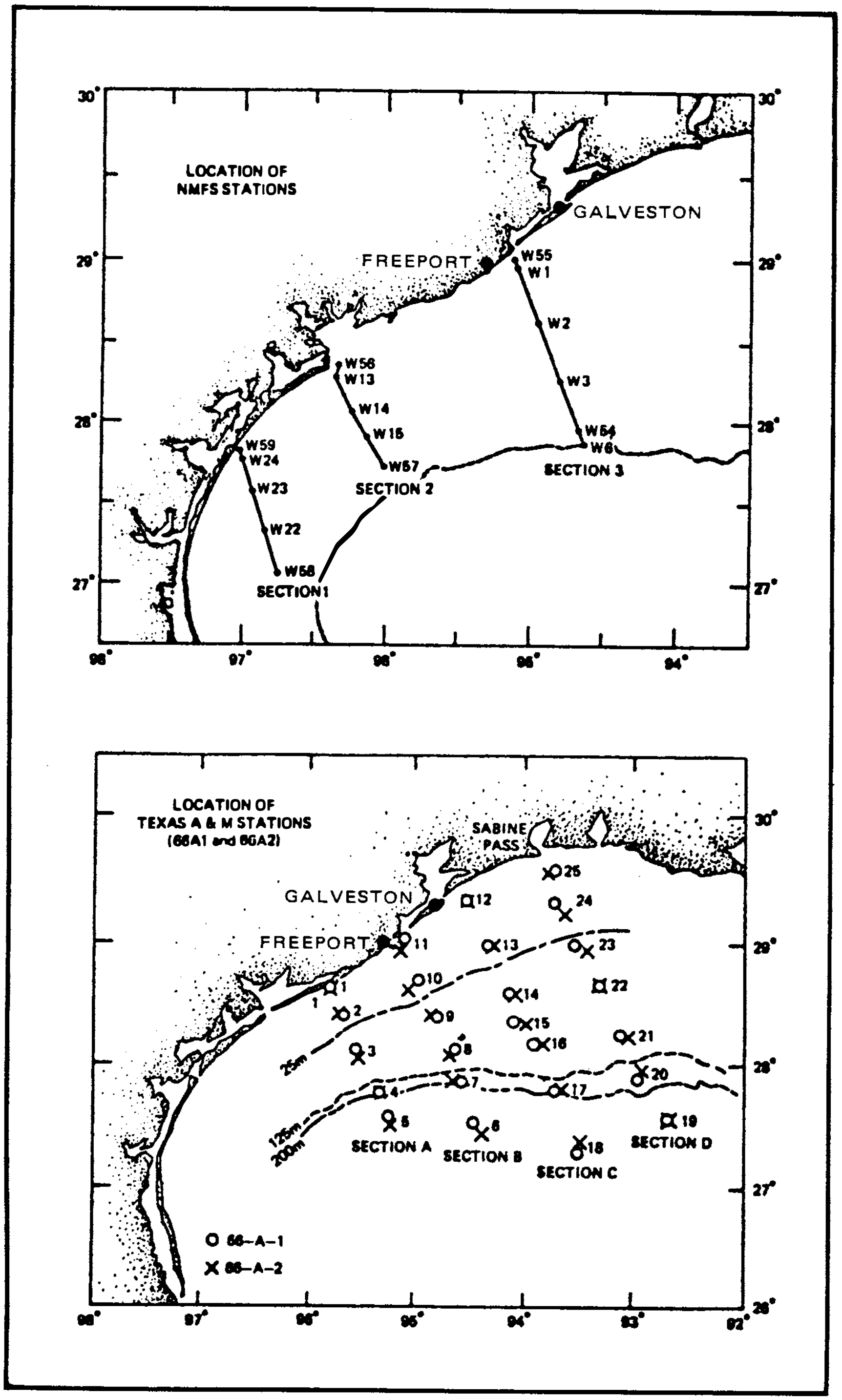
Vertical profiles (cross sections) of temperature, salinity, and density have been constructed by NMFS (Galveston) and TAMU, and are presented in Figures G.2-9 through G.2-11. Section 3 of the NMFS data and Section B of the TAMU data (cruises 66-A-1 and 66-A-2) correspond to a transect originating in Galveston and trending SSE across the continental shelf.

During the period of October through March, the shelf waters are nearly homogenous. Weak vertical temperature and salinity gradients are observed, but they deteriorate offshore. From March through May, a thermal gradient develops in the shallow coastal waters, but the nearshore less-saline water (at depths less than about 65 feet) is nearly isohaline. Thermal heating from the sun continues during June and July, and by August there are isothermal conditions to a depth of 65 to 80 feet (20 to 25 meters). In the intermediate offshore zone, a shallow narrow band of relatively fresh water remains from the spring runoff parallel to the shoreline.

G.2.2.2.2 Bryan Mound Vicinity

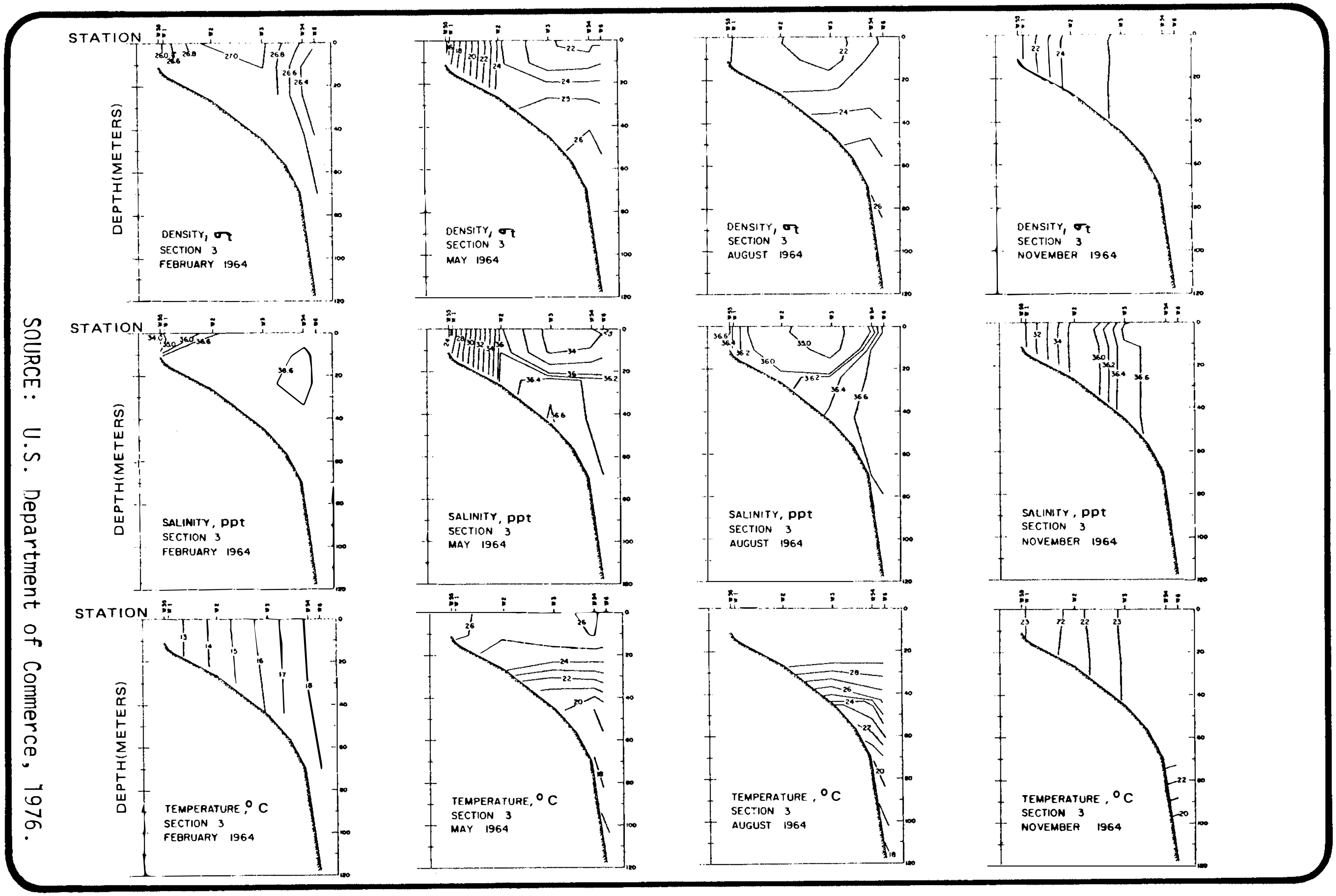
G.2.2.2.2.1 Salinity - Temperature - Density Relationships

Temperature - salinity (T-S) relationships developed from monthly over the side measurements (Figure G.1-12) for all stations and all depths in the study area are summarized for the period September through December 1977 in Figure G.2-12. The data for temperature and salinity are presented separately by month, on Figures G.2-13a and G.2-13b, respectively. These T-S relationships show, by month, clearly demarcated water conditions which occur primarily as a function of



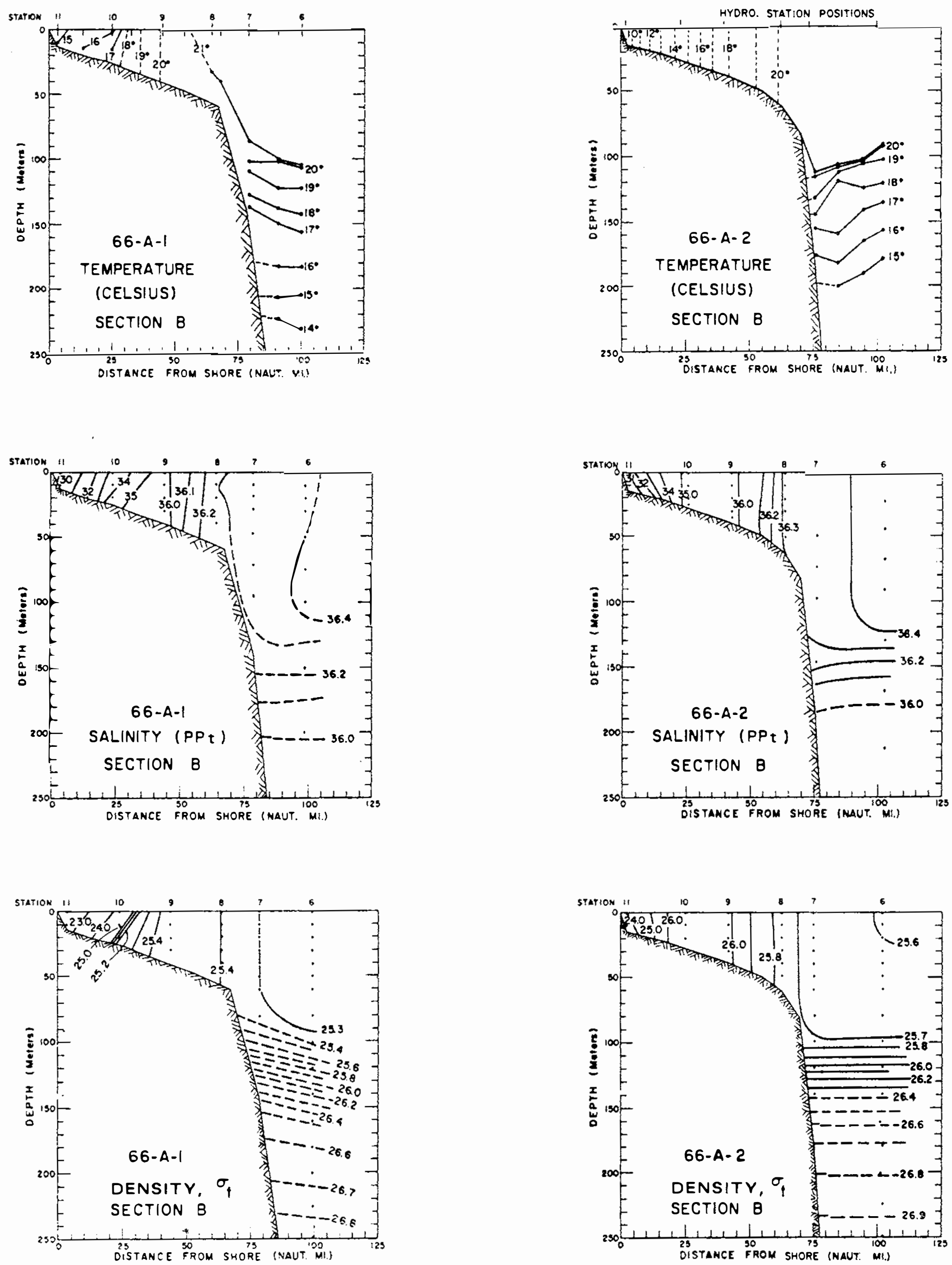
SOURCE: U.S. Department of Commerce, 1976.

FIGURE G.2-9. Location of stations used for vertical sections.



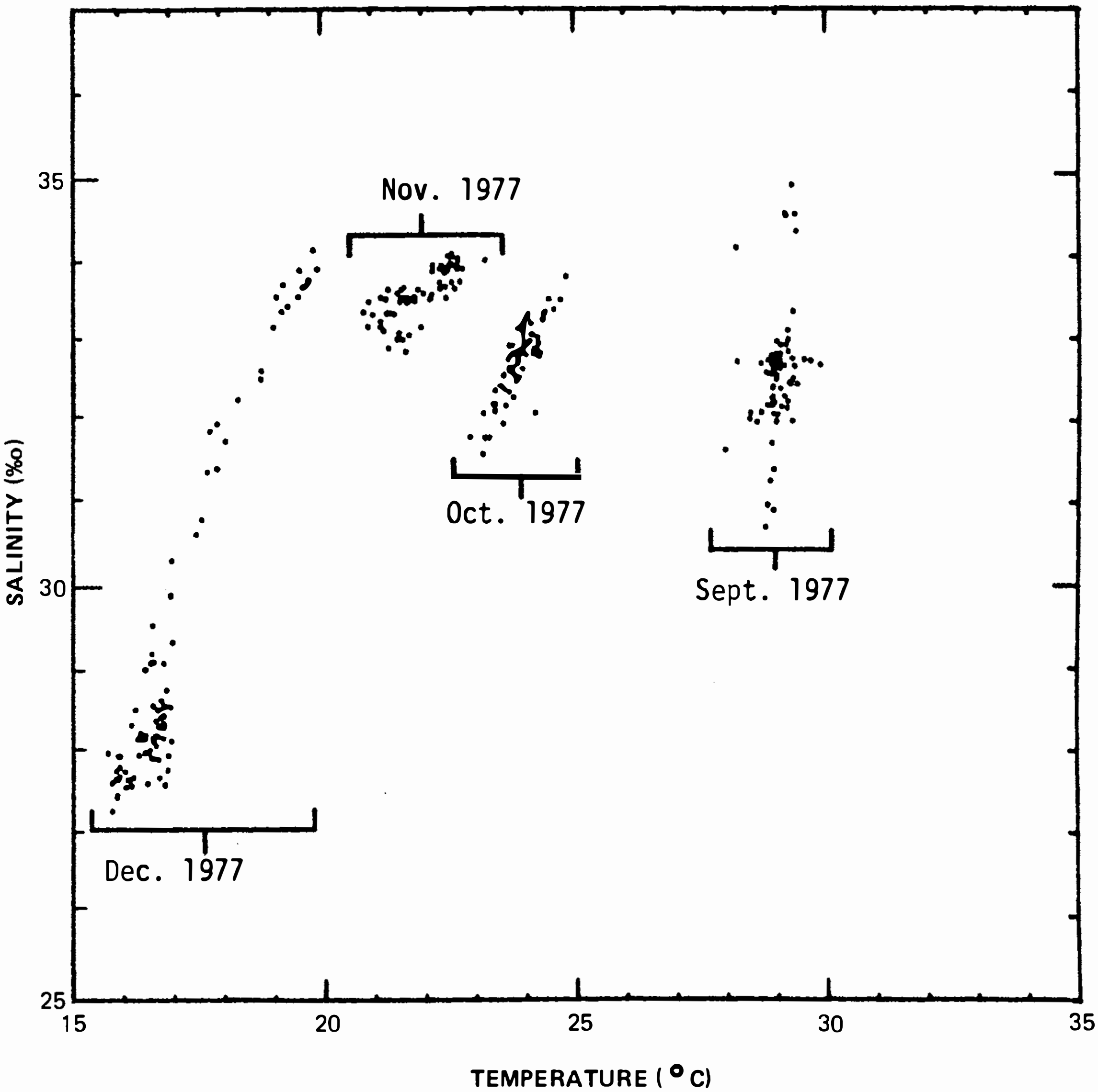
SOURCE: U.S. Department of Commerce, 1976.

FIGURE G.2-10. Temperature, salinity, and density cross sections of shelf southeast of Galveston, Texas, Section 3.



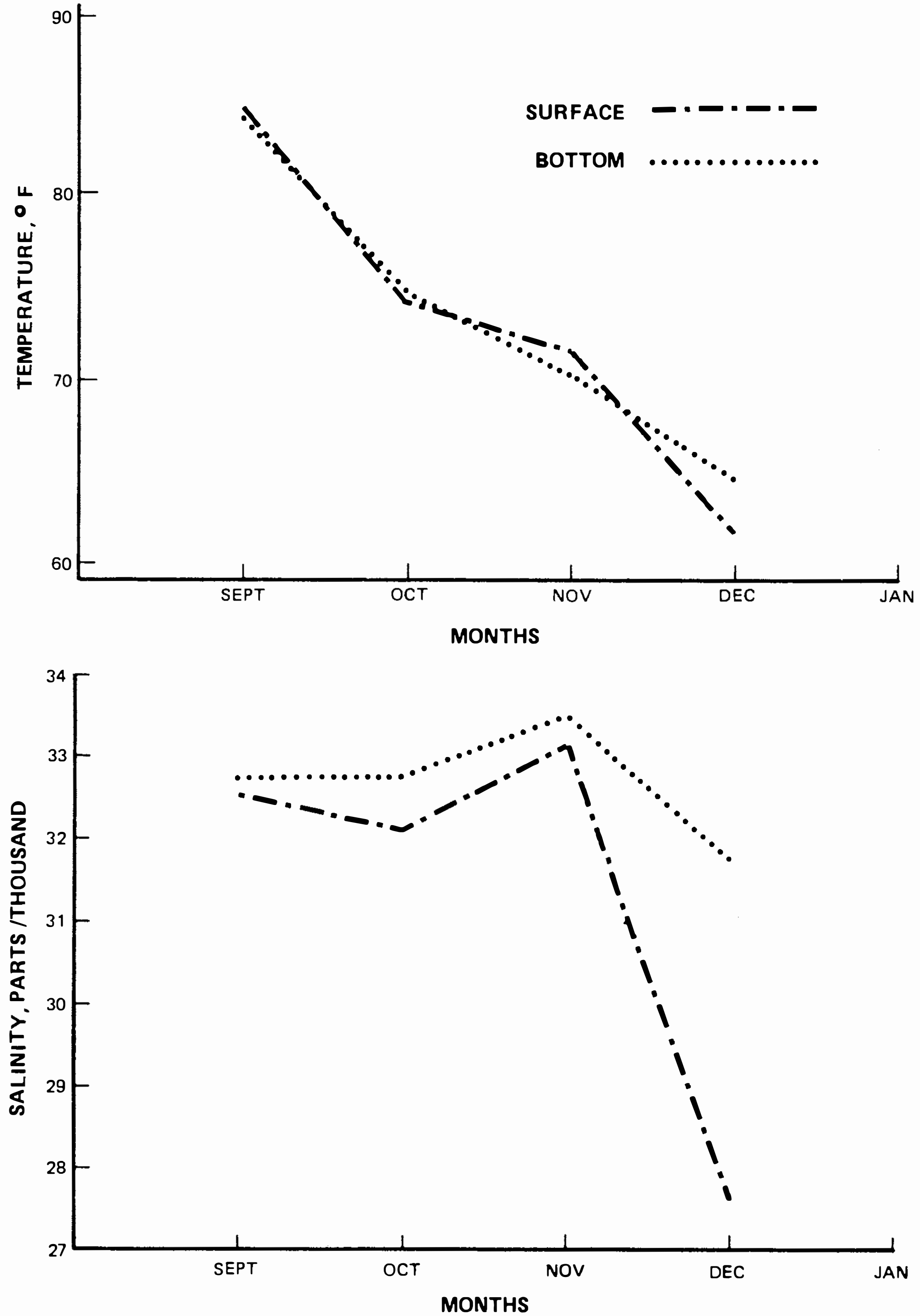
SOURCE: Nowlin and Parker, 1974.

FIGURE G.2-11. Temperature, salinity and density cross sections for January of shelf southeast of Galveston, Texas, cruises 66-A-1 and 66-A-2, Section B.



SOURCE: Texas A & M, 1978.

FIGURE G.2-12. Temperature-salinity relationships for the study area from September through December 1977.



SOURCE: Texas A & M, 1978.

FIGURE G.2-13a. Temperature trends (top) and G.2-13b, Salinity trends (bottom) at the proposed brine diffuser site, September 1977 through December 1977.

seasonal cooling from a September temperature maximum. The data show that the study area was relatively isothermal in September and averaged about 29^{o}C (84.2^{o}F); the maximum water temperature for the period was 29.9^{o}C (85.8^{o}F). Salinity concentrations ranged from 30.72 to 34.86 ppt, the latter value being characteristic of outer-shelf water; the average salinity was 32.7 ppt. When water temperatures declined in October and November the salinity average increased slightly but the range decreased. During this same period, a positive correlation between temperature and salinity became evident where low salinities corresponded with low temperatures. This correlation may be attributed to the effect of warm, salty outer-shelf water meeting rapidly cooling runoff from land.

In December, the T-S correlation became even more pronounced and was reflected in the elongation of the data points along the salinity axis (Figure G.2-12). Salinity in December ranged from 27.32 to 34.11 ppt, indicating a continued freshening of the water column but with limited mixing with outer-shelf water. The low salinities corresponded to a temperature minimum of 15.7^{o}C (60.3^{o}F). The maximum temperature observed in December was 20.0^{o}C (68.0^{o}F) and corresponded to the salinity maximum of the outer-shelf water.

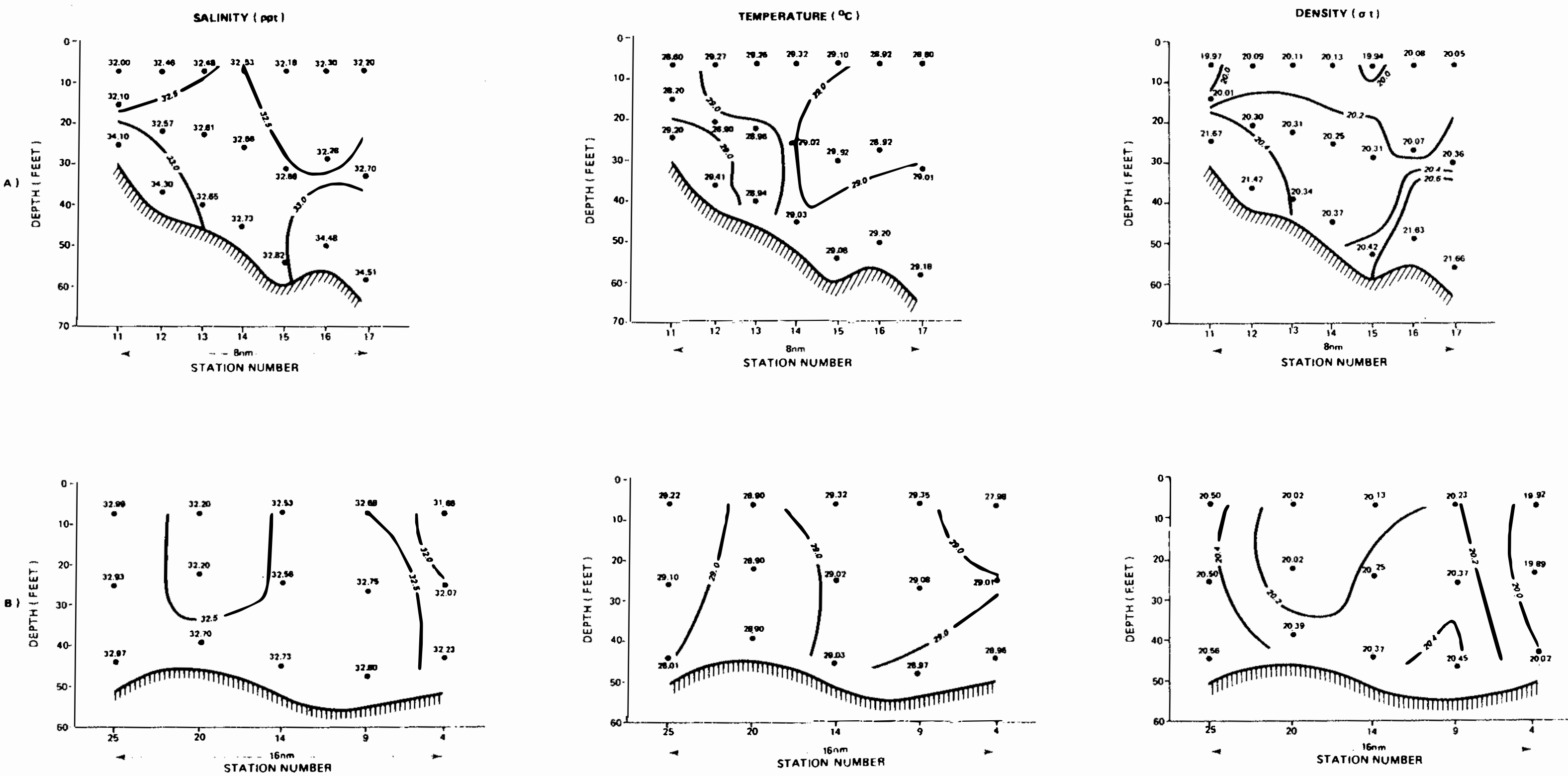
G.2.2.2.2.2 Vertical Density Profiles

The change in structure of the water column over time and space is shown in the vertical profiles of salinity, temperature, and density developed for a cross-shelf transect along the proposed pipeline route and a longshore transect through the proposed diffuser site. The profiles are arranged by month, September through December, in Figures G.2-14 through G.2-17.

Density, which varies directly with salinity and inversely with temperature, was calculated from salinity and temperature observations and is represented in terms of the variable sigmat (σ_t):

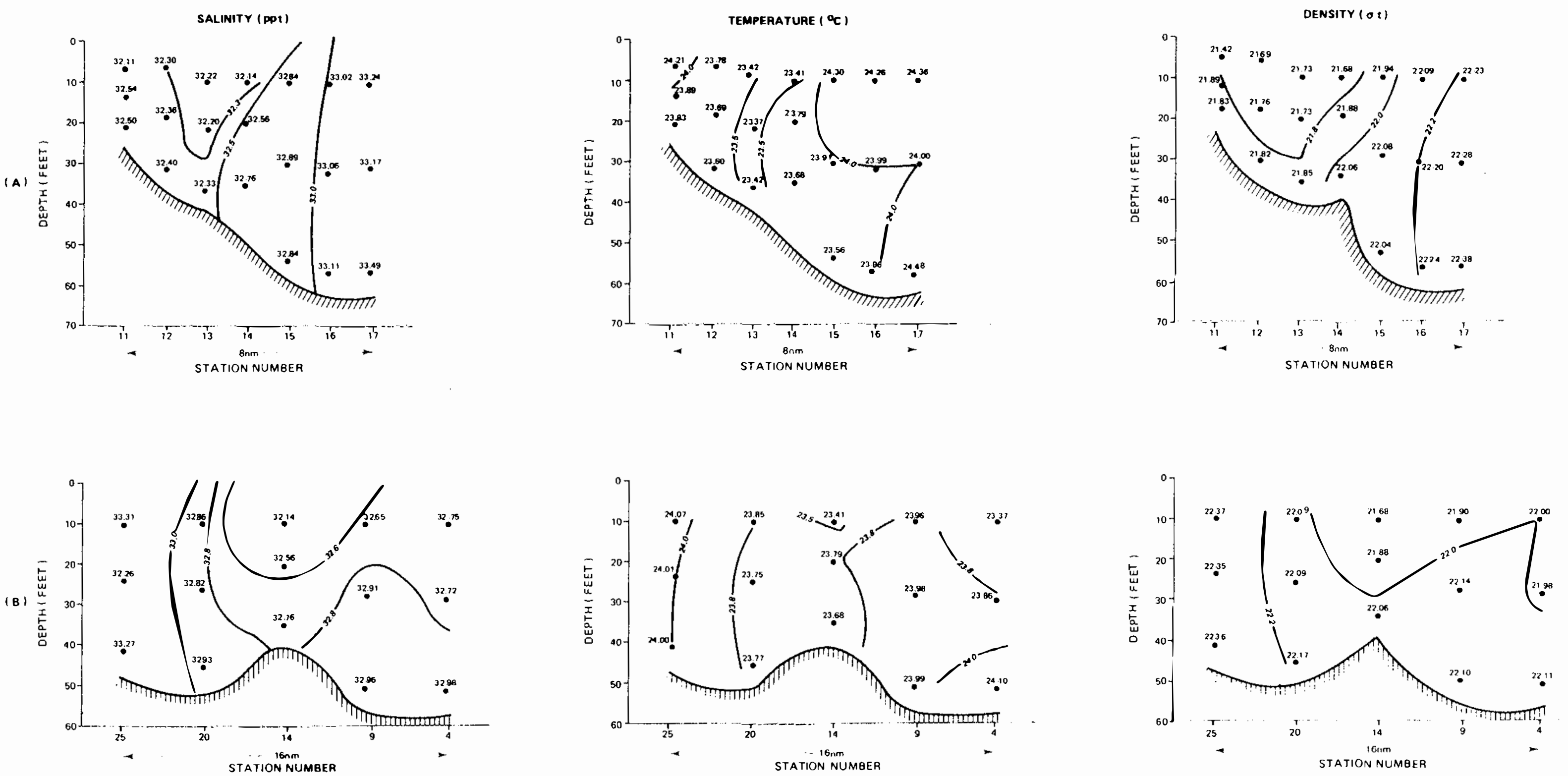
$$\sigma_t = (\rho - 1) \times 10^3$$

where ρ is the calculated density in g/cm^3. As an example, for seawater with a density of 1.0200 g/cm^3, $\sigma_t = (1.0200 - 1) \times 1000 = 20.0$.



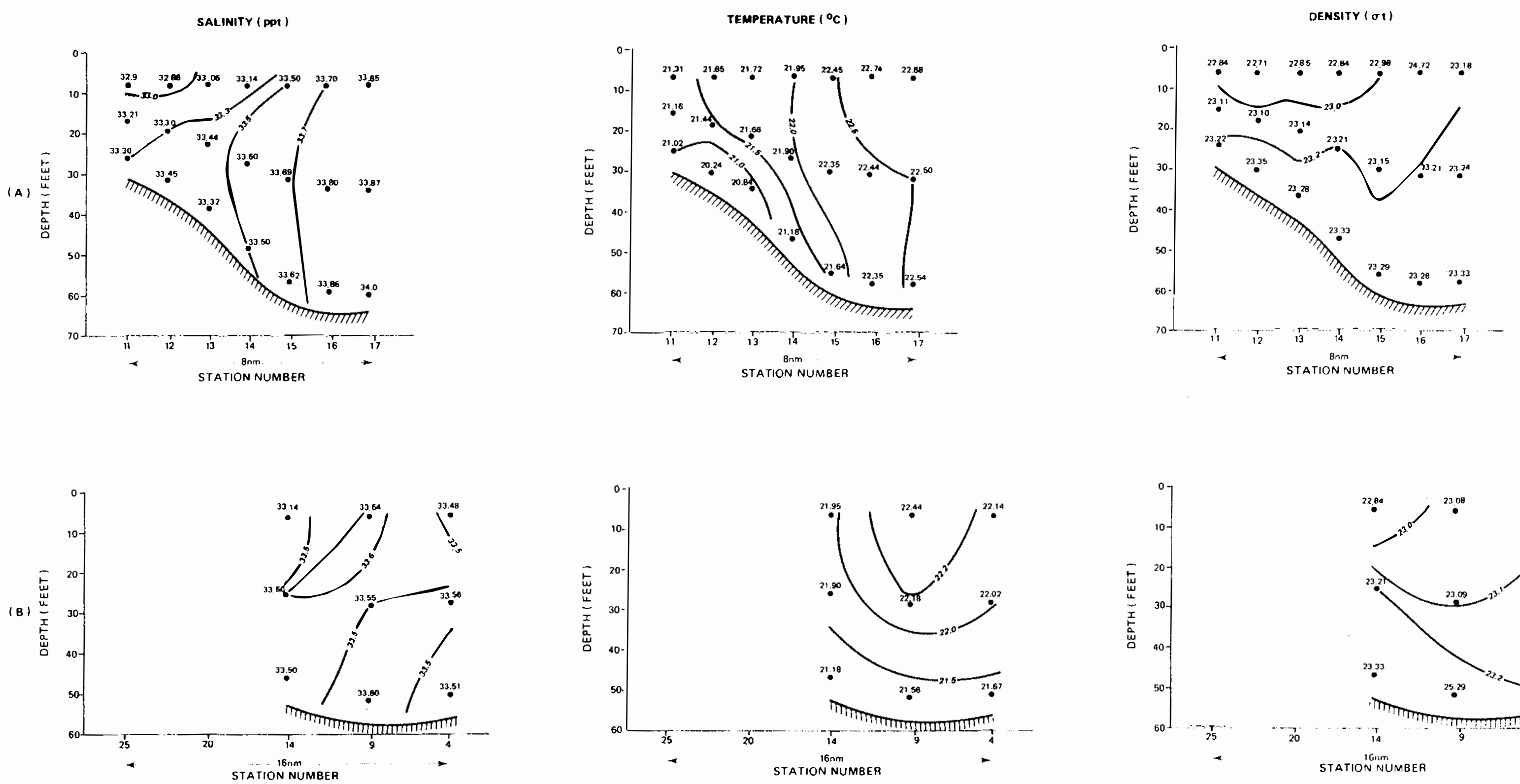
SOURCE: Texas A & M, 1978.

FIGURE G.2-14 Vertical cross sections of salinity, temperature and density (sigma-t) for (A) transshelf (Stations 11-17) and (B) alongshore transects (Stations 25-4) for proposed diffuser site, September 1977.



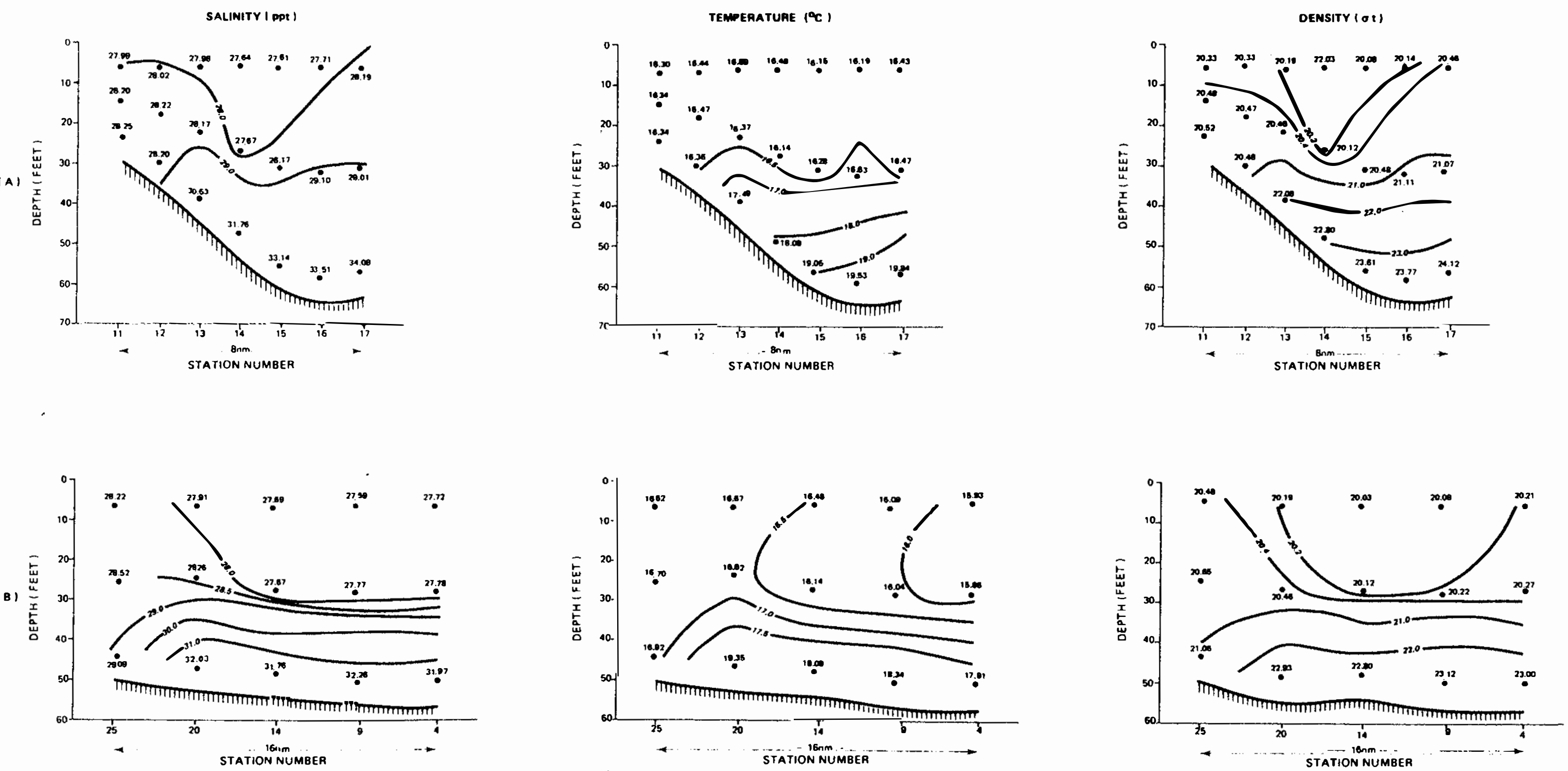
SOURCE: Texas A & M, 1978.

FIGURE G.2-15 Vertical cross sections of salinity, temperature and density (sigma-t) for (A) transshelf (Stations 11-17) and (B) alongshore transects (Stations 25-4) for proposed diffuser site, October 1977.



SOURCE: Texas A & M, 1978.

FIGURE G.2-16 Vertical cross sections of salinity, temperature and density (sigma-t) for (A) transshelf (Stations 11-17) and (B) alongshore transects (Stations 25-4) for proposed diffuser site, November, 1977.



SOURCE: Texas A & M, 1978.

FIGURE G.2-17 Vertical cross sections of salinity, temperature and density (sigma-t) for (A) transshelf (Stations 11-17) and (B) alongshore transects (Stations 25-4) for proposed diffuser site, December 1977.

Thus, σ_t is oceanographer's short hand to note the significant portion of numerically small but important density differences among water masses. The units of measurement are given by implication.

As suggested by the T-S diagram (Figure G.2-12) the minor degree of density structure observed for the study area in September may be attributed to isolated salinity differences (Figure G.2-14). In the cross-shelf profile, higher salinity outer-shelf water is found in an isolated blob along the shore (Stations 11 and 12) and at the shell ridge about 2.5 nautical miles seaward of the proposed diffuser site (Stations 16 and 17).

In the longshore profile, low surface salinities, suggesting mixed remnants of runoff, were observed roughly 4 miles upcoast (northeast) and downcoast (southwest) from the diffuser site. Isotherms (lines of constant temperature) in the water column were essentially vertical except for the outer-shelf water which was located on the bottom near the shore and at the shell ridge. Density values increased slightly alongshore from northeast to southwest. The vertical density gradients associated with the bottom shelf water nearshore and at the shell ridge were 1.3 σ_t units in 40 feet of water at Station 12 and 1.6 σ_t units in 64 feet of water at Station 17, respectively. In the immediate vicinity of the proposed diffuser site (Stations 13, 14, and 15), the water column was well-mixed, and the observed salinities and temperatures tended to be clustered about the mean values calculated for the study area as a whole.

In October and November (Figures G.2-15 and G.2-16) density continued to increase while temperature declined, as previously noted above but the mean salinity for the study area increased. The water column was either mixed or only weakly stratified for the period. The correlation observed between temperature and salinity was associated with small horizontal gradients, with cool, fresh water found primarily in the upper water column and close to shore. As in September, the October and November salinity and temperature measurements in the immediate vicinity of the diffuser exhibited a narrow range and were clustered about the mean values as determined for the whole study area.

In December, the water column changed markedly and exhibited significant vertical density stratification in the cross-shelf and longshore transects (Figure G.2-17). Salinity and temperature measurements in the study area showed similar stratification. The outer-shelf water as reflected by the 34 ppt isohaline retreated to the shell ridge at the bottom. The change in the profiles suggest that the source of cool, fresh water in the upper water column was from the shore and from the northeast quadrant of the study area.

The mean circulation pattern of the entire study area changed between mid-November and mid-December 1977. This change resulted in the influx of fresh, cool water which displaced and overrode the warm, salty water. Angelovic (1976) also presented data showing that the only source of fresh water to be to the northeast of the study area during December. He also showed that the mean outflow of the Mississippi River increases from 6.5 x 10^3 m^3/s in November to 9 x 10^3 m^3/s in December. Thus, it may be hypothesized that in the early fall of 1977, there existed a small net transport of water toward the northeast part of the study area. In late fall, the circulation pattern changed to a much larger net transport of water toward the southwest. The result of this latter net transport was to introduce fresh, cool, but less dense waters from the northeast into the study area.

G.2.2.3 Currents

G.2.2.3.1 Regional Historical Data

The inshore currents off the Texas coastline have not been studied in detail, but it can be inferred from the present limited field work and other studies that the prevailing set of nearshore coastal currents is to the west and southward. Water from the Mississippi Delta area flows westward in the Gulf of Mexico towards a zone of convergence off the Texas coast. The area of convergence changes from a location off the southern Texas coast in the winter to one near the Corpus Cristi-Freeport area in the early summer. The resultant surface water currents at any one time depend on several factors, including the large-scale permanent current, the tidal currents, and the wind drift currents. The shift in the location of the convergence area southward in the winter conforms with changes in the wind-pattern shift. This wind-pattern is predominantly from the southeast in early spring and summer, but is predominantly from the east in the fall and the north in early winter.

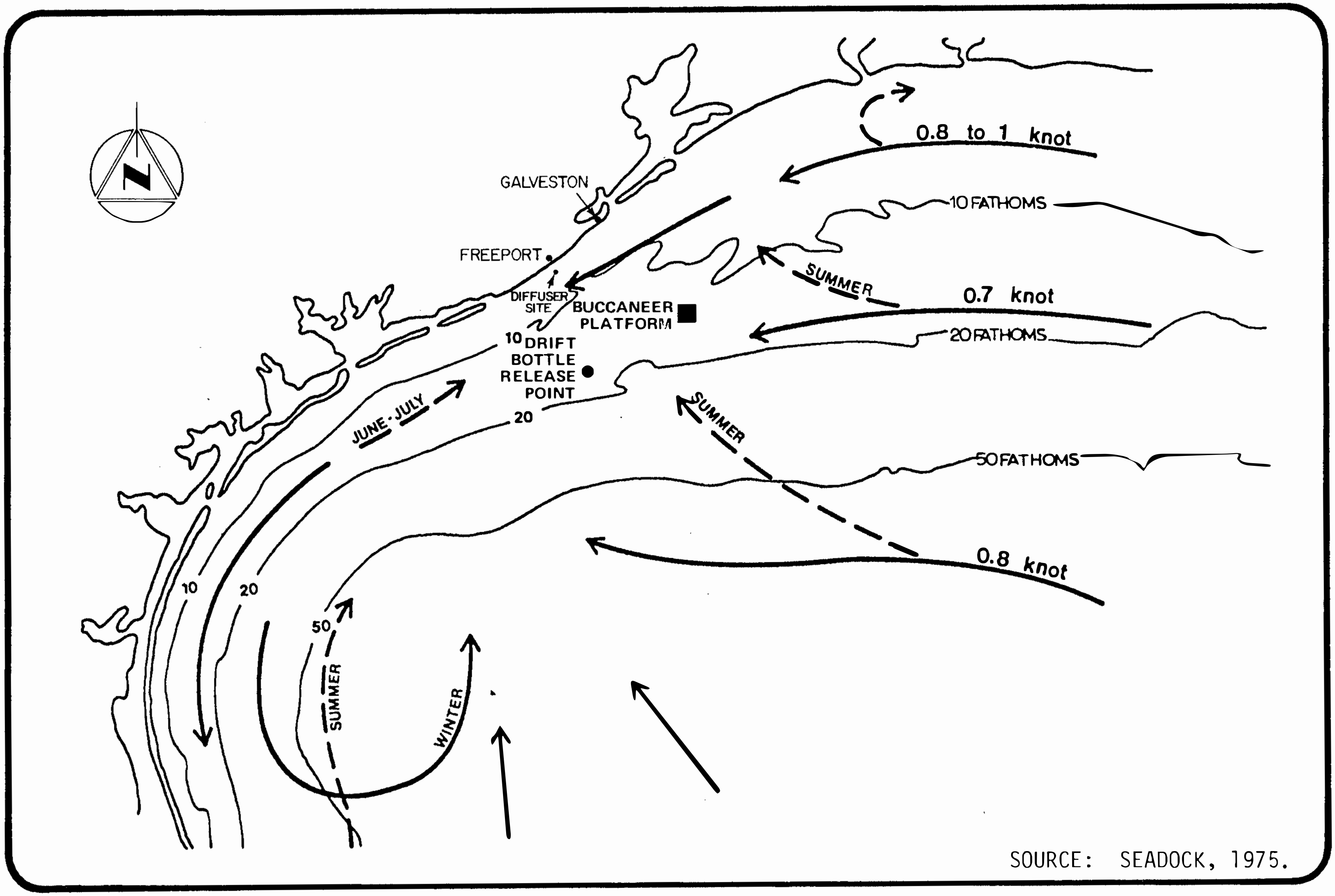
Water current patterns off the Texas coast (Figure G.2-18) suggest that the currents shift towards the northeast off Freeport, Texas, in June and July. This circulation pattern was partially confirmed by a drift-bottle survey conducted during the summer and fall of 1973 as part of the Seadock investigation. The bottles released from the proposed Seadock platform site in July were generally found to the east of Freeport, but those released in August and September were found to the west of Freeport. Current measurements taken during the spring, summer, and fall showed that current velocities generally ranged from 0.3 to 0.8 knots (0.5 to 1.4 ft/sec). Maximum current velocities of one to two knots occurred on several occasions.

Current information was obtained from the Shell Oil Company's Buccaneer Platform, located 38 nautical miles northeast of the proposed Seadock complex as shown on Figure G.2-18.

Monthly current roses, measured 12 feet below the surface at the Buccaneer Platform (Figures G.2-19 and G.2-20), suggest that the average surface currents at the Buccaneer Platform are generally less than one knot and appear to be primarily wind driven. The dominant direction of the surface current was toward the west from March through June, but to the northeast between July and September. From October through February the surface current was quite variable.

Mid-depth (32 feet) currents were mainly toward the west from March through June and to the northeast from July through January.

Bottom (57 feet) currents at the Buccaneer Platform had predominantly westerly components for the months of February through May and also during October; during July, August, November and December the main flow was easterly. No bottom observations were taken during June and September. The strongest currents with speeds greater than 51 cm/sec (1 knot) were recorded in July and August. Approximately 15 percent of the time the set of these currents was to the northeast.



SOURCE: SEADOCK, 1975.

FIGURE G.2-18. Currents off the Texas coast.

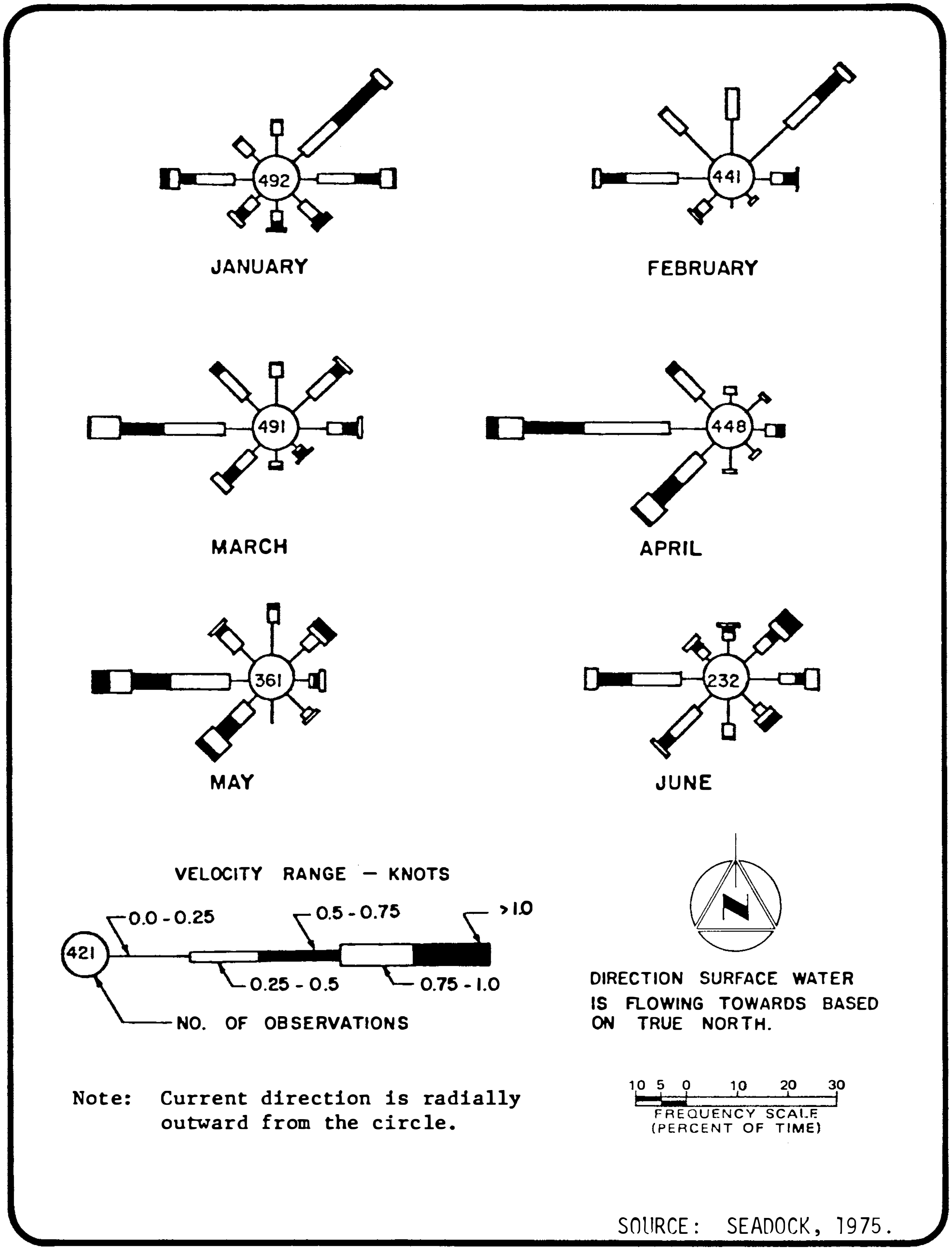


FIGURE G.2-19. Surface water current roses off Galveston, Texas, January-June.

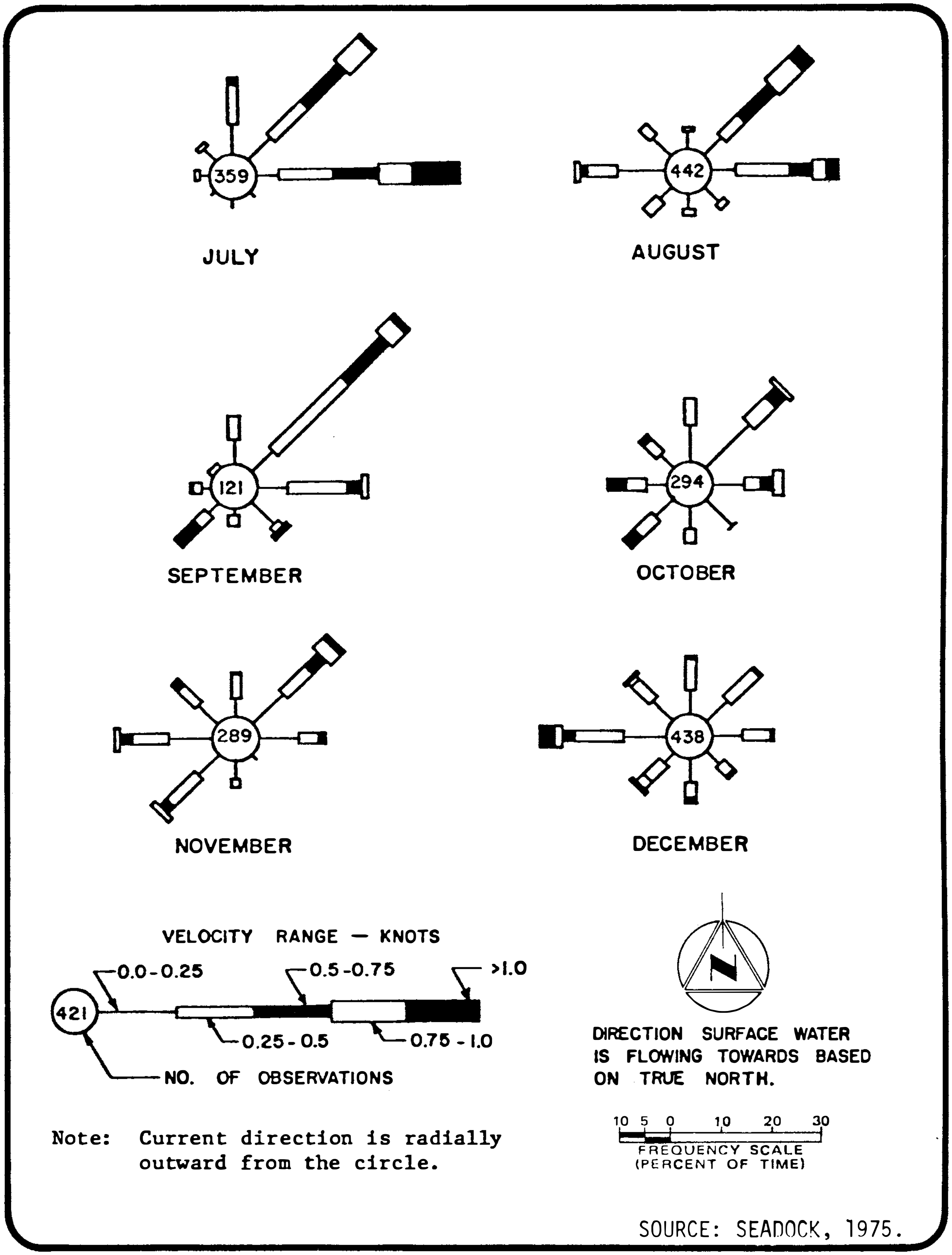


FIGURE G.2-20. Surface water current roses off Galveston, Texas, July-December.

Commercial trawlers report that pronounced differences between surface and bottom currents occur in the shallow water of the nearshore region especially during the summer months and this reverse flow of surface and bottom currents makes trawling with nets difficult.

G.2.2.3.2 Observed Currents - Bryan Mound Vicinity

G.2.2.3.2.1 Over-the-Side Current Meter Measurements

Over-the-side current measurements were taken 7 to 10 feet below the surface, at mid-depth, and 7 feet above the bottom. Mean current speeds decreased with depth as expected, during the October, November, and December cruises. On the September cruise, however, the mean bottom currents were actually flowing faster than the surface currents. This could be explained by the passage of a storm a day or two before the measurements were taken. In this case, the energy imparted to the bottom waters would continue to be a driving force even after the storm had subsided. The range of current speeds at all three levels was the lowest (2.6 to 28.3 cm/sec) during November and the greatest (7.7 to 64.3 cm/sec) during December. Table G.2-7 presents a statistical summary of the current data obtained during the 4-month interval.

The bottom current speeds measured at Station 14 (proposed nearshore site) were greater than the calculated monthly means for all stations except in December for which case the difference is insignificant. In September and October, the speeds measured at Station 14 were greater than the mean, plus one standard deviation.

Current direction measured in December showed a general flow in a northerly-northeasterly direction (Figures G.2-21, G.2-22, and G.2-23). This is the opposite behavior to what would be expected during this time of the year. Current direction in the bottom waters appears more consistent between stations than the upper waters, probably due to the decreased influence of wind and tide and runoff.

It should be noted that the speed and direction of an over-the-side current measurement are usually highly variable, as mean speed and direction are visually estimated from instrument needle which fluctuates. In most instances, speed recorded is a good estimate of the mean speed. This may not be true for the current direction recorded.

TABLE G.2-7 Statistical properties of the over-the-side current measurements for September through December 1977.

MONTH		MIN. SPEED (cm/s)[b]	MAX. SPEED (cm/s)	MEAN SPEED (cm/s)		STANDARD DEVIATION (cm/s)
		All Stations	All stations	All Stations	Station 14 Proposed Site	
Sept.	Top	10.3	32.4	23.1	30	6.2
	Middle	7.7	48.9	27.3	33	9.8
	Bottom	10.3	43.7	28.8	40	9.8
Oct.	Top	11.3	38.6	20.3	34	7.1
	Middle	5.1	40.1	18.9	38	8.6
	Bottom	5.1	36.5	15.4	36	7.6
Nov.[a]	Top	5.1	28.3	18.7	15	6.2
	Middle	2.6	24.7	15.9	21	4.5
	Bottom	2.6	23.1	14.1	17	4.7
Dec.	Top	15.4	64.3	30.6	30	13.0
	Middle	13.9	48.9	27.9	33	8.0
	Bottom	7.7	37.0	21.8	21	6.0

[a]Only the data from 17 November (19 stations) were used in the November computations.

[b]1 cm/sec = 3.28×10^{-2} feet/sec.

SOURCE: Texas A & M, 1978.

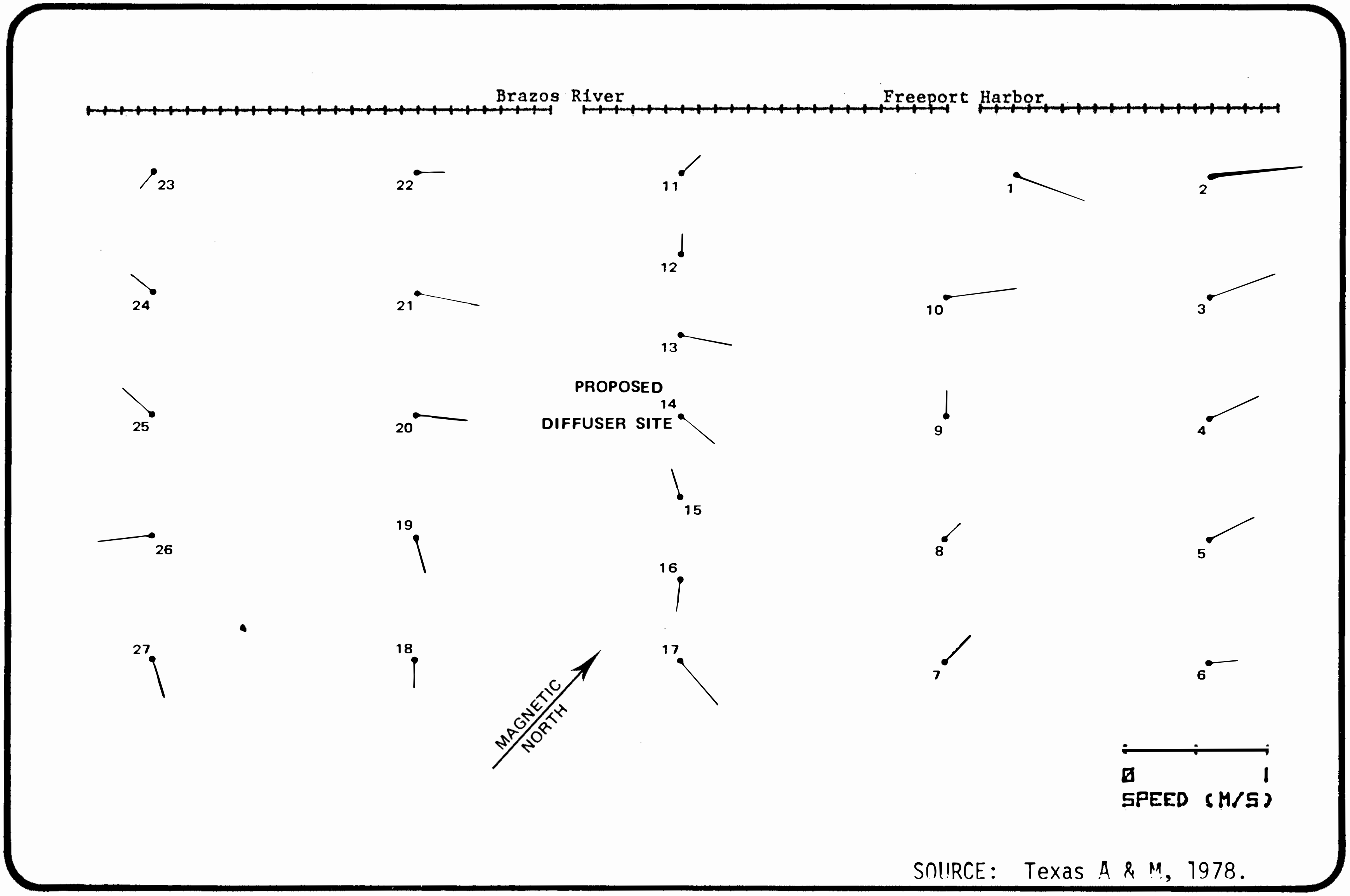


FIGURE G.2-21. Surface currents (7 ft.). Stations 1 through 21 sampled 0825 to 1610 hours, December 18, 1977; stations 22 through 27 sampled 0905 through 1110 hours, December 19, 1977.

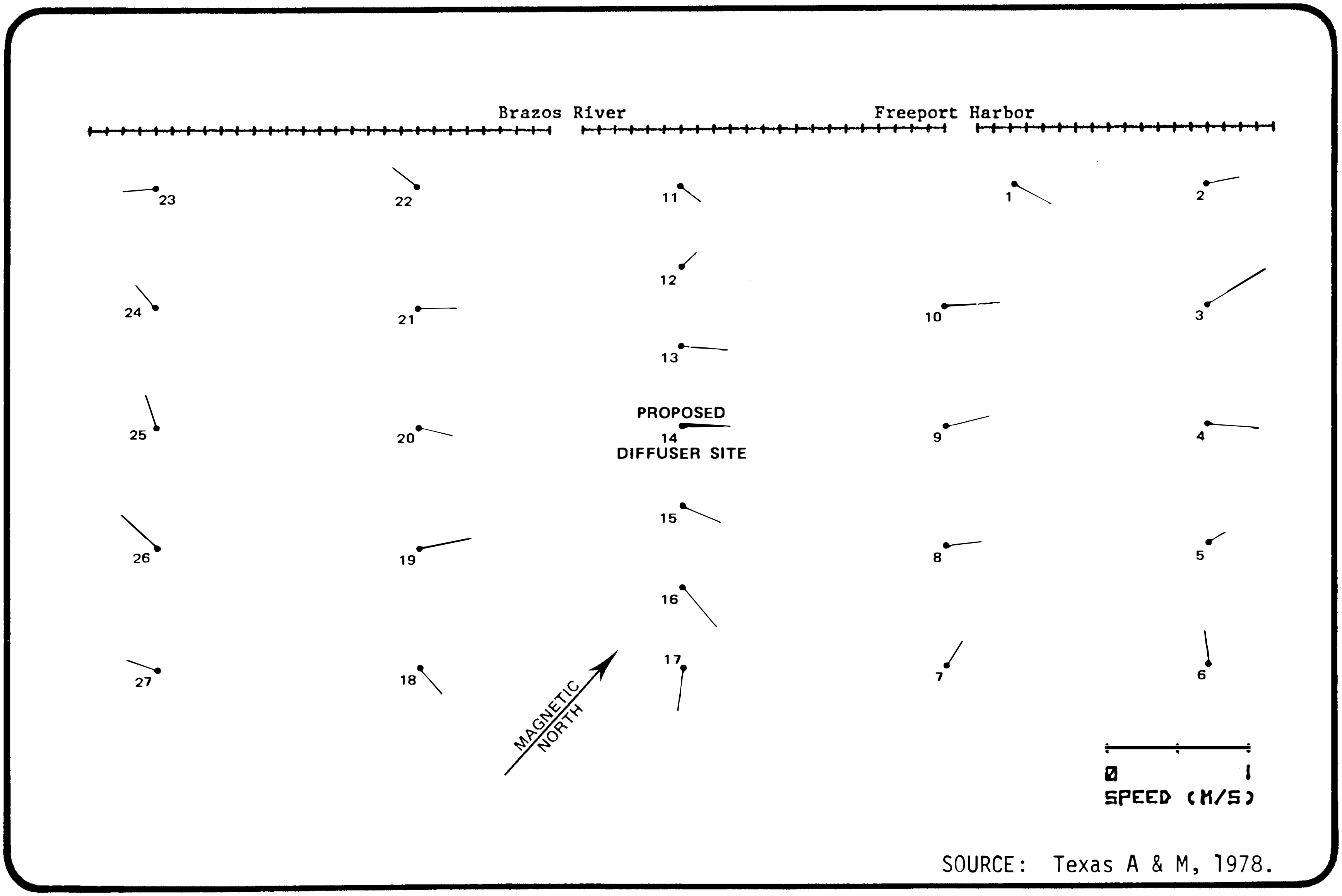
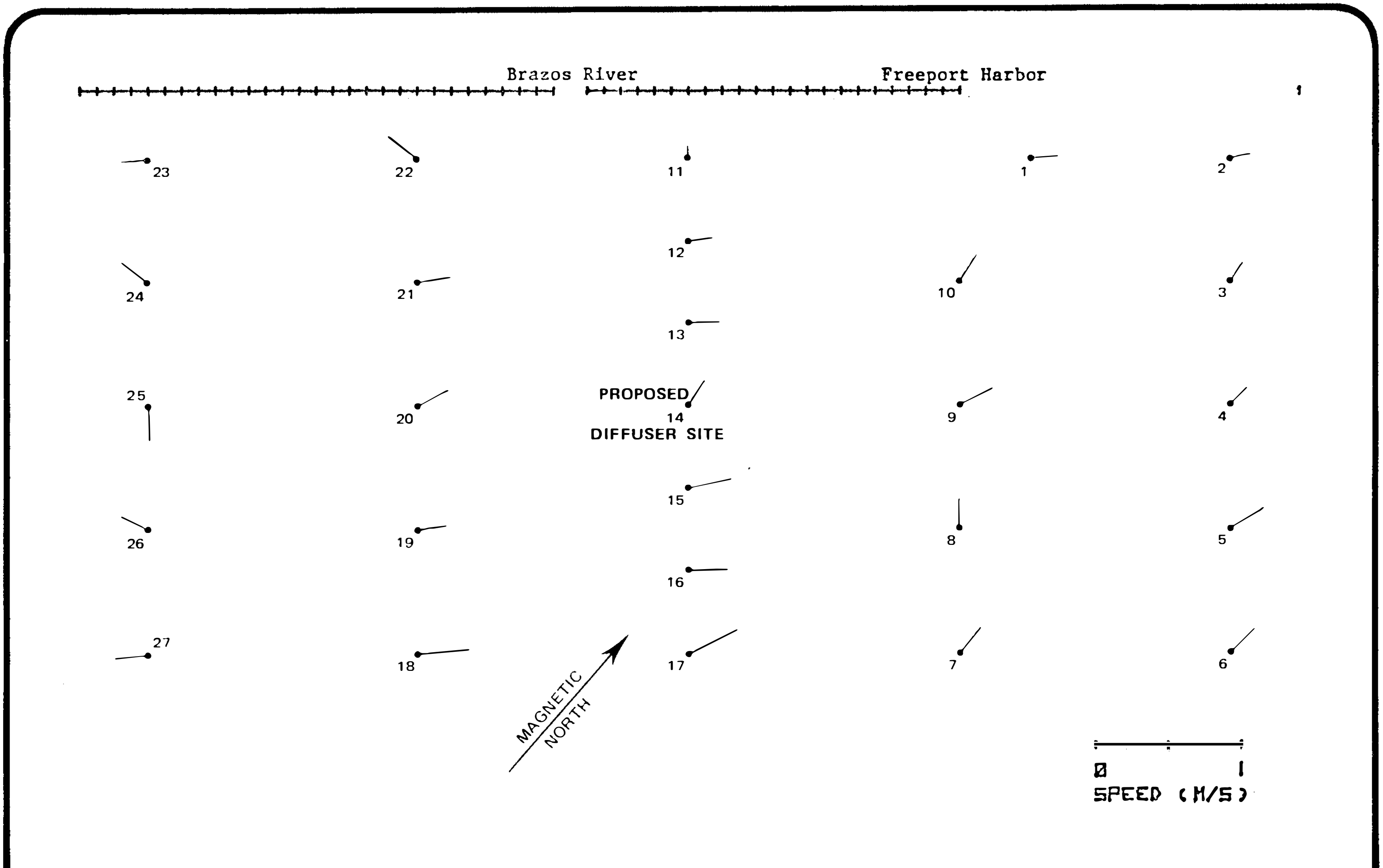


FIGURE G.2-22 Mid-depth currents (7-30 ft.). Stations 1 through 21 sampled 0825 to 1610 hours, December 18, 1977; stations 22 through 27 sampled 0905 through 1110 hours, December 19, 1977.



SOURCE: Texas A & M, 1978.

FIGURE G.2-23. Bottom currents (7 ft. from bottom). Stations 1 through 21 sampled 0825 to 1610 hours, December 18, 1977; stations 22 through 27 sampled 0905 through 1110 hours, December 19, 1977.

G.2.2.3.2.2 Fixed Current Meter Measurements

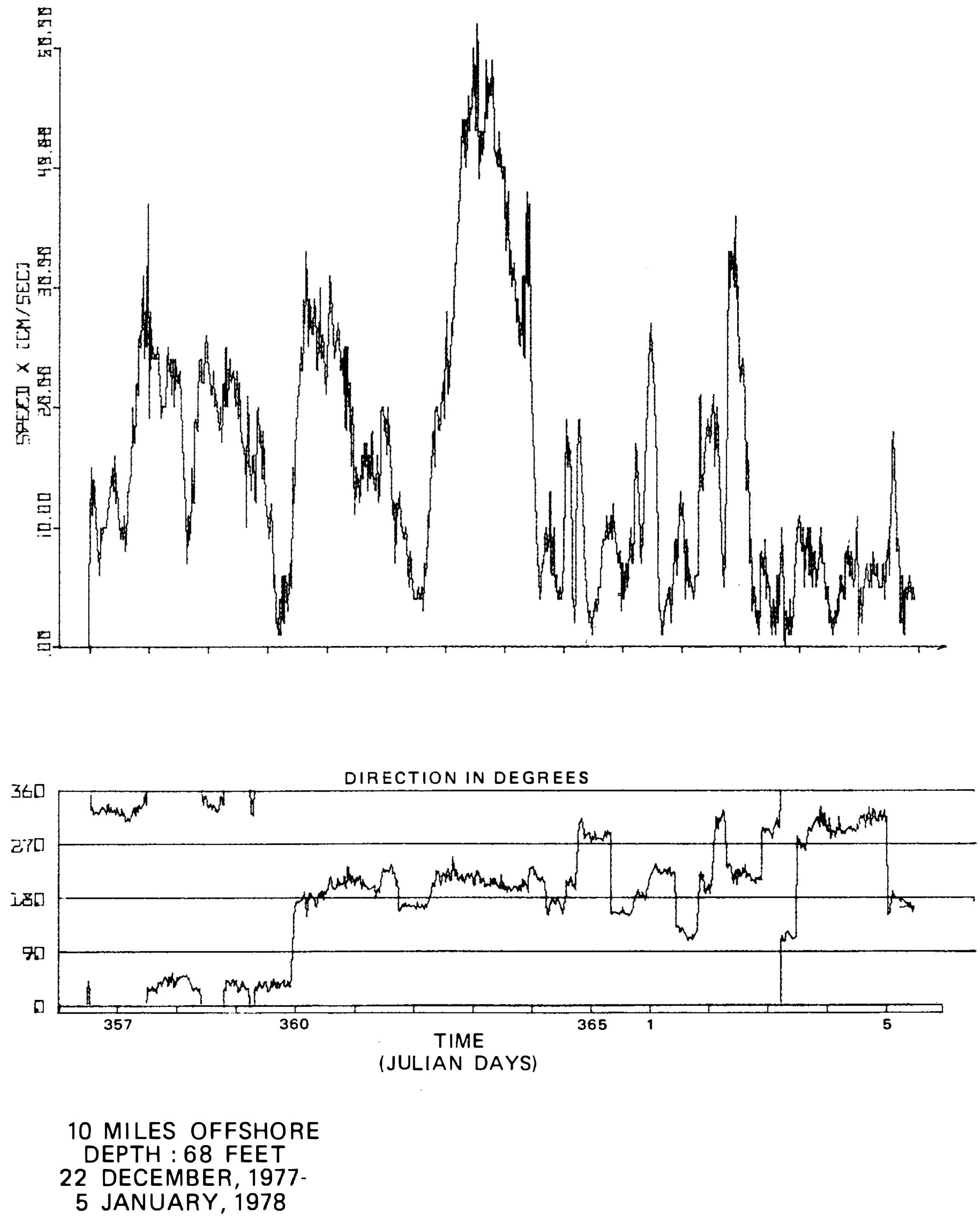
Observed Currents

Analysis of a current speed histogram and directional plot, (Figure G.2-24) developed from in situ current meter measurements taken at the alternative site 10.9 nautical miles offshore in 68 feet of water, showed that speeds ranged from 0 to 53 cm/sec (1 knot), but most frequently the speed was between 5 and 30 cm/sec. Only one instance of a rotary tide (Julian days 2 to 3) was observed, when the current speed was very low. The predominant direction of current flow is to the south; one continuous event was noted which extended over a period of five days (Julian days 360 through 365). At the beginning of the record, the currents flowed generally in a northerly direction for several days.

Velocity Scatter Plots

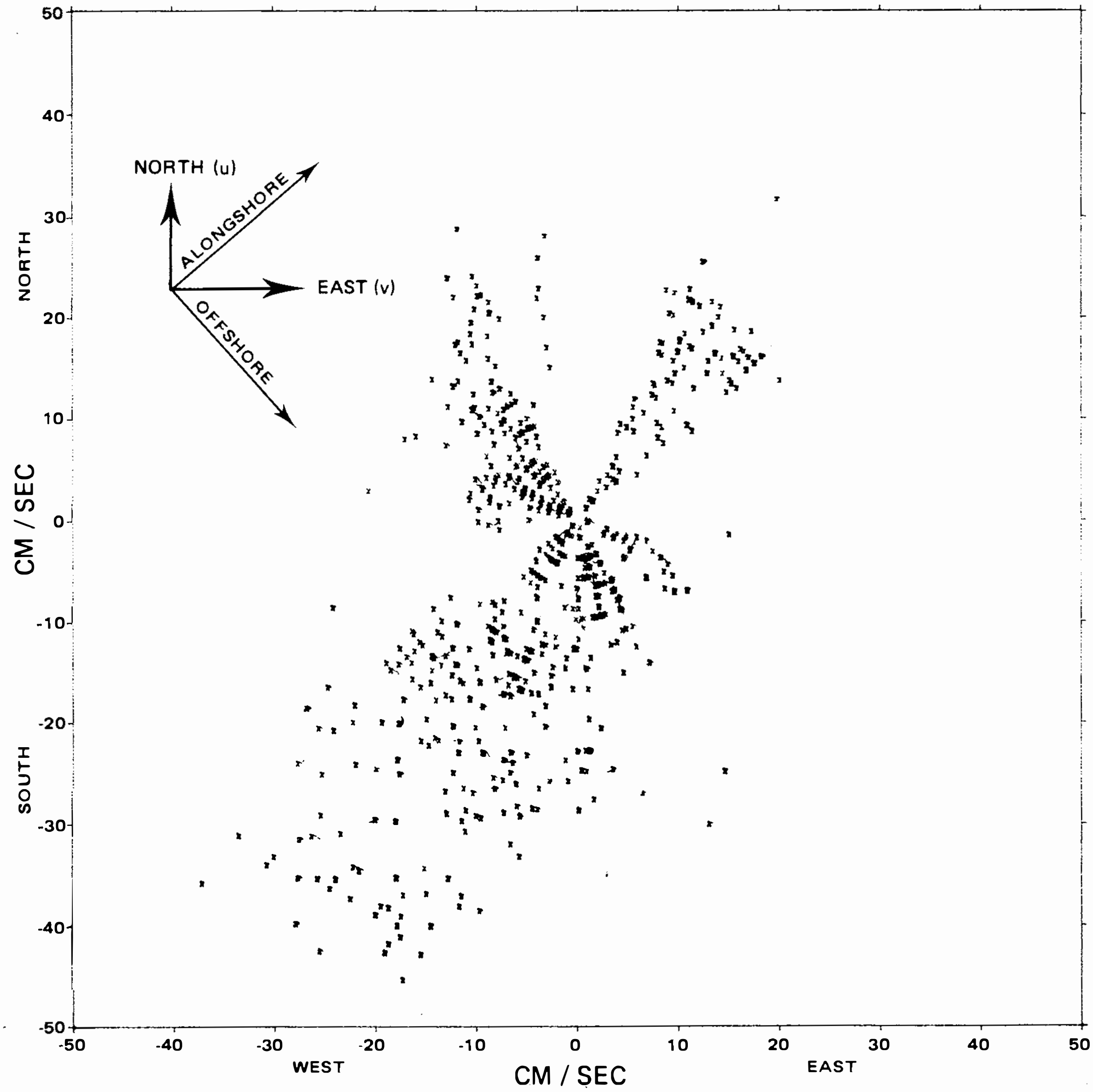
A scatter plot of half-hourly current velocities (u is positive northward, v is positive eastward) is shown in Figure G.2-25. Scatter plots can be used to evaluate current meter behavior, and "the presence of a 'hole' around the zero speed point may indicate a tendency for high measured speeds in low flow conditions (i.e., high starting speeds or wave-induced contamination" (Beardsley, Boicourt and Huff, 1977). Similarly, the presence of a "hole" in the band in the ESE-WSW quadrant (355^o to 21^o; 55^o to 35^o and 241^o to 260^o) without any speed or directional data points indicates a directional malfunction in the current meters. These holes may be attributed to 1) proximity of the meter to metalic anchors or weights, which would affect the magnetic compass or 2) an unbalanced meter since meter specifications suggest a maximum tilt of 15^o or directional measurements will be adversely affected. These differences will influence the orientation of the principal axis, although it may be affected by other factors.

The scatter plot exhibits a broad ellipse, with the greatest concentration of points falling in the southwest quadrant. The principal axis of the ellipse closely parallels the shoreline and the offshore bathymetry and trends in a northeast-southwest direction.



SOURCE: Texas A & M, 1978.

FIGURE G.2-24. Speed histogram and directional plot of currents. (Data taken from alternative diffuser location).



10 MILES OFFSHORE
DEPTH : 68 FEET
22 DECEMBER, 1977-
5 JANUARY, 1978

SOURCE: Texas A & M, 1978.

FIGURE G.2-25. Velocity scatter plot. (Data taken from alternative diffuser location).

Mean Currents

Current speeds were filtered using a 49-point running average and the data developed to present the average velocity vector for every sixth hour (Figure G.2-26). The average velocities ranged from less than 5 cm/sec (stagnation) to approximately 40 cm/sec. The predominant flow direction was alongshore to the southwest. This behavior persisted during the major portion of the record (December 26, 1977, to January 3, 1978; Julian days 360 through 2). During the early portion of the record, the stick diagram shows a strong northward flow; a very weak onshore flow occurred during the final day and a half.

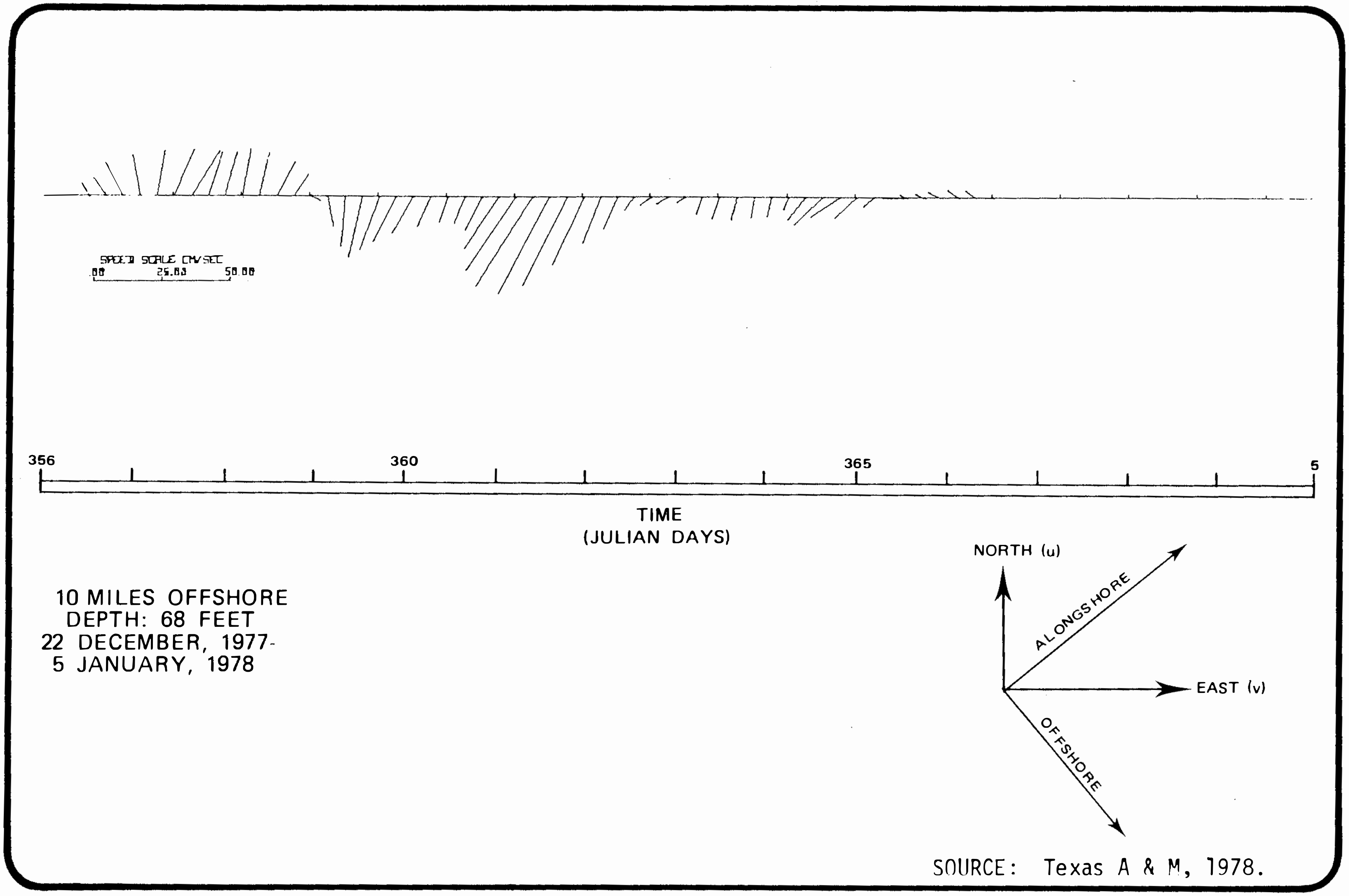
Progressive Vector Diagrams

A progressive vector diagram (PVD) is constructed by integrating in time each half-hourly velocity vector. Particular care must be taken in the interpretation of a PVD, because it does not represent the mean drift direction. In the absence of a drift current, tidal forces become predominant and produce a flow pattern of overlapping loops with little or no net displacement. As the strength of the drift current increases, the loops become separated and may disappear entirely if the drift velocity prevents a tidal reversal.

The PVD (Figure G.2-27) shows a consistant alongshore drift. During the first 4 days (Julian days 356 to 360) the drift was toward the northeast shifting to the southwest for the remiander of the record. The drift current predominates throughout the record without any rotary tidal cycles evident.

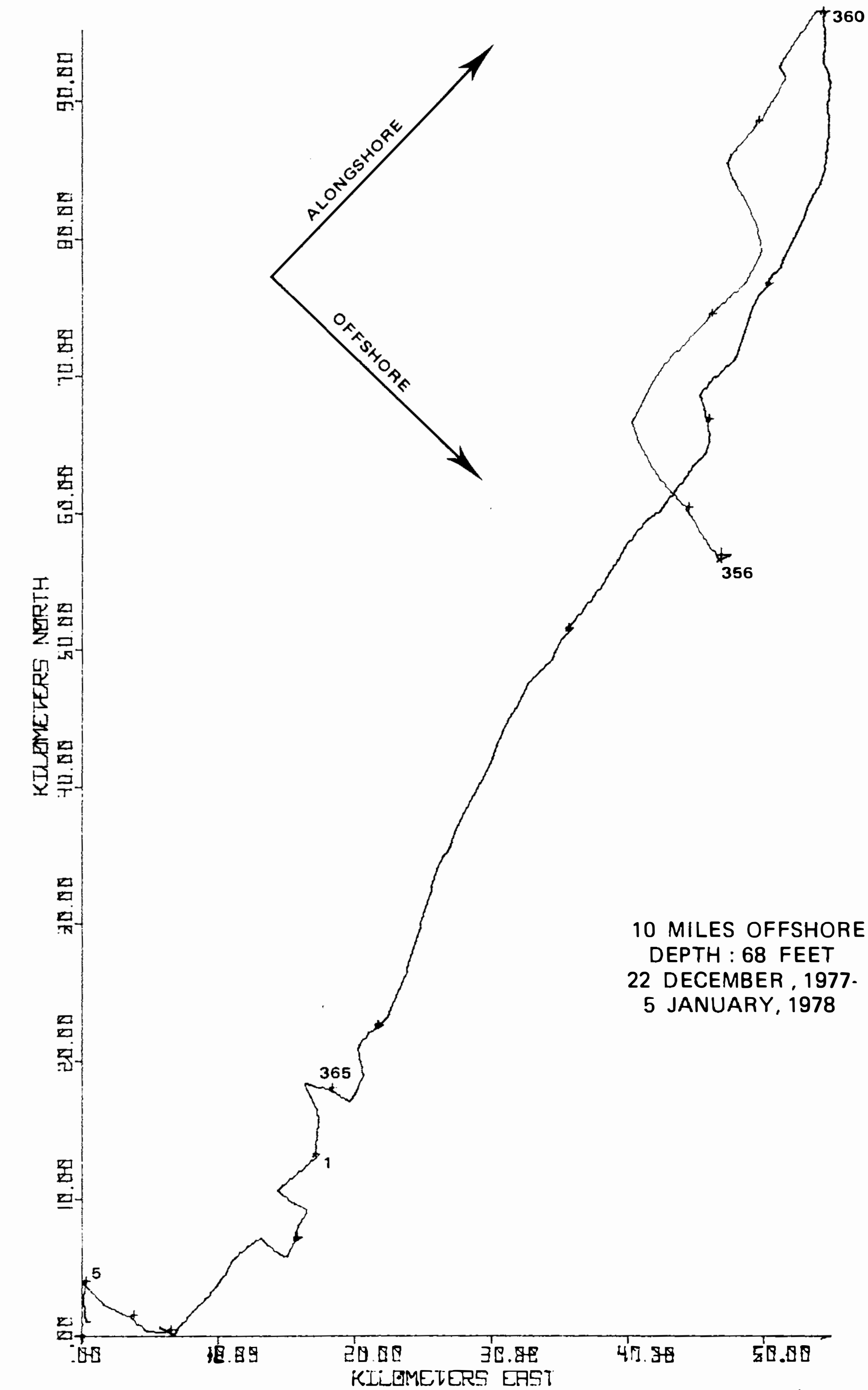
G.2.2.4 Waves and Tides

The distribution of wave heights during the year closely follows wind velocity. Minimum wave heights occur during July and August; maximum wave heights occur from December through February. Generally, wave heights increase from north to south along the coast and in a seaward direction for all months. Waves greater than 11 feet have been observed during all months (Figure G.2-28). Wave heights greater than 20 feet have been observed from September to April and in June. Significant (average of the highest one-third waves) wave heights as discussed



SOURCE: Texas A & M, 1978.

FIGURE G.2-26. Average velocity stick diagram. (Data taken from alternative diffuser location).



SOURCE: Texas A & M, 1978.

FIGURE G.2-27. Progressive vector diagram. (Data taken from alternative diffuser location).

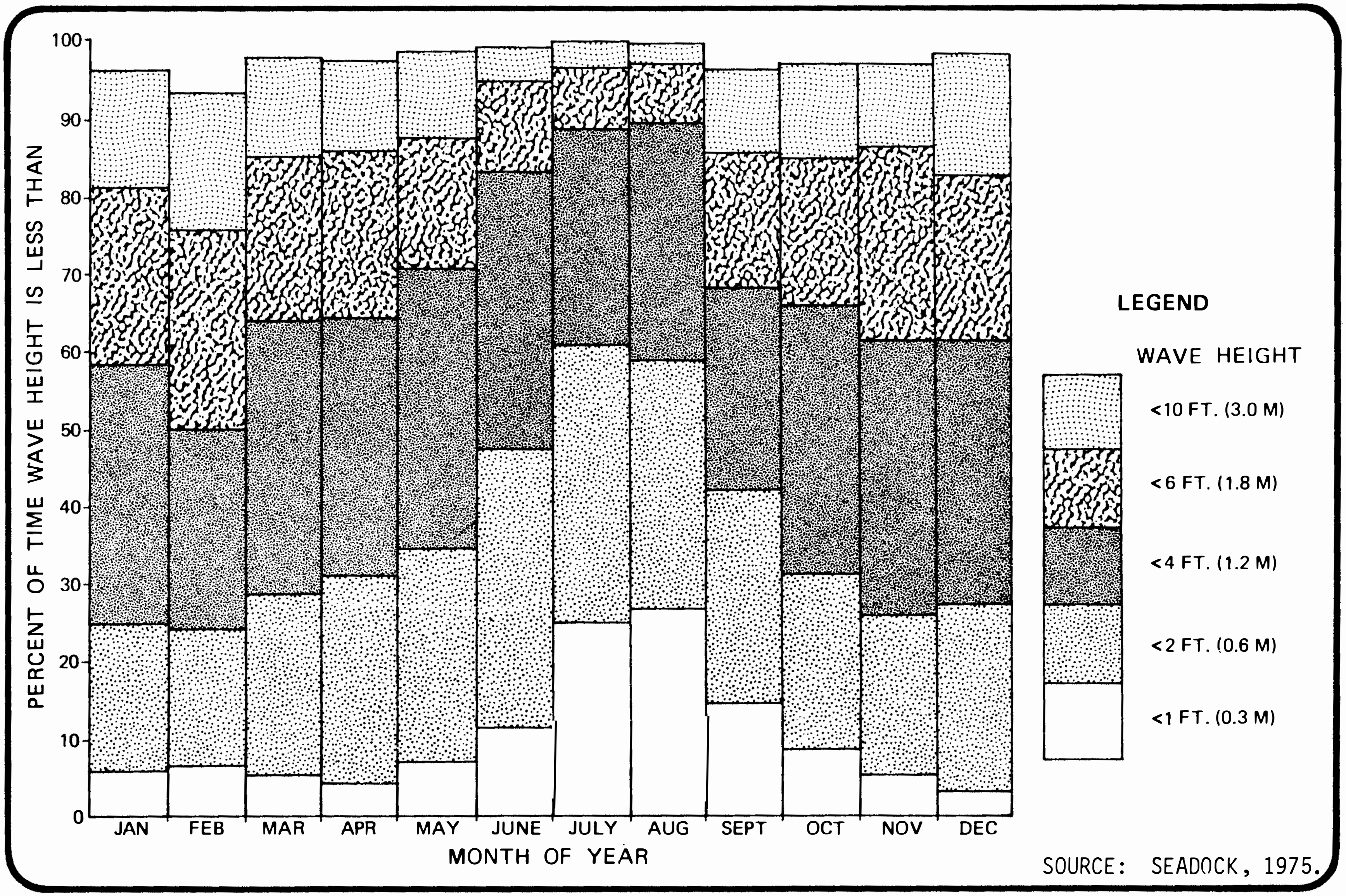


FIGURE G.2-28. Monthly occurrence of waves off Galveston, Texas.

by Brower et. al. (1972) for the Galveston-Freeport area and statistical estimates indicate the following predictions for the proposed diffuser area:

Mean Recurrence Interval	5 year	10 year	25 year	50 year
Maximum Significant Wave Height (feet)	29	32	37	41

These predicted values would be expected only in deep water areas; in shallow waters wave height would be limited to about 0.78 of the water depth because of the affect of this area to produce breaking in high waves.

Observations collected by the National Climatic 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 (U.S. Dept of Commerce, 1976). But these median heights are biased since it is recognized that reporting ships tend to avoid areas with severe weather or high waves.

Tides at Freeport Harbor are predominantly diurnal, and the predicted tidal range is 1.8 feet (U.S. Dept. of Commerce, 1977e). Near the diffuser site, tides have a vertical range of about 3 feet. Tidal velocity over the shelf (including the diffuser site) is approximately 0.5 knots (0.8 ft/s), but increases by several times near some Bay entrances.

Moderate winds can produce fluctuations in the tidal range of up to 3 feet in shallow estuaries along the Gulf Coast. Hurricanes can produce surges of up to 15 feet. Seiching action in the bays is common and is usually induced by winds; however, changes in barometric pressure can also modify the water levels.

The controlling dynamics of the tide in the western Gulf are not well understood. The predominant diurnal tide is thought to be caused by cooscillation with the Atlantic (Zetler and Hansen, 1972). Platzman (1972) feels that the hypothesis of resonant oscillation with diurnal forcing may be valid.

G.2.2.5 Sediments

G.2.2.5.1 Regional Stratigraphy

Surficial sediments of the northwestern Gulf of Mexico consist of a blanket of Holocene (Recent) sands, silts, and clays. The Holocene sediments overlie the Pleistocene Prairie formation and are divided into two facies - the basal nearshore sands and the shelf facies (muds, silty clays, and clayey silts). The basal sands were deposited during the marine transgression following the Wisconsin glaciation. These sands are exposed at the surface close to shoreline and across most of the continental shelf off of eastern and southern Texas and western Louisiana. The shelf facies overlie the basal sands off the central portion of Texas and most of Louisiana. The thickness of these Holocene sediments is generally less than 20 feet in areas where the basal sands have not been buried by the shelf facies.

Texturally, about half of the bottom sediments are polymodal mixtures of various sediment masses deposited on the shelf during the alternating periods of postglacial activity. These bottom sediments have either been reworked by burrowing organisms or by storm surges associated with hurricane waves. The sandy sediments off the central Texas coast are orthoquartzites. Frequently the sediments contain a mixture of shallow and deep shelf faunas. The outer shelf silty clays contain sand-sized foraminifera and echinoid fragments. Glauconite is an abundant constituent of the relict basal sands in the outer shelf (Curray, 1960).

G.2.2.5.2 Local Lithology

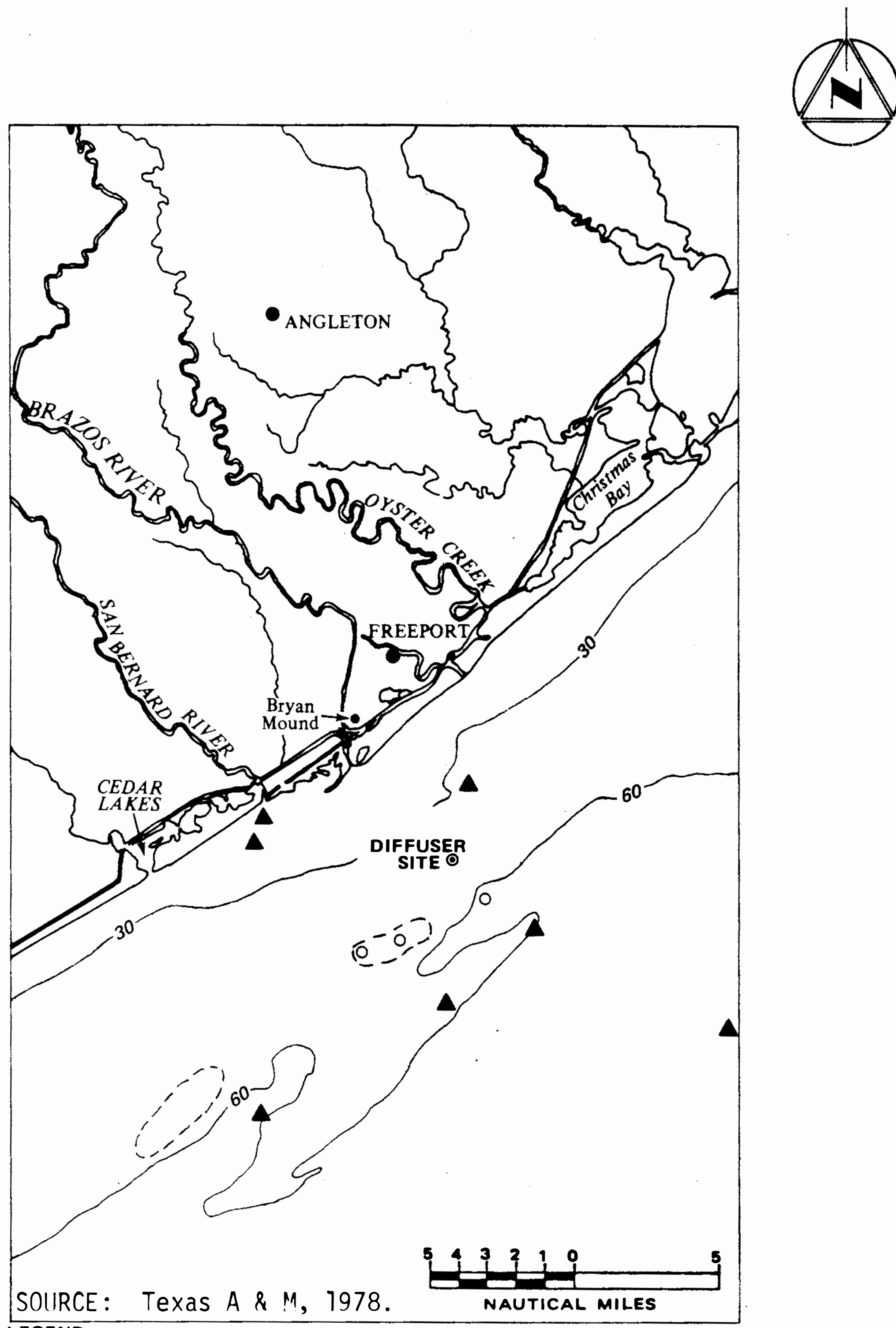
Recent sediments in the lower Brazos River and Galveston Island areas are presently being deposited on the late Pleistocene Prairie formation (Bernard, Major, Parrott and LeBlanc, 1970). The thickness of the early and late Recent sediments is reported to range from a few feet to 50 feet along the coast between deltaic areas, and from a few feet to 30 feet on the shelf off the interdeltaic areas (LeBlanc and Greenman, 1953; Greenman and LeBlanc, 1956). Curray (1960) states that:

> A plume of modern shelf facies of silty clay extends offshore and to the west from the mouths of the Colorado and Brazos Rivers at about Longitude

> 96^{o}. The outer edge of this plume lies at a maximum depth of 15 fathoms and a maximum distance of 21 miles from shore. Any deposition outside of this plume edge is apparently slow with respect to the rate of activity of the burrowing organisms, so that it is being reworked into the sandy sediments of the basal facies. The maximum rate of sedimentation of these shelf muds must then lie within the plume, i.e., not farther than 21 miles from shore, and probably nearer to the center of the plume, approximately 10 miles from shore.

The proposed brine diffuser site is located on the subaqueous delta of the Brazos River; sediments are primarily firm clays overlain by a thin layer of very soft silt, which may shift during periods of stormy weather. The clays at the shallower sampling stations are red, gray, or, if bioturbation has been extensive, mottled red-gray; gray clay occurs at the deeper stations.

Mattison (1948) reported that four groups of coral heads were located 8 miles off the Brazos River. These groups varied from 36 feet to 48 feet in depth and rise from 12 to 18 feet from the surrounding depths. A total of 10 heads were found in three of the groups which had a distance of about 2 miles between the groups. Coral reefs require definite limited conditions for growth, such as clear water, water temperature of about 70^{o}F and high salinities. Corals cannot tolerate low salinities and are killed by freshwater. For these and other reasons it is not expected that the coral heads reported by Mattison are actively growing heads. These coral heads fall within the fishing areas known as East Bank, Middle Bank, and West Bank. These three sites have also been recorded as locations where shrimpers have snagged their nets (Graham, 1973). The west coral head reported by Mattison, the West Bank fishing area reported by Graham, and a mound located during a 1973 geophysical survey (SEADOCK, 1975) are in the same area (Figure G.2-29).



LEGEND

▲ SHIPWRECKS FROM USC & GS CHART 1117

( ) LOCATION OF GOOD FISHING AREAS FROM OFFSHORE FISHING CHART

O CORAL HEADS FROM SEADOCK, 1975

FIGURE G.2-29. Locations of coral heads, shipwrecks, and fishing areas (depths contours in feet).

G.2.3 CHEMICAL OCEANOGRAPHY

At the proposed diffuser site, water chemistry (for example, dissolved oxygen (DO), pH balance, nutrients, organic carbon, trace metals, hydrocarbons and suspended matter) is strongly influenced by the seasonal variability in the discharges of the Brazos and San Bernard Rivers, by the exchange processes with adjacent bays, and by *in situ* degradation processes.

G.2.3.1 Dissolved Oxygen and pH Balance

Dissolved oxygen levels in the area of the proposed diffuser are generally above 5.0 milligrams per liter (mg/l) (SEADOCK, 1975). Occasionally low DO values were measured near the bottom of the water column during the warm seasons of the year (Table G.2-8); however, these low levels did not persist for long periods. Two SEADOCK stations (Nos. 22 and 28, Figure G.2-30) showed oxygen values of less than 5 mg/l during more than one season. In the vicinity of the proposed diffuser site, DO levels of 7.5 to 8.0 mg/l were measured in the spring (FEA, 1977b) and oxygen levels were relatively homogeneous throughout the water column.

Five-day biochemical oxygen demand (BOD) values in the water column were low and usually less than 3 parts per million (ppm); sediment BOD values were higher than those of the water column (Table G.2-8). During the summer at SEADOCK Station 28 near the proposed diffuser site, BOD values were less than 1 ppm for surface and mid-water samples, and 2 ppm for bottom samples. The highest sediment BOD value was 340 ppm measured at the 0-8 cm interval. Sediment chemical oxygen demand (COD) ranged from 1800 to 24,000 ppm offshore and 400 to 16,000 ppm nearshore. The BOD and COD values reported for the diffuser area (Table G.2-8) are not unusual for coastal waters (SEADOCK, 1975).

Alkalinity values range from 106 to 140 mg/l in nearshore waters and from 124 to 146 mg/l in offshore waters. At the diffuser site (SEADOCK Station 28) alkalinity measurments averaged about 133 mg/l (Table G.2-8).

The water column pH in the study area is normal for coastal areas, and ranged from 6.3 to 9.0. At the diffuser site a pH of 8.4 was reported (FEA, 1977b). A pH value of 8.2 is normal for open ocean waters.

TABLE G.2-8 Dissolved oxygen and pH balance parameters at Stations in the vicinity of the proposed brine diffuser site.

	DO (mg/l)	BOD (ppm)	COD (ppm)	Alkalinity (mg/l)	pH	Eh
SPRING[a]						
Surface	6.5	<1		130		
Mid	6.8	<1		131		
Bottom	0.2	2		136		
Sed 0-8 cm		340	5800		7.3	+62
Sed 16-25 cm		250	8700			
SPRING[b]						
Surface	8.0				8.4	
Mid	7.5				8.4	
Bottom	7.5				8.4	
SUMMER[a]						
Surface	6.2					
Mid	5.7					
Bottom	4.9					
Sediment			11300		7.6	-73
AUTUMN						
Sed 0-10[c]					7.55	
Sed 10-20[c]					7.85	
Sed 20-30[c]					7.55	
Sed[d]					7.80	
Sed[e]					7.47	

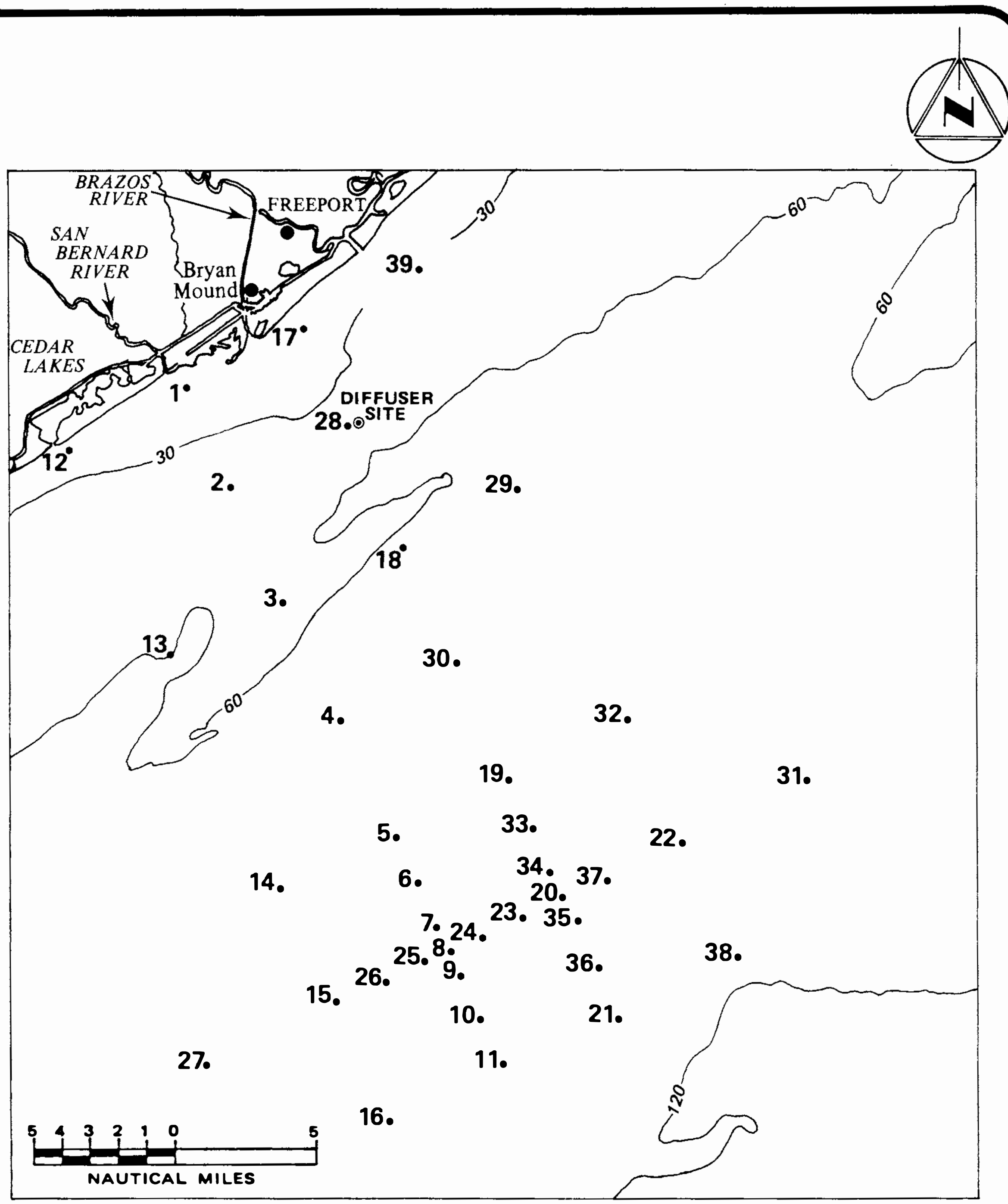
[a] SEADOCK, 1975; Station 28.

[b] FEA, 1977b; sampled at the proposed diffuser site.

[c] Texas A&M, 1978; mean of Stations L and N.

[d] Texas A&M, 1978; mean of sediment depths 0-40 cm, Station 9.

[e] Texas A&M, 1978; mean of sediment depths 0-30 cm, Station 20.



SOURCE: Texas A & M, 1978.

FIGURE G.2-30. SEADOCK study station locations (depth contours in feet).

The range of sediment pH values (6.0 to 9.3) is wider than those of the water column. Spring, summer, and fall sediment pH values at a station near the diffuser were 7.3, 7.6 and 7.65, respectively. The redox potential (Eh) values of +62 and -73, show that the sediment changed from an oxidizing environment in the winter and spring to a reducing environment in the summer (Table G.2-8).

G.2.3.2 Inorganic Nutrients and Organic Carbon

Inorganic nutrient (NH_3, NO_2, NO_3 and PO_4) levels in the water column of the study area (Table G.2-9) were often low, but increased in late winter. Low inorganic nitrogen values were found in the sediments; however, organic nitrogen (as measured by total Kjeldahl nitrogen) was present (SEADOCK Station 28) in the sediment at levels ranging from 360 to 405 ppm. Sediment phosphate values were also higher than those measured in the water column.

Total organic carbon (TOC) in the offshore and nearshore waters of the region off Freeport, Texas ranged from 1 to 30 ppm with most samples, including those near the diffuser site, containing 10 ppm or less. Organic material measured regionally in the sediment, in percent of volatile solids, ranged from about 1 to 8 percent in nearshore and offshore areas. Samples obtained near the diffuser location were generally in the middle of this range (SEADOCK, 1975). Means of other sediment values at the proposed site (Texas A&M, 1978), ranged from 6.2 to 6.8 percent volatile solids and 0.53 to 0.71 percent organic carbon. In a study of the Buccaneer Oil Field, 36 miles northeast of the diffuser site (U.S. Dept. of Commerce, 1977b), sediment TOC ranged from 0.1 percent to just under 1 percent with a mean of 0.33 percent (U.S. Dept. of Commerce, 1977b).

G.2.3.3 Heavy Metals

Heavy metal concentrations have been measured in various studies in the vicinity of the brine diffuser site. These results are presented in Table G.2-10. Sources of trace metals in coastal marine waters are generally land erosion, runoff, and industrial or municipal discharges.

TABLE G.2-9 Inorganic nutrient and organic carbon parameters at stations in the vicinity of the proposed diffuser site.

	NH_3 (ppm)	NO_2 (ppm)	NO_3 (ppm)	Total Kjeldahl N (ppm)	PO_4 (ppm)	TOC (ppm)	% Volatile Solids	% Organic C
SPRING[a]								
Top	<0.01	<0.01	0.02		<0.1	3		
Mid	<0.01	<0.01	0.02		<0.1	9		
Bottom	<0.01	<0.01	0.03		<0.1	4		
Sed 0-8 cm		<0.03	<0.02	360	2.9		4.8	
Sed 16-25 cm		<0.03	<0.02	405	4.8		2.3	
SUMMER[a]								
Top	<0.01	<0.01	<0.01		<0.1	10		
Mid	<0.01	<0.01	<0.01		<0.1	8		
Bottom	<0.01	<0.01	<0.01		0.2	10		
Sediment		0.44	8.5	365	1.6		4.7	
AUTUMN								
Sed 0-10 cm[b]							6.2	0.69
Sed 10-20 cm[b]							6.35	0.71
Sed 20-30 cm[b]							6.8	0.61
Sed[c]							5.13	0.53
Sed[d]							5.87	0.65

[a] SEADOCK, 1975; Station 28.

[b] Texas A&M, 1978; mean of Stations L and N.

[c] Texas A&M, 1978; mean of sediment depths 0-40 cm, Station 9.

[d] Texas A&M, 1978, mean of sediment depths 0-30 cm, Station 20.

TABLE G.2-10 Heavy metal concentrations from various studies in the vicinity of the proposed Bryan Mound brine diffuser site.

		As	Ba	B	Cd	Cr	Cu	Ag	Fe	Pb	Mn	Hg	Ni	Sb	Se	V	Zn	Ca	Mg
SPRING[a]																			
Surface	(ppb)						3.0			<1.0			<1.0				21.0		
Mid	(ppb)				0.5		3.3			<1.0			<1.0				19.0		
Bottom	(ppb)				0.2		1.3			<1.0			<1.0				14.0		
Sed 0-8 cm	(ppm)		79			15.0	10.0			21.0	303	0.036	19.0			16.0	42		
Sed 16-25 cm	(ppm)		13			8.0	9.0			13.0	39	0.070	66.0			2.0	135		
SPRING[b]																			
Surface	(μg/l)	<50	30	2760	8	60	18	<2		230	13	2.9	60	<10	<80		120	332.0	1150.0
Mid	(μg/l)	<50	30	2800	8	60	18	<2		230	13	2.4	70	<10	<80		120	336.0	1157.0
Bottom	(μg/l)	<50	30	3700	6	90	17	<2		220	13	2.1	70	<10	<80		120	328.0	1150.0
SUMMER[a]																			
Surface	(ppb)				<0.1		1.1			4.2	<3.0		<1.0				1.6		
Mid	(ppb)				<0.1		<0.5			<1.0			2.6				4.8		
Bottom	(ppb)				<0.1		0.9			<1.0			<1.0				3.7		
Sed	(ppm)		71		0	17.0	9.0			20.0	260	0.059	10.0			11.0	48		
SUMMER[c]																			
Surface	(ppb)	<20			<1.0	<0.5	1.2	<0.5		2	1.6	0.2	4	<10	<20		5.3		
Mid	(ppb)	<20			<1.0	<0.5	1.6	<0.5		4	2.1	0.17	4	<10	<20		3.7		
Bottom	(ppb)	<20			<1.0	<0.5	1.2	<0.5		2	1.8	0.2	4	<10	<20		3.2		
AUTUMN[d]																			
Sed 0-10 cm	(mg/kg dry wt)[d]				<0.1	17.5	10.1		15035	7.7	517.5	0.11	31.0				54	26400	11750
Sed 10-20 cm	(mg/kg dry wt)[d]				<0.1	18.0	9.65		14355	7.35	470.0	0.08	27.5				51	26250	10450
Sed 20-30 cm	(mg/kg dry wt)[d]				0.14	23.0	10.45		17390	7.25	500.0	0.075	36.0				55.5	39450	16500
Sed	(mg/kg dry wt)[e]				<0.1	15.25	7.75		16198	5.75	401.25	0.070	25.0				45.25	21175	9925
Sed	(mg/kg dry wt)[f]				<0.1	18.33	8.9		17970	6.2	478.33	0.070	29.67				51.0	30667	10767

[a] Station 28; Seadock, 1975.

[b] Sampled at the proposed diffuser site, total metals; FEA, 1977.

[c] Sampled at the proposed diffuser site, dissolved metals; FEA, Personal Communication.

[d] Mean of Stations L and N; Texas A&M, 1978.

[e] Mean of sediment depths 0-40 cm, Station 9; Texas A&M, 1978.

[f] Mean of sediment depths 0-30 cm, Station 20; Texas A&M, 1978.

Ranges of dissolved metals (in parts per billion) in the nearshore and offshore areas of the waters off Bryan Mound are (SEADOCK, 1975):

(ppb)	Cd	Cu	Hg	Ni	Pb	Zn
Offshore	<0.1-2.4	<0.3-8.5	<0.2-1.3	1-19	<1-12	<1-59
Nearshore	<0.1-2.7	<0.5-8.9	<0.1-0.7	<1-9	<1-4.5	5-50

Concentrations observed for these metals are in the range normally expected for coastal waters. Water column dissolved metal levels at the diffuser site (spring and summer, SEADOCK; summer, FEA; Table G.2-10) were at the lower end of the ranges presented above. However, total metal concentrations (spring, FEA; Table G.2-10) were generally one to two orders of magnitude greater than the dissolved values. Sediment metal concentrations at the diffuser site, as expected, were greater than dissolved metal values, but these values also fall within the range of sediment metals reported (in parts per million) for offshore and nearshore stations (SEADOCK, 1975):

(ppm)	Ba	Cr	Cu	Pb	Mn	Hg	Ni	Zn	V
Offshore	4-310	7-29	4-35	6-25	39-545	<0.01-0.14	9-66	19-66	<1-28
Nearshore	2-199	1-45	1-15	2-30	62-673	<0.01-0.068	<1-45	8-53	2-24

Sediment metal values from the Buccaneer Oil Field area (U.S. Dept. of Commerce, 1977b) offshore of Galveston, are generally lower than, or within range of, the values obtained in the studies near the brine diffuser site. Concentrations of heavy metals in organisms were also investigated and the results, as well as those from the Bureau of Land Management's South Texas Outer Continental Shelf Study, are presented in Table G.2-11. In most cases these results show that the plankton had the highest metal levels, which is partially due to these small organisms having a large surface area to mass ratio; while fish and shrimp had the lowest metal values. These metal values are within the expected range for coastal marine organisms.

TABLE G.2-11 Heavy metal concentration in organisms collected from the Texas coast.

ppm		Cd	Cr	Cu	Mn	Pb	Zn
USDC/NOAA							
Barnacles	Avg.	19.2	2.70	18.20	10.62	7.8	200.8
	Range	11.0-25.0	<0.1-64.25	12.5-27.25	5.5-18.5	3.5-11.5	151.5-281.0
Shrimp	Avg.	0.8	<0.1	25.8	1.75	4.6	108.0
	Range	0.5-1.5	0-<0.1	23.0-46.5	0.5-3	2.0-8.5	99-123
Fish	Avg.	<0.1	5.9	2.6	<0.1	<0.1	41.60
	Range	0-<0.1	<0.1-61.75	0.5-5.5	0-<0.1	0-<0.1	24.25-85.5
Fish Liver	Avg.	6.4	6.6	72.8	4.8	9.1	86.8
	Range	<0.1-15.25	<0.1-26.25	25.0-154.0	1.5-7.75	6.0-13.5	25.5-130.75
Plankton	Avg.	<0.1	88.3	78.0	82.1	334.3	222.75
	Range	0-<0.1	55.25-120.25	47.25-100.0	57.0-101.0	185.25-469.0	205.5-234.25
Squid	Avg.	<0.1	2.75	15.0	2.0	4.5	60.5
	Range	0-<0.1	2.5-3.0	13.0-17.0	1.5-2.5	4.25-4.75	53.7-67.25
USDI/BLM							
Shrimp	Avg.	0.12	2.1	24.3	--	0.95	47.90
	Range	0.05-0.33	0.4-3.8	22.5-28.5	--	0.6-1.8	20.5-57.5
Fish	Avg.	0.11	1.30	0.66	0.18	1.30	10.2
	Range	0.05-0.21	1.0-2.0	0.5-0.9	0.1-0.3	0.3-2.9	0.6-11.7
Fish Liver	Avg.	3.7	2.2	14.7	3.4	2.8	146.4
	Range	0.7-6.1	2.0-2.2	9.0-15.0	3.0-4.7	1.0-7.6	100.0-268.0
Plankton	Avg.	4.72	18.0	14.2	--	42.4	134.1
	Range	0.86-5.25	1.9-82.0	2.7-61.0	--	3.1-474.0	26.5-560.0
Squid	Avg.	1.03	4.7	65.70	--	2.0	144.0
	Range	0.91-1.18	3.0-6.1	61.0-69.0	--	1.3-2.7	50.0-290.0

SOURCE: U.S. Department of Commerce, 1977b.

G.2.3.4 Hydrocarbons

Hydrocarbons in marine waters can be derived from a variety of sources including plant and animal decomposition, terrestrial runoff, natural seepage, atmospheric fallout, shipping, and offshore production activities. A high hydrocarbon content might be expected in the coastal waters of the Gulf of Mexico because of the high oil production activity, vessel traffic, and river discharge. However, hydrocarbon levels measured in the coastal Gulf of Mexico are the same order of magnitude (less than 10 ppb at the surface and much lower in deeper waters) as those found in open ocean waters. Parker, Winters and Morgan, (1972) found n-alkane levels of 0.2 ppb in East Bay, Louisiana, 0.1 ppb 15 miles off Corpus Christi, Texas, and 0.63 ppb near a burning oil rig 15.5 miles southwest of Point Au Fer, Louisiana.

The types of hydrocarbons found in the Gulf of Mexico are dominated by the saturated hydrocarbons and usually contain low concentrations of aromatic hydrocarbons. Nonvolatile hydrocarbons were found in the range of 1 to 12 ppb; aromatics ranged from 1 to 3 ppb with many samples containing undetectable levels. The levels of paraffin compounds (indicative of biogenic hydrocarbons) in samples were elevated, with the most abundant compound being single ring naphthenes (Brown, Searl, Elliot, Phillips, Brandon, and Monaghan, 1973).

Total n-alkane levels in the Buccaneer Oil Field study ranged from 0.7 to 24.8 ppb; bottom waters had greater n-alkane concentrations than surface waters. Surface water samples, however, contained petroleum-derived n-alkanes, while in bottom water samples n-alkanes were probably of bacterial origin.

Oil and grease concentrations at the diffuser site were less than 0.3 ppm during spring and summer throughout the water column (SEADOCK, 1975) and were 2.5 ppm in surface and mid-waters and 2.2 in bottom waters during the fall (FEA, 1977b). These values increase toward the shipping lane 14 nautical miles offshore, suggesting that a major source of dissolved oil and grease in this region may result from heavy ship traffic. Phenol levels were 9 ppb in surface waters and 8 ppb in mid and bottom waters (FEA, 1977b). Sediment oil and grease levels have been reported to range from 151 to 235 ppm (SEADOCK, 1975) and 150 to 3900 ppm (Texas A&M, 1978); samples from the latter study are being reanalyzed.

G.2.3.5 Suspended Matter

Suspended matter in coastal waters is usually variable due to large changes in the sediment load, flow of the rivers, and offshore wave action which can resuspend the sediments in the water column. Total suspended solids (TSS) was lower during the spring sampling period than during the summer sampling. However, a greater turbidity and lower Secchi depth (depth at which a 30-centimeter white disk disappears from view) were found in the spring at the diffuser site (SEADOCK Station 28) than in the summer (Table G.2-12). Low total suspended solids and Secchi depths versus high turbidity and vice versa have been found in other coastal regions. These discrepancies may result from differing methods; Secchi disk and turbidity readings depend on optical techniques which may vary with the orientation and type of biogenic matter present whereas total suspended solids, which is measured gravimetrically, would not. Higher spring TSS values during the FEA spring sampling may have resulted from the study being conducted during a freshet.

G.2.3.6 Summary

Dissolved oxygen are generally above 5.0 mg/l but occasionally are low in bottom waters during the warm seasons. Nutrient levels (NH_3, NO_2, NO_3 and PO_4) in the water column near the diffuser site are often low but increase in concentration during the late winter. Heavy metals in the water column, sediments and organisms are within the range expected for coastal regions. Oil and grease concentrations increase from the proposed diffuser site out to the offshore shipping lanes. Suspended matter varies seasonally due to river input and biological productivity.

TABLE G.2-12 Suspended sediment parameters in the vicinity of the proposed brine diffuser site.

	TSS (mg/l)	Turbidity (FTU)	Secchi depth (meters
SPRING [a]			7.5
Surface	10	7.0	
Mid	0	3.3	
Bottom	0	14.0	
SUMMER [a]			12.2
Surface	35	0.2	
Mid	40	0.3	
Bottom	35	32.0	
SPRING [b]			
Surface	13		
Mid	14		
Bottom	25		

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[a]FEA, 1977 Sampled at the proposed diffuser site.

[b]SEADOCK, 1975; Station 28.

G.2.4 BIOLOGICAL OCEANOGRAPHY

G.2.4.1 Habitats and Biological Components

G.2.4.1.1 Abiotic Habitats

With the exception of the Brazos River delta and the region east of Bolivar Peninsula, the Texas coastline is protected by a series of low barrier islands. These islands enclose shallow (3 to 10 foot) bays that function as nursery grounds for many of the shrimps, crabs, and finfishes of commercial importance in Texas. Tidally influenced open bay areas have relatively high salinities that range from 20 to 35 ppt. In these tidal embayments, species diversity is relatively high and circulation is good. In comparison, the salinity in enclosed embayments is influenced largely by river inflow, and is therefore generally low and seasonally variable. The enclosed bays generally have low species diversity and poor circulation (FEA, 1977b).

The continental shelf, in the vicinity of the proposed brine diffuser, is broad, gently sloping, and generally flat. Within 10 to 12 miles of the coast, the water depths on the shelf vary from 5 to more than 60 feet. The sediments in this area of the shelf are highly variable and range from clays to sand and shell. Several inactive coral outcrops occur on the shelf, three of which occur near the study area just off the Brazos River mouth near the 10-fathom contour (Figure G.2-29).

Salinity values around the diffuser site are strongly influenced by two factors: the freshwater discharge from major rivers along the Texas coast, such as the Brazos River (5.23×10^6 acre-feet per year (ac-ft/yr)) and the Colorado River (1.54×10^6 ac-ft/yr) to the southwest, and the Trinity River (5.24×10^6 ac-ft/yr) to the northeast (SEADOCK, 1975); and the open waters of the Gulf of Mexico. It is in the neritic zone that the fresh and saline water masses meet and mix. Salinities in this zone seasonally range from 17 ppt to 32 ppt, while in the open Gulf, they approach 36.5 ppt. The water column is usually well mixed vertically in the winter, while in the summer it is weakly stratified. Water temperatures range from a low of approximately 55^{o}F in January to a high of almost 85°F in August. Many of the chemical constituent concentrations in the water column are typical for a neritic zone (FEA, 1977b).

Currents over the inner continental shelf near the diffuser site generally drift parallel to the coast. Current velocities range from 0.2 to 0.4 knots (5 to 37 cm/sec). The tides in this area are diurnal and have a vertical range of about 3 feet. Tidal velocity over the shelf is approximately 0.5 knots; however, near tidally influenced bay entrances, values of 3.7 knots have been recorded (FEA, 1977b).

G.2.4.1.2 Biological Components

The biological community inhabiting the inner continental shelf near the proposed diffuser site is typically highly productive. The primary producers (phytoplankton) in this region vary seasonally in both abundance and composition but generally consist of diatoms, dinoflagellates, and microflagellates. Phytoplankton cell densities progressively decrease seaward from the coast.

In the neritic zone, the zooplankton are seasonally dominated by the nauplii and copepods, in particular, *Acartia tonsa*. Zooplankton densities vary temporally and spatially. Zooplankton abundance peaks in late spring and early fall, and follows the pulse in phytoplankton abundance. Zooplankton numbers in the neritic zone also decrease seaward (FEA, 1977b).

Two benthic assemblages have been identified in the vicinity of the proposed brine diffuser: a high salinity, offshore community and a low salinity, nearshore community. The composition of offshore fauna in waters more than 5 miles from the coast, is generally stable, due to the relative stability in the environmental parameters such as temperature and salinity in these deeper waters. The offshore community is dominated by polychaetes. In the nearshore zone, temperature and salinity are highly variable over the year; thus, no dominant group in the nearshore assemblage has been identified.

Two major groups of fishes are found over the continental shelf: the inner shelf species include the Atlantic threadfin, Atlantic croaker, sand seatrout, and silver seatrout; and the intermediate shelf species include the longspine porgy, inshore lizard fish, Gulf butterfish, and several of the inner shelf species. In general, the intermediate shelf assemblage is more diverse than the inner shelf assemblage.

The three major commercial shrimp species found in the study area are the brown, white, and pink shrimp. The brown shrimp is considered the most important and abundant. In addition, the blue crab, menhaden, shad, mullet, sea catfish, and drum are actively fished (FEA, 1977b).

G.2.4.2 Plankton

G.2.4.2.1 Phytoplankton

The area's marine phytoplankton, which rely on water currents for movement, are predominantly unicellular algae. A major portion of the productivity of the Gulf of Mexico is the result of planktonic conversion of nutrients, such as nitrates, phosphates, water, and carbon dioxide, through the process of photosynthesis, into organic compounds. Phytoplankton have been considered "the grasses of the sea" because of their unique role in converting inorganic compounds into an energy source that can be used by the primary consumers, such as zooplankton, as well as by many filter-feeding organisms (oysters, clams, and fish). In turn, zooplankton are fed upon by other members of the food web including fish, whales, and filter-feeding benthic invertebrates.

The phytoplankton community of the Gulf of Mexico is both diverse and productive. Throughout much of the year, the diatoms dominate this community, with the dinoflagellates periodically codominating. The euryhaline conditions in the nearshore zone limit the number of species of dinoflagellates in this area (SEADOCK, 1975). Some of the most conspicuous genera found in the coastal Gulf waters include *Asterionella*, *Chaetoceros*, *Coscinodiscus*, *Rhizosolenia*, *Nitzschia*, *Skeletonema*, *Navicula*, *Ceratium* and *Peridinium*. In the neritic zone, where seawater mixes with freshwater discharge from rivers, a diverse plankton community is found which consists of marine, neritic, and freshwater species.

Regional primary productivity is highest in the bays and decreases seaward. Productivity in these waters is sustained by nutrient (nitrates and phosphates) input by freshwater discharge of rivers especially during the winter and early spring. It is during this late winter-early spring period that both chlorophyll *a* (which is a measure of the standing crop of the phytoplankton), and primary productivity are maximum. An overall annual minimum in productivity is attained during the summer months and increases slightly in the fall. Average annual productivity in the nearshore area is greater than in the open Gulf and ranges between 20 and 30 milligrams carbon per cubic meter per day (mgC/m^3/day) (FEA, 1977b). In the coastal area phytoplankton cell densities average approximately 4.1×10^5 cells/ liter, 7.8×10^4 cells/liter in the intermediate areas, and 2.6×10^3 cells/liter at offshore stations (Van Baalen, 1976).

Phytoplankton species characteristic of the waters near the proposed brine diffuser are presented in Table G.2-13. The community is dominated by the diatoms with several representatives of the blue-green and green algae as well as dinoflagellates. Primary productivity at the diffuser site would be expected to range from 20 to 30 mgC/m^3/day as an annual average. Seasonal variations in algal biomass, productivity, and species are comparable to other neritic areas in the northern and northwestern Gulf of Mexico.

G.2.4.2.2 Zooplankton

Zooplankton are animals that rely on currents for transportation. This community comprises a variety of organisms including copepods, coelenterates, annelids, and chaetognaths, as well as certain life stages of fish, shrimp, crabs, and molluscs. Zooplankton are an important segment of the aquatic food web; they feed on the primary producers (phytoplankton) and detrital material. This energy source is then available to higher trophic levels, which feed upon zooplankton.

Within the Gulf of Mexico, a number of environmental factors regulate the spatial and temporal distribution, composition, and density of the zooplankton community. Gillespie (1971) discusses several of these factors including temperature, salinity, phytoplankton distribution and abundance, reproductive cycles, and predators. Of these factors,

TABLE G.2-13 Phytoplankton characteristic of the Gulf of Mexico in the vicinity of the proposed brine diffuser.

CHLOROPHYTA

Volvox sp.
Gleocystis ampha
Scenedesmus sp.

BACILLARIOPHYTA

CENTRALES

Actinoptychus undulatus
Bacteriastrum hyalinum
Bacteriastrum delicatulum
Biddulphia aurita
Biddulphia chinensis
Biddulphia dubia
Biddulphia mobiliensis
Biddulphia regia
Biddulphia rhombus
Cerataulina bergonii
Chaetoceros affinis
Chaetoceros atlanticus
Chaetoceros brevis
Chaetoceros coarctatus
Chaetoceros compressus
Chaetoceros concavicornis
Chaetoceros curvisetus
Chaetoceros decipiens
Chaetoceros dichaeta
Chaetoceros didymus
Chaetoceros lorenzianus
Chaetoceros messanensis
Chaetoceros peruvianus
Chaetoceros pendulus
Climacodium frauenfeldianum

CENTRALES (Cont'd)

Coscinodiscus centralis
Coscinodiscus concinnus
Coscinodiscus curvatulus
Coscinodiscus excentricus
Coscinodiscus granii
Coscinodiscus marginatus
Coscinodiscus nitidus
Coscinodiscus oculus-iridis
Coscinodiscus perforatus
Coscinodiscus radiatus
Coscinodiscus stellaris
Coscinosira sp.
Corethron hystrix
Ditylum brightwelli
Eucampia cornuta
Eucampia zoodiacus
Guinardia flaccida
Hemiaulus cuneiformis
Hemiaulus hauckii
Hemiaulus membranaceus
Hemiaulus sinensis
Hemidiscus cuneiformis
Leptocylindrus sp.
Lithodesmium undulatum
Melosira sulcata
Rhizosolenia acuminata
Rhizosolenia alata
Rhizosolenia calcar-avis
Rhizosolenia castracanei
Rhizosolenia delicatula
Rhizosolenia hebetata

TABLE G.2-13 continued.

CENTRALES (Cont'd)

- Rhizosolenia imbricata
- Rhizosolenia robusta
- Rhizosolenia setigera
- Rhizosolenia stolterfothii
- Rhizosolenia styliformis
- Schroderella delicatula
- Skeletonema costatum
- Stephanopyxis palmeriana
- Stephanopyxis turris
- Thalassiosira decipiens
- Thalassiosira hyalina

PENNALES

- Amphiprora sp.
- Amphiprora gigantea
- Asterionella japonica
- Gyrosigma sp.
- Navicula sp.
- Nitzschia bilobata
- Nitzschia closterium
- Nitzschia delicatissima
- Nitzschia longissima
- Nitzschia paradoxa
- Nitzschia pungens
- Nitzschia seriata
- Nitzschia sigma
- Nitzschia sp.
- Pleurosigma sp.
- Synedra sp.
- Thalassionema nitzschioides
- Thalassiothrix frauenfeldii
- Thalassiothrix delicatula

PYRROPHYTA

- Ceratium candelabrum
- Ceratium carriense
- Ceratium extensum
- Ceratium furca
- Ceratium fusus
- Ceratium gallicum
- Ceratium lunula
- Ceratium macroceros
- Ceratium massiliense
- Ceratium pendulus
- Ceratium pentagonium
- Ceratium pulchellum
- Ceratium symmetricum
- Ceratium trichoceros
- Ceratium tripos
- Dinophysis caudatum
- Goniaulax sp.
- Gymnodinium sp.
- Noctiluca sp.
- Oxytoxum sp.
- Peridinium pentagonum
- Peridinium sp.
- Prorocentrum micans

CYANOPHYTA

- Anabaena sp.
- Oscillatoria erythreae

SOURCE: SEADOCK, 1975.

predation, competition, and temperature were, in that study, considered the most important. Gillespie (1971) notes that zooplankton abundance is inversely proportional to the abundance of ctenophores which graze on other zooplankton. In the Texas Gulf waters, zooplankton population densities are often described as "patchy" in their spatial and temporal distribution in response to the relative abundance of phytoplankton on which they graze.

In general, maximum zooplankton densities are found in the estuaries and bay mouths. These densities decrease toward the open Gulf waters. Seasonally, the magnitude of the zooplankton populations lag behind the peaks and valleys of the phytoplankton pulses. Zooplankton studies (Fotheringham, 1977) were undertaken in the northwestern Gulf of Mexico off Galveston Bay, Texas, from May to December, 1976. This investigation revealed three zooplankton density peaks (number of organisms per cubic meter): May-June ($4300/m^3$), October ($7700/m^3$) and December ($4000/m^3$). Minimum densities were observed in August ($300/m^3$) and in November ($200/m^3$). These seasonal variations in zooplankton densities concur with those found in other studies undertaken in the northern Gulf of Mexico.

Important representative taxa found in the waters around the diffuser site include coelenterates, rotifers, nematodes, annelids, arthropods, molluscs, chaetognaths, echinoderms, urochordates, and chordates. The predominant groups are the copepods and meroplanktonic stages of several benthic invertebrates. As elsewhere in the Gulf of Mexico, the copepod *Acartia tonsa* is the numerically dominant zooplankton species throughout much of the year.

G.2.4.3 Benthic Invertebrates

Benthic organisms are important contributors to the trophic structure of the coastal region in the area of the diffuser site. Many phyla and trophic levels are represented in the benthic community. Some of the benthic organisms feed on detritus and phytoplankton, and convert this energy into a form usable by higher organisms. Many benthic animals are carnivores; some also are prey for higher carnivores. Substrate, depth, DO level, salinity, and temperature affect the distribution and abundance of benthic organisms.

The benthic organisms discussed in this section are limited to the benthic macroinvertebrate infauna, which includes only invertebrates that live in the substrate and are large enough to be retained by a 0.5 mm mesh screen. Demersal fish (bottom dwellers) and many of the large invertebrates, such as shrimp and crabs, are an integral part of the benthic environment; however, these organisms have been considered nekton (Section G.2.4.4), because they are most often collected with trawl nets.

Approximately 400 benthic invertebrate species were reported for the offshore area around the Buccaneer Oil Field (Harper, 1977), and more than 290 have been identified in the nearshore area of the proposed diffuser (SEADOCK, 1975). The abundance of benthic invertebrates has been reported to be greater around the mouth of the Brazos River compared with adjacent offshore areas (SEADOCK, 1975). The offshore area is dominated by polychaetes, although amphipods and nemerteans are also common. The most characteristic organisms include one polychaete and several molluscs and crustaceans (Section G.5, Table G.5-1).

There have been 107 species of benthic invertebrates (Table G.2-14) identified at 15 sampling stations (Figure G.1-5) in the vicinity of the diffuser site. This fauna was dominated by polychaetes, of which 51 species were found. Prionospio pinnata was the most abundant polychaete species encountered throughout the sampling period. Other commonly encountered taxa were amphipods, decapod crustacea, nemerteans, gastropods, and pelecypods.

The total number of taxa collected at a given station ranged from 28 to 41 taxa (Figure G.2-31). The density of the benthic invertebrates ranged from 1673 organisms/m^2 to 5008 organisms/m^2 (Figure G.2-31). While the number of taxa and density of organisms at the various stations do not appear to have any particular pattern, a cluster analysis was

TABLE G.2-14 Benthic invertebrates collected at the proposed diffuser site, September through December, 1977.

	Sept.	Oct.	Nov.	Dec.
CLASS HYDROZOA				
Clytia coronata			X	
Clytia cylindrica				X
Lovenella grandis				X
CLASS ANTHOZOA				
Anemone A		X	X	
Anemone B			X	X
Anemone C			X	
Anemone D		X		
Renilla mulleri		X	X	X
CLASS TURBELLARIA				
Flatworm A	X			
PHYLUM NEMERTEA				
Cerebratulus lacteus	X	X	X	X
Cerebratulus luridus	X	X	X	X
Nemertean A	X	X	X	X
Nemertean B			X	X
Nemertean C	X	X	X	X
PHYLUM NEMATODA				
Nematode A	X		X	X
PHYLUM PHORONIDA				
Phoronis architecta				X
CLASS GASTROPODA				
Anachis obesa		X		
Anachis avera			X	
Cantharus cancellarius			X	
Nassarius acutus		X	X	X
Natica pusilla	X	X	X	X
Nudibranch A	X			
Sinum perspectivum	X			

TABLE G.2-14 continued.

	Sept.	Oct.	Nov.	Dec.
CLASS GASTROPODA (Cont'd)				
Teinostomia biscayense		X		
Terebra protexta	X	X	X	
Vitrinella helicoidea	X		X	X
Volvulella texasiana		X	X	X
CLASS PELECYPODA				
Abra aequalis	X	X	X	X
Corbula barrattania	X	X	X	X
Lima pellucida		X		
Nuculana concentrica		X	X	X
CLASS POLYCHAETA				
Amphinomidae		X		
Ancistrosyllis jonesi	X		X	X
Ancistrosyllis sp. A		X		X
Aricidea snecica	X	X		X
Aricidea cerrutii	X			X
Armandia maculata	X	X	X	X
Asychis elongata		X	X	
Capitellidae	X			
Cauleriella cf *killariens*				X
Cirratulus hedgpethi			X	
Cirratulus sp. A		X		
Clymenella torquata calida	X		X	
Clymenella zonalis				X
Cossura delta	X	X	X	X
Diopatra cuprea	X	X	X	X
Gyptis vittata			X	
Lepidasthenia sp. A	X	X		X
Lepidepecreum sp. A	X			
Lepidonotus sublevis			X	X
Lumbrineris tenuis	X	X	X	X

TABLE G.2-14 continued.

	Sept.	Oct.	Nov.	Dec.
CLASS POLYCHAETA (Cont'd)				
Magelona rosea	X	X	X	X
Magelona sp. A	X	X	X	X
Mediomastus californiensis	X	X	X	X
Nephtys incisa	X	X	X	X
Nereis succinea	X	X	X	X
Nereis sp. A	X	X	X	X
Ninoe nigripes	X	X	X	X
Notomastus latericeus	X	X	X	X
Onuphis nebulosa	X			X
Owenia fusiformis				X
Paleonotus heteroseta		X	X	X
Paraonidae	X			
Phyllodocidae			X	
Poecilochaetus johnsoni	X		X	
Polychaete A		X	X	X
Polydora socialis	X			X
Polynoidae sp. A				X
Polynoidae sp. B				X
Prionospio cirrifera			X	
Prionospio cirrobranchia			X	X
Prionospio cristata				X
Prionospio cf *dayi*			X	
Prionospio pinnata	X	X	X	X
Sigambra tentaculata	X	X	X	X
Sigambra wassi	X		X	
Sigambra sp. A	X			X
Spiochaetopterus oculatus	X			
Spiophanes bombyx				X
Sthenelais boa		X	X	X
Tharyx marioni	X	X	X	X
Tharyx setigera		X		

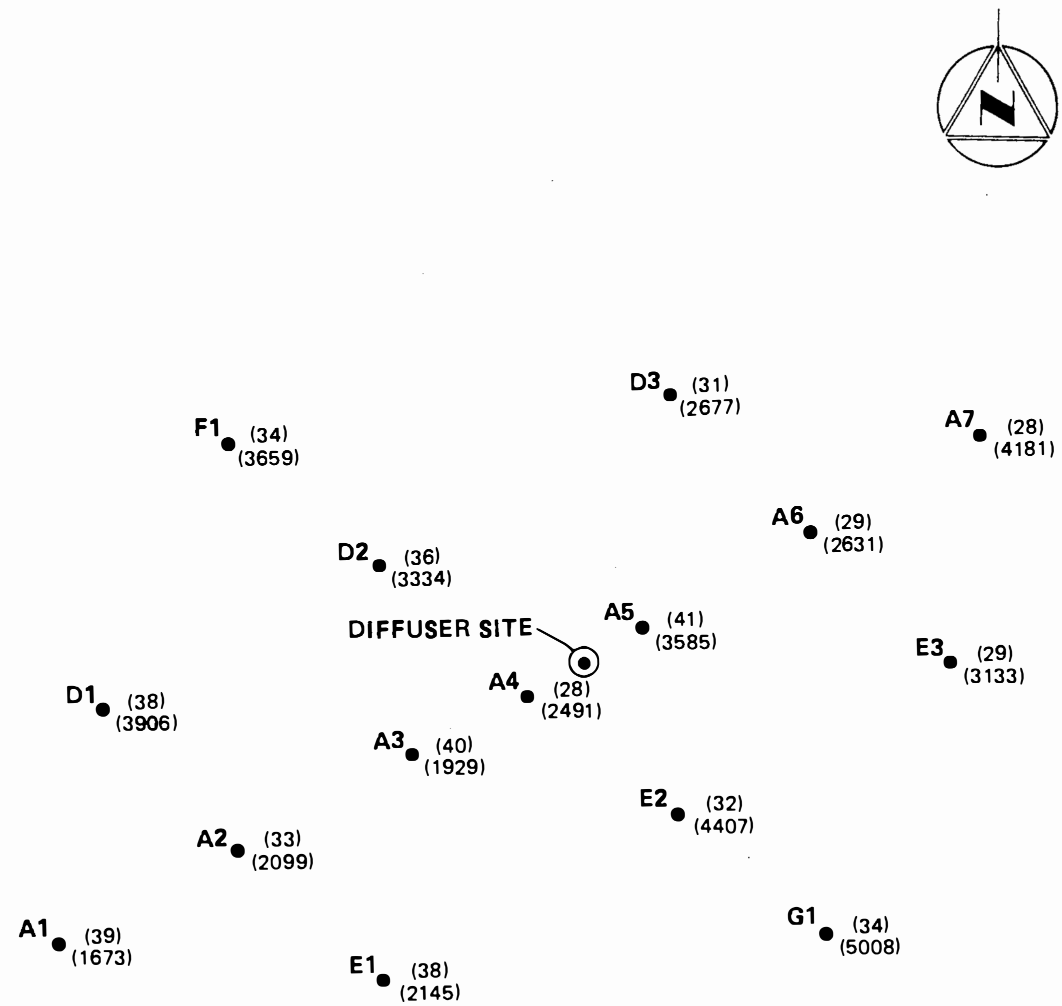
TABLE G.2-14 continued.

	Sept.	Oct.	Nov.	Dec.
PHYLUM SIPUNCULIDA				
Phascolion strombi		X	X	X
ORDER STOMATOPODA				
Squilla empusa		X		
ORDER AMPHIPODA				
Ampelisca abdita	X	X		
Ampelisca agassizi	X	X	X	X
Ampelisca verrilli				X
Listriella barnardi	X		X	
Photis sp. A	X			
ORDER CUMACEA				
Oxyurostylis salinoi			X	
ORDER DECAPODA				
Alpheus floridanus	X	X	X	X
Automate evermanni	X	X	X	X
Callianassa latispina		X		X
Callianassa sp. A				X
Chasmocarcinus mississippiensis			X	
Libinia dubia				X
Pagurus annulipes	X	X	X	X
Penaeidae (postlarva)	X	X	X	
Pinnixa sayana	X	X		X
Portunidae			X	
Spiocarcinus lobatus	X	X	X	
Trachypeneus similis	X			X
Xanthidae	X		X	
CLASS OPHIUROIDEA				
Hemipholis elongata		X		
Micropholis atra	X	X	X	X

TABLE G.2-14 continued.

	Sept.	Oct.	Nov.	Dec.
CLASS HOLOTHUROIDEA				
Holothuroid sp. A	X	X	X	X
PHYLUM HEMICHORDATA				
Balanoglossus sp. A			X	

SOURCE: Texas A & M, 1978.



SOURCE: Texas A & M, 1978.

FIGURE G.2-31. Areal distribution of the total number of taxa (top number) and total number of individuals per square meter (bottom number) of benthic invertebrates, September through December, 1977 at the proposed diffuser site.

used to group associative benthic assemblages. This analysis indicates that two distinct benthic assemblages occur (Figure G.2-32). Frequent occurrence and/or large numbers of the amphipods (Ampelisca abdita and Ampelisca agassizi and the bivalve Nuculana concentrica in Site Group I, set it apart from Site Group II, where the frequency of occurrence and/or numbers of these organisms was low. This distribution is not particularly well correlated with depth or available substrate data which generally characterizes the inshore site area as being predominantly red or gray clay (Section G.2.2.5.2). Similarly, no significant differences were noted in sediment chemistry between site group 1 (Station N) and site group 2 (Station L) based on one core sample at each station (Texas A&M, 1978).

The general features of this fauna are similar to those of the fauna of the same area examined during the 1973 SEADOCK survey (SEADOCK, 1975), which characterized the area as having a mixture of inner shelf and intermediate shelf benthic assemblages. However, temporal variation can be seen in specific elements. For example, the amphipod Ampelisca abdita was a numerically dominant component of the benthic fauna in 1973, but was only encountered during the first two sampling periods in the present study. This faunal assemblage is also similar to that examined during the 1977 Buccaneer Oil Field study (Harper, 1977) in its general features, i.e. dominance by polychaetes, amphipods, and nemerteans, but dissimilar in the relative importance of particular species.

G.2.4.4 Nekton

The fisheries resources of the Texas Gulf coast are well documented and more than 600 species of fish have been reported for the region (SEADOCK, 1975). Many of these fish are found in the offshore region of the Bryan Mound brine diffuser site, although it is expected that the study area around the diffuser site would be more specifically characterized by less than 200 species of nektonic invertebrates and fish (Section G.5, Table G.5-2). Most of these fish follow seasonal inshore-offshore migration patterns, because they use the bay-river estuary ecosystems at

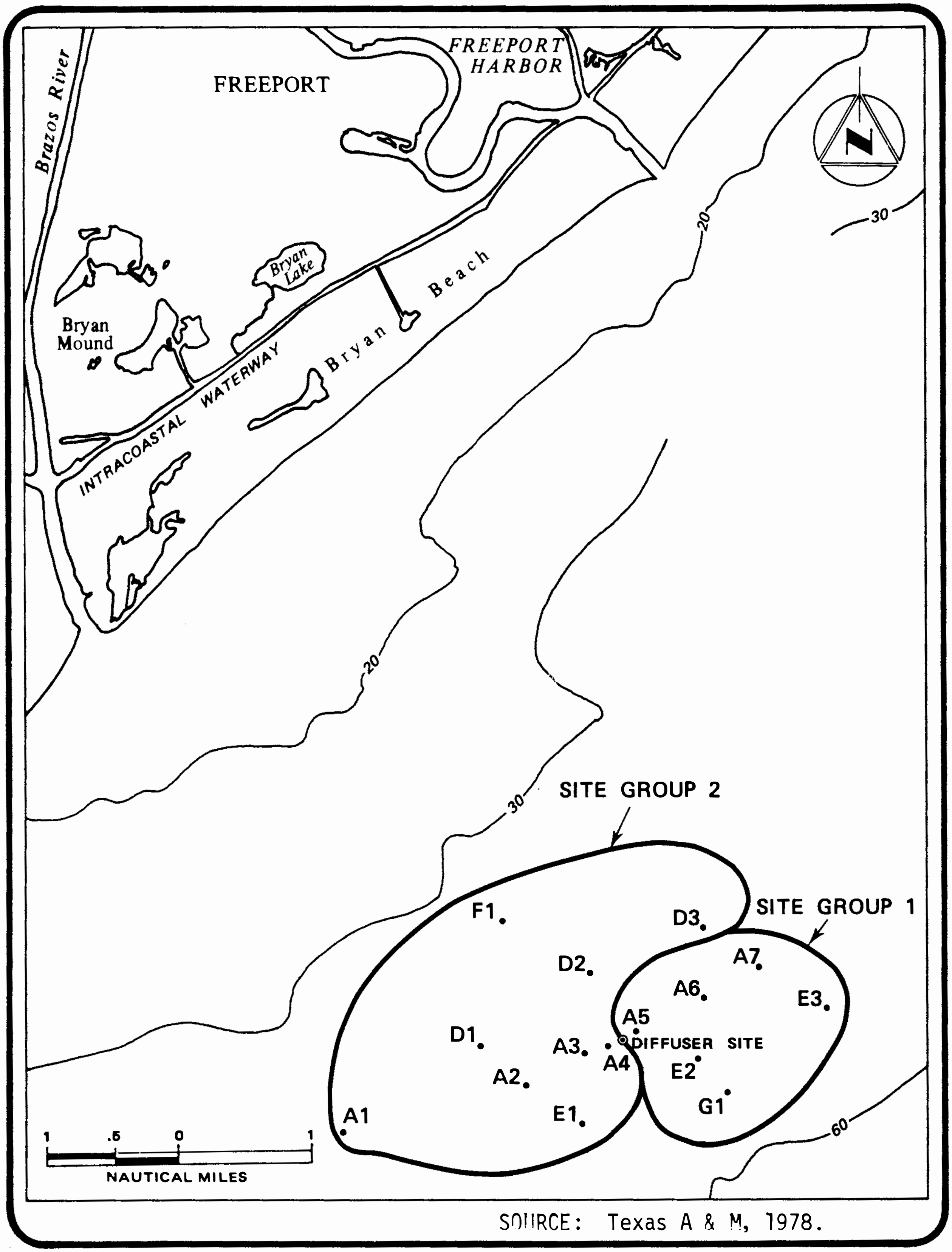


FIGURE G.2-32. Areal distribution of benthic macroinvertebrate site groups (depth contours in feet).

some stage in their life cycle. Some of the more abundant fish in the coastal region are the bay anchovy, menhaden, striped mullet, and Atlantic croaker (SEADOCK, 1975). Many young fish remain in the estuaries to nurture and grow until late spring, when they migrate to offshore regions of the Gulf. Other fish species remain in the estuaries or progress through their larval and juvenile development in offshore waters.

Commercial fisheries landings for the Texas coastal region during 1976 amounted to 93 million pounds and were valued at $126 million. During the last 4 years (1973-1976) total landings on the coast ranged from 86 to 98.3 million pounds; the total value ranged from $71.8 to $126 million. The variation in weight and value of these fisheries landings is closely linked to the shrimp fisheries catches, which are highest in both weight and value and are usually many times higher than any other species (Table G.2-15). Shrimp landings for the Galveston district were five or more times greater in 1976 and 1977 than in 1974 and 1975. Other important commercial fisheries include the blue crab, seatrout, drum (Table G.2-15) and menhaden.

Sportfishing in the Texas coastal area is extremely popular and provides for a large industry. Both the bays and nearshore regions yield Atlantic croaker, spot, red and black drum, seatrout, southern flounder, sheepshead, and Atlantic spadefish. Offshore oil rigs provide a reef-like environment and are highly productive areas with assemblages of cobia, crevalle jack, greater amberjack, sheepshead, great barracuda, king mackerel, blue runner, and Atlantic spadefish.

Two distinct nekton communities have been identified in the vicinity of the proposed brine diffuser site; names for these communities have been derived from the dominant commercial shrimp fishery in each area. These communities are referred to as the white shrimp grounds which are located on the inner shelf in water depths from 12 to 72 feet and the brown shrimp grounds, which occupy the intermediate shelf in areas 72 to 300 feet deep.

TABLE G.2-15 Texas landings statistics for the Galveston District for selected[a] nekton species, 1974-1977.

SPECIES	DATE					
	1974		1975		1976	1977[b]
	Pounds	Dollars	Pounds	Dollars	Pounds	Pounds
INVERTEBRATES						
Shrimp (heads on)						
Brown and Pink	1,422,600	378,773	828,400	344,578	16,207,895	17,304,034
White	2,392,400	1,432,538	3,927,200	2,960,075	8,198,005	5,870,565
Blue Crab	1,983,000	273,301	1,863,500	287,019	1,619,245	1,737,542
FISH						
Seatrout	273,900	87,835	225,400	85,820	371,725	213,779
Drum (black and red)	62,500	14,512	125,900	30,863	188,258	161,299
Sea Catfish[c]	33,200	1,828	29,600	2,995	23,586	31,003
Croaker	23,900	2,840	23,200	2,596	27,559	6,350
Sheepshead	28,500	3,283	32,000	4,694	85,392	40,653
Mullet	24,500	1,464	3,100	627	18,574	3,386
Flounder	20,100	6,710	21,200	8,489	97,748	50,879
Kingfish	6,100	566	18,500	2,680	61,758	24,494
GRAND TOTAL[d]	7,218,400	2,964,278	8,471,600	4,706,457	30,691,967	27,294,927

[a] Based on greatest abundance or value.

[b] 1977 data do not include November or December catches.

[c] Reported as Gaftop sail catfish in 1976 and 1977.

[d] Grand total includes total of all fish and shellfish (including oysters) reported in current fisheries statistics.

SOURCE: U.S. Department of Commerce, 1975a, 1977c, and 1977d.

Although there are many fish species common to both areas, certain species are more abundant in one area than in the other (Table G.2-16). The most notable difference is that the white shrimp grounds are dominated by the Atlantic croaker and the brown shrimp grounds are dominated by the longspine porgy. Fish on the white shrimp grounds tend to depend more on the estuaries than do those of the brown shrimp grounds. Fewer fish species and lower biomass have been reported for the white shrimp grounds than for the brown shrimp grounds (Chittenden and McEachran, 1976).

Because most fish have short life spans of one or two years, they mature rapidly. There is, therefore, a rapid turnover in biomass and large seasonal changes in the numbers of each species. The high turnover tends to protect the nekton community, to some extent, from overfishing. This is illustrated by reports that an average of 53 million pounds of fish were discarded annually (between 1962-1971) as byproducts of shrimping operations. Seasonal variations indicate that species composition is richer in winter than in summer, but biomass is lower in winter than in summer (Chittenden and McEachran, 1976).

A number of wide-ranging, fast-spawning predatory fish are found along the Texas coast during the summer months, which complete most of their life cycles elsewhere in the Gulf of Mexico and are not part of the indigenous ichthyofauna. These wide-ranging fish include dolphin, billfishes, mackerels, bonito, amberjack, blue runner, and several other species of jackfish. These species are not often reported with trawl catch data, since they are typically fast swimmers and their pelagic nature allows them to escape the relatively slow moving bottom trawls.

The unique reef communities (Figure G.2-29) found in the diffuser study area are not a major marine habitat for the Texas coastal region; however, these communities play an important role in area fisheries. For example, the red drum (redfish) spawns near the reef communities. It is also likely that some of the fish inhabiting these areas are more typical of the broken-relief communities that support tropical reef

TABLE G.2-16 Predominant invertebrates and fish for major regional nekton communities.

COMMON NAME	SCIENTIFIC NAME	RELATIVE ABUNDANCE (%)[a]
Inner Shelf- (12-72 Feet) - White Shrimp Grounds		
White Shrimp	*Penaeus setiferus*	--
Atlantic croaker	*Micropogon undulatus*	30
Atlantic cutlassfish	*Trichiurus lepturus*	14
Silver seatrout	*Cynoscion nothus*	13
Star drum	*Stellifer lancelatus*	10
Sand seatrout	*Cynoscion arenarius*	8
Sea catfish	*Arius felis*	5
Atlantic threadfin	*Polydactylus octonemus*	5
Gulf butterfish	*Peprilus burti*	4
FAMILIES		
Drums	Sciaenidae	64
Cutlassfishes	Trichiuridae	14
Threadfins	Polynemidae	5
Sea catfishes	Ariidae	5
Intermediate Shelf - (72-300 Feet) - Brown Shrimp Grounds		
Brown Shrimp	*Penaeus aztecus*	--
Longspine porgy	*Stenostomas caprinus*	39
Mexican searobin	*Prionotus paralatus*	8
Horned searobin	*Bellator militaris*	6
Dwarf goatfish	*Upeneus parvus*	6
Atlantic croaker	*Micropogon undulatus*	4
Shoal flounder	*Syacium gunteri*	4
Pancake batfish	*Halieutichthys aculeatus*	3
Blackear bass	*Serranus atrobranchus*	3
FAMILIES		
Porgies	Sparidae	40
Searobins	Triglidae	17
Drums	Sciaenidae	8

[a] Data are based on one trawl sample.

Source: Chittenden and McEachran (1976)

fishes (Chittenden and McEachran, 1976). The shipwrecks in the area (Figure G.2-29) are also likely to be good fishing areas and have a fauna more characteristic of reef areas than of a mud bottom.

Recent trawl surveys conducted in the vicinity of the brine diffuser site (Figure G.1-7) tend to confirm the regional characterization of local fish fauna, namely the white shrimp grounds. All of the major species characteristic of the white shrimp grounds (Table G.2-16) were present during this survey (Table G.2-17; Section G.5, Tables G.5-3, G.5-4, and G.5-5). The white shrimp was the most abundant of the three target shrimp species collected; the Atlantic croaker was by far the most abundant fish of the 11 target species sought. The star drum, silver seatrout, and Gulf butterfish were also abundant. Nearshore trawls (Stations 1 to 8) showed a general decline in the nekton collected from October to December 1977, which is characteristic of seasonal trends in fishery catches discussed above.

To further characterize the nekton of the region, five trawl stations were located several miles offshore from the proposed brine diffuser site (Figure G.1-6). Stations 9 through 13 characterize the proposed site. The fauna at these stations were more characteristic of the brown shrimp grounds than of the white shrimp grounds (Table G.2-18; Section G.5, Tables G.5-3, G.5-4 and G.5-5). The brown shrimp was the most abundant shrimp species collected. The longspine porgy was much more abundant at the offshore stations than those stations occupied closer to the shore (Stations 1 to 8). The star drum and the Atlantic cutlassfish, characteristic fish of the white shrimp grounds, were either not very abundant or not collected at Stations 9 through 13. The low number of these fish in the collection also characterize the area as part of the brown shrimp grounds. Total biomass of the target fish species was generally much lower on the brown shrimp grounds than in the white shrimp grounds. This differs from regional data which suggests that biomass is usually greater on the brown shrimp grounds than on the white shrimp grounds.

TABLE G.2-17 Summary of trawl catches for selected[a] invertebrates and fish collected near the proposed diffuser site, Stations 1-8 (October-December 1977).[b]

COMMON NAME	SCIENTIFIC NAME	COLLECTION DATA October	November	December
	Invertebrates			
Brown shrimp	*Penaeus aztecus*	C	UC	R
Pink shrimp	*Penaeus duorarum*	NC	NC	NC
White shrimp	*Penaeus setiferus*	A	C	A
	Fish			
Sea catfish	*Arius felis*	UC	R	NC
Longspine porgy	*Stenotomus caprinus*	R	NC	NC
Southern kingfish	*Menticirrhus americanus*	R	R	R
Gulf kingfish	*Menticirrhus littoralis*	NC	NC	NC
Atlantic croaker	*Micropogon undulatus*	A	C	UC
Sand seatrout	*Cynoscion arenarius*	C	UC	UC
Silver seatrout	*Cynoscion nothus*	C	A	A
Star drum	*Stellifer lanceolatus*	C	R	UC
Atlantic threadfin	*Polydactylus octonemus*	C	R	R
Atlantic cutlassfish	*Trichiurus lepturus*	R	UC	R
Gulf butterfish	*Peprilus burti*	A	C	R

[a]Selected invertebrates and fish include those organisms considered to be either of great commercial importance or abundance (referred to as target species).

[b]Relative abundance based upon average number of fish collected per 10-minute trawl. A-Abundant (more than 100 collected); C-Common (20-99 collected); UC-Uncommon (5-19 collected); R-Rare (less than 5 collected); NC-Not Collected.

SOURCE: Texas A & M, 1978.

TABLE G.2-18 Summary of trawl catches for selected[a] invertebrates and fish collected offshore from the proposed diffuser site, Stations 9-13 (October-December 1977).[b]

COMMON NAME	SCIENTIFIC NAME	COLLECTION DATA		
		October	November	December
	Invertebrates			
Brown shrimp	*Penaeus aztecus*	C	R	UC
Pink shrimp	*Penaeus duorarum*	NC	NC	R
White shrimp	*Penaeus setiferus*	UC	C	R
	Fish			
Sea catfish	*Arius felis*	C	NC	R
Longspine porgy	*Stenotomus caprinus*	C	NC	UC
Southern kingfish	*Menticirrhus americanus*	R	R	R
Gulf kingfish	*Menticirrhus littoralis*	NC	NC	NC
Atlantic croaker	*Micropogon undulatus*	A	UC	UC
Sand seatrout	*Cynoscion arenarius*	UC	R	R
Silver seatrout	*Cynoscion nothus*	C	C	A
Star drum	*Stellifer lanceolatus*	NC	NC	NC
Atlantic threadfin	*Polydactylus octonemus*	C	NC	NC
Atlantic cutlassfish	*Trichiurus lepturus*	UC	NC	R
Gulf butterfish	*Peprilus burti*	A	NC	R

[a] Selected invertebrates and fish include those organisms considered to be either of great commercial importance or abundance (referred to as target species).

[b] Relative abundance based upon average number of fish collected per 10-minute trawl. A-Abundant (more than 100 collected); C-Common (20-99 collected); UC-Uncommon (5-19 collected); R-Rare (less than 5 collected); NC-Not Collected.

SOURCE: Texas A & M, 1978.

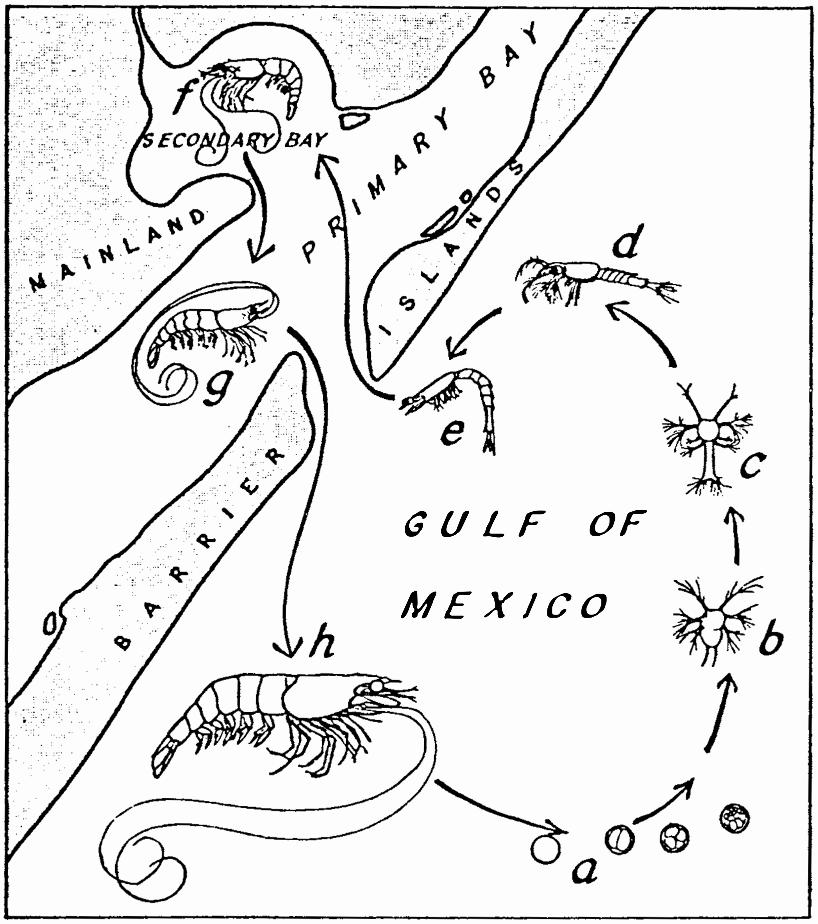
G.2.4.4.1 Shrimp

The Gulf of Mexico supports an extensive shrimp fishery, which consists of nine species of shrimp; however, only the brown, white, and pink shrimp species are caught in significant numbers. The harvest of brown shrimp is the most important shrimp resource in Texas. White shrimp landings are usually much lower than brown shrimp landings (e.g. one third less in 1977)(Table G.2-15). Pink shimp landing data are included with brown shrimp data in some cases, however, they account for only a small percentage of reported brown shrimp landings.

A generalized life cycle for shrimp is depicted in Figure G.2-33. Like that of many coastal fish their life span is of short duration; 18 to 24 months is the norm, although some may live to be several years old. For this reason shrimp are considered an annual stock in terms of harvest (FEA, 1977b).

The life cycle of the brown shrimp starts in the Gulf when the semi-buoyant eggs are spawned into the offshore water. Spawning may occur all year at depths of 150 to 360 feet and from March through December at 60 to 150 feet. Eggs hatch within 24 hours, and the larvae commence migration to the less saline estuaries and bays along the Texas coastline. During this time, the young go through several larval stages, feeding on microscopic marine plants and animals. By the time brown shrimp develop to the postlarval stage, they reach the bays or estuaries and enter these water bodies between late winter and early spring. Here they summer, feed on algae, small molluscs, marine worms, and small crustacae and grow in length to about 3 to 4 inches (FEA, 1977b).

Several factors, such as increasing water temperatures, increased salinities, storms, and approaching sexuality, combine to trigger the shrimps' return to the offshore spawning grounds beginning in June. In the Gulf, the shrimp complete their life cycle and become adults. It is principally here, in the offshore waters, that they are caught by the fleet of shrimp trawlers. Although brown shrimp are widely distributed in the Gulf over the continental shelf, this fishery is centered along



LIFE HISTORY OF SHRIMP. a) shrimp eggs; b) nauplius larva; c) protozoea; d) mysis; e) postmysis; f) juvenile shrimp; g) adolescent shrimp; h) mature adult shrimp.

SOURCE: Moffett, 1970.

FIGURE G.2-33. Life cycle of a Penaeid shrimp.

the northwestern Texas coast. Brown shrimp are usually caught at night when they emerge from their burrows in the sand and mud bottoms of the offshore region (FEA, 1977b).

The life cycle of the white shrimp is similar to that of the brown shrimp. However, white shrimp spawning occurs in shallow water, between 42 and 150 feet, primarily around the 48 foot depth contour. White shrimp spawn from March through August, and postlarval stages enter the nursery grounds from May through June and again in September. White shrimp arriving late in the year may overwinter in the estuaries, whereas the spring arrivals, after feeding and growing to about 4½ to 5½ inches, begin their migration back to the Gulf in the fall (FEA, 1977b).

The period when the young shrimp are most subject to outside pressures is between the egg and postlarval stages, during their migration from the offshore area to the nursery ground. Recent information indicates that a white shrimp spawning stock occurs 5 to 7 miles off Bryan Beach, Texas, in the vicinity of the proposed brine diffuser. In addition, mass movement of white shrimp has been observed from central and southern Texas south toward Mexico in fall and winter and then north again in spring (FEA, 1977b).

Although white shrimp have the same geographical range in the Gulf of Mexico as brown shrimp, this fishery is centered on the sand and mud bottoms off the Louisiana coastline. Unlike brown shrimp, white shrimp do not burrow into the bottom during the day; the largest catches of white shrimp are taken by shrimp trawlers during daylight hours. During the spring and fall, white shrimp are occasionally caught along with brown shrimp.

G.2.4.4.2 Blue Crab

Blue crabs have an extremely wide distribution and range from Nova Scotia to Uruguay; they are found mainly in estuaries and shallow marine environments. Females tend to live in more saline waters than males, but both sexes can tolerate waters with salinities from 0.7 to 88 ppt. Blue crabs mate from late winter to early fall, when females are in the soft-shell stage of molt; the male passes spermatozoa to the female crab, where it can be stored for up to 1 year. After the female crab migrates to more saline waters, spawning occurs. When the 700,000 to 2,000,000 eggs are deposited by the female they are fertilized by the stored sperm. The crab embryos are deposited onto the abdomen of the female until they hatch, a process which takes from 9 to 15 days. Only one or two of these eggs are likely to survive to adulthood (Jaworski, 1972).

The larval zoeal stage of the blue crab lasts from 30 to 39 days during which the organism undergoes from 4 to 8 molts. Optimum salinity range for survival and growth of the crab larvae are from 15 to 45 ppt. The zoea then metamorphose into megalops, a stage lasting 6 to 20 days. The megalops is crablike in appearance and is able to swim or walk on the bottom. Optimum salinities for this crab stage are greater than 15 ppt. The final metamorphosis leads to the juvenile crab, which is an active predator. Crab juveniles migrate throughout the estuary in search of food. During the period of growth, the crab exoskeleton is repeatedly shed; growth to maturity takes 12 to 18 months. The life span of the blue crab is from 2 to 4 years, although many are caught upon reaching commercial size 12 to 18 months after hatching (Jaworski, 1972).

The blue crab is omnivorous and as such plays an important role in the ecology of the coastal environment. Rangia clams, mussels, xanthid crabs, snails, fish, plants, and insect larvae, as well as scavenged material, have been reported as part of the diet of the blue crab. Blue crabs, especially smaller members of this species, are fed upon by fish such as the spotted seatrout, red drum, Atlantic croaker, black drum, and sheepshead. Crab larvae and eggs are also found in the diet of many fish (Adkins, 1972).

G.2.4.4.3 Anchovy

The two most abundant anchovy species found off the Texas coast are the bay and the striped anchovy. Striped anchovy prefer clear salty water and are thus found further offshore than the bay anchovy, which is generally restricted to bays or other inshore areas. Both species are found in large schools and have similar life histories. Their diet consists mainly of mysids and copepod zooplankton (Hildebrand and Schroeder, 1972). Anchovies spawn in the spring, summer, and fall; the pelagic eggs hatch within a day. An influx of bay anchovy eggs and larvae into the Texas estuaries has been reported year-round except in July, August, and October. Anchovy larvae and young juveniles tend to reside in low salinity areas and then move to high salinity waters as they grow (Dunham, 1972). Anchovies provide an important food source for carnivorous fish such as seatrout and jack fish.

G.2.4.4.4 Menhaden

The menhaden are of tremendous commercial importance, although they are unsuitable for human consumption. Menhaden support the largest commercial fishery in the United States to provide oil for a variety of commercial products such as paints and resins. The Gulf menhaden, found mainly in the Gulf of Mexico, comprises a majority of the U.S. menhaden fishery and are fished mainly by means of purse seine from mid-April to mid-October (Dunham, 1972; U.S. Department of Commerce, 1977a).

Adult menhaden overwinter between 40 and 62 miles offshore in waters of 280 feet depth; here, they spawn from late fall through the winter. Menhaden larvae move into the estuarine nursery areas in September through April where they remain in the low salinity waters until they metamorphose into juveniles and return to the open Gulf from October through February. Menhaden have a relatively short lifespan and return to the spawning areas after 1 year. Most of the menhaden catch consists of 1 and 2 year old fish. In general, menhaden are found in a wide range of salinities, 0 to 60 ppt (U.S. Department of Commerce, 1977a).

G.2.4.4.5 Atlantic croaker

The Atlantic croaker is one of the most abundant fishes in the white shrimp grounds. Spawning occurs from October to May in the shallow open sea after which the larvae move into the estuary where they feed and grow. Croakers remain in the estuary until the onset of cold weather, whereupon they move offshore to the warmer water. Croakers are bottom feeders, consuming mainly annelids, molluscs, and ascidians. Atlantic croaker are distributed from Massachusetts to Texas and are found in salinities ranging from 0 to 75 ppt (Hildebrand and Schroeder, 1972; U.S. Department of Commerce, 1977a).

G.2.4.4.6 Seatrout

Various types of seatrout are found in the Gulf of Mexico including the sand, silver, and spotted seatrout. The sand seatrout is one of the most common coastal species. It is confined to the Gulf of Mexico and the estuaries of Gulf tributaries, in waters of from 1.3 to 32.5 ppt salinity. Spawning occurs in the spring and summer near passes and inlets. The adults and larvae move into the bays during the summer, then offshore with the onset of cold weather (U.S. Department of Commerce, 1977a).

G.2.4.4.7 Red Drum

Red drum or redfish are found in the coastal waters of the United States from Massachusetts to northern Mexico. Red drum commonly prefer salinity ranges from 5 to 30 ppt though they have been taken in waters with salinities between 0 to 50 ppt. Adult drum under 3 years of age generally remain in the bays and spawn in the fall in the shallow waters of the Gulf near the passes. Juveniles tend to remain in the bays until fall, then migrate to the Gulf. Redfish are known to live for at least 8 years. Adults make spawning runs along the coast in the late summer and winter (U.S. Department of Commerce, 1977a).

G.2.4.5 Threatened or Endangered Species

Several threatened or endangered marine species, including three marine turtles (Hawksbill-*Eretmochelys imbricata*, Leatherback-*Dermochelys coriacea*, and Atlantic Ridley-*Lepidochelys kempi*), have been reported in the northern and northwestern Gulf of Mexico (U.S. Dept. of the Interior, 1977b).

The Leatherback and Atlantic Ridley turtles have been recorded as nesting on Padre Island, Texas. The Leatherback turtle is listed as a tropical nesting species but ranges throughout the Gulf and western

North Atlantic. The Atlantic Ridley turtle nests in abundance only in Tamaulipas, Mexico. The northern Gulf of Mexico coastal area (i.e., shrimping grounds) is the primary forage area for this species. The Hawksbill turtle has been reported to range the warmer coastal waters of the Atlantic between Massachusetts and Brazil (Conant, 1958).

Seven species of endangered marine mammals have been reported in the Gulf of Mexico (Table G.2-19). Most of these records are based on observations of stranded individuals or fortuitous sightings (U.S. Dept. of the Interior, 1977b) and do not represent indigenous populations. The regional distribution, occurrence, population dynamics, and primary food sources for these species are noted in Table G.2-19.

Each of the above species has been listed as "endangered" by the U.S. Fish and Wildlife Service (U.S. Dept. of the Interior, 1977a). However, none have been observed in the area of the diffuser site.

G.2.4.6 Unique or Important Habitats

Several coral heads have been observed in the vicinity of the proposed diffuser (Figure G.2-29). One of these coral heads is located 1.6 nautical miles south of the site in 62 feet of water. The other two are 3.3 and 5.0 nautical miles southwest of the diffuser. These habitats are considered unique to the area, since most of the benthic habitats in the coastal zone near the diffuser site consist of sand or mud substrate.

It is possible that a unique floral and faunal assemblage is associated with these reefs (Section G.2.2.5.2) due to the hard, stable substrate offered; sea fans and other marine growth have been reported attached to these coral heads (Mattison, 1948). Good fishing has also been reported in the vicinity of these coral heads (Figure G.2-29).

TABLE G.2-19 Species of endangered marine mammals known to occur in the Gulf of Mexico.

Common Name	Scientific Name	Regional Distribution	Occurrence	Population	Primary Food Source
Sperm Whale	*Physeter catodon*	Offshore Louisiana, Alabama, and Mississippi	Common	Decreasing	Squid, shark, and bony fish
Black Right Whale	*Eubalaena glacialis*	Entire Gulf of Mexico	Rare	Increasing	Zooplankton-copepods
Humpback Whale	*Megaptera novaeangliae*	Rare to the Gulf of Mexico, one siting off-shore Florida	Rare	Increasing	
Sei Whale	*Balaenoptera borealis*	Offshore Louisiana	Rare	Declining	Krill, schooling fish; copepods
Fin Whale	*Balaenoptera physalus*	Offshore Texas and Louisiana	Limited number	Stable	Krill, squid, and small fish
Blue Whale	*Balaeonptera musclus*	Offshore Texas	Uncommon	Unknown	Euphausiids
West Indian Manatee	*Trichechus manatus*	Louisiana Coastal Lakes	Rare	Few	Aquatic vegetation

Source: U.S. Department of the Interior, 1977b.

G.3 IMPACTS OF BRINE DISPOSAL ON THE MARINE ENVIRONMENT

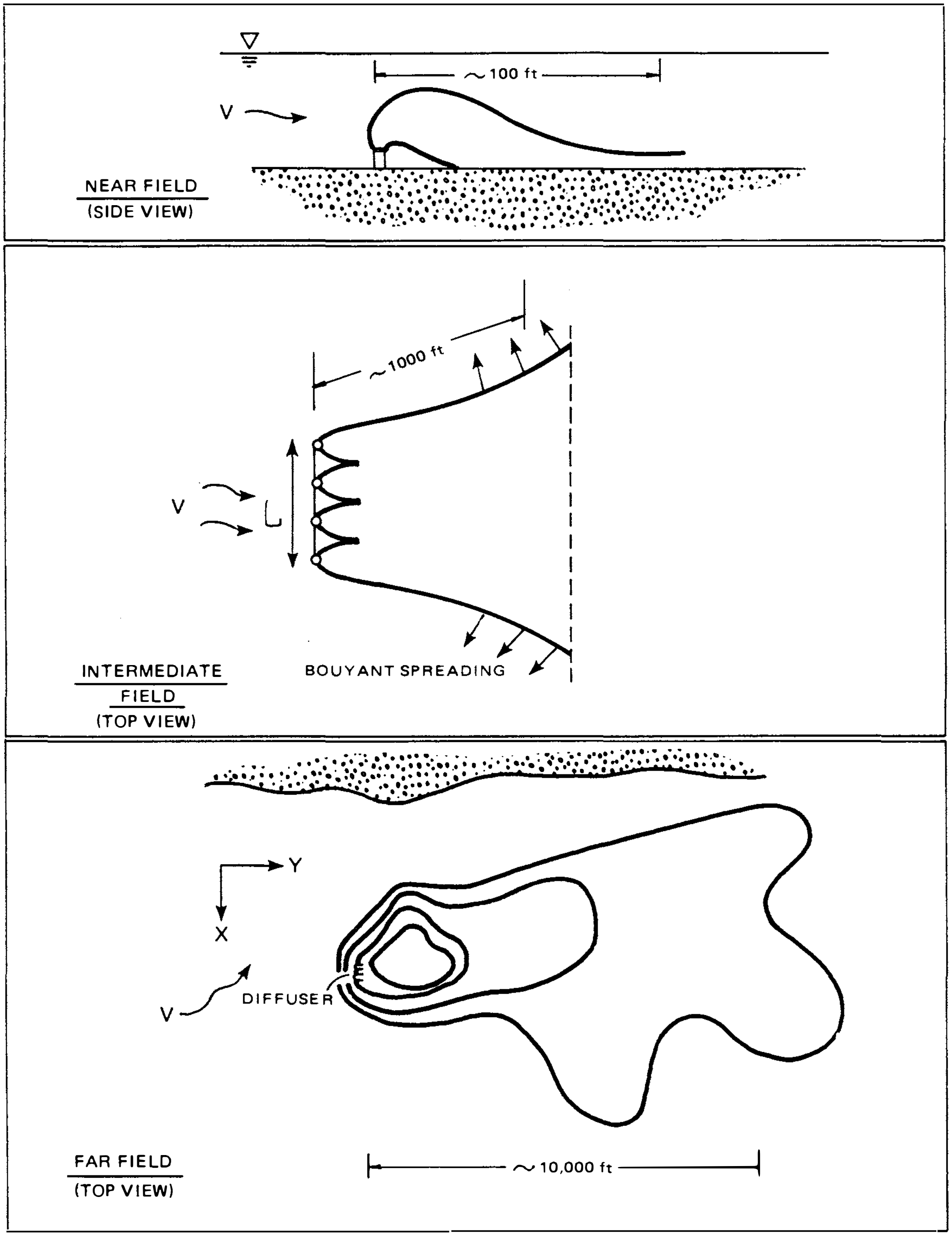
G.3.1 Impacts on the Physical Environment

G.3.1.1 Introduction

Disposal of brine from the Seaway Group in the Gulf of Mexico would be a large scale operation over the short term, but over the life of the project would be undertaken only infrequently. Initially, expansion of Seaway Group crude oil storage capacity by 100 MMB would involve discharge of 534,000 BPD of brine over a period of 50 to 60 months. Subsequent filling of new capacity or (up to 4) refills of the new plus existing 163 MMB capacity would require disposal of 240,000 BPD over 24 months. For study purposes, the larger disposal rate was selected to maximize the magnitude of projected impacts.

To determine the most efficient diffuser design and location for the diffuser system, a mathematical simulation model was used. The model was developed by the Ralph Parsons Laboratory at the Massachusetts Institute of Technology (MIT) and the model runs were used by the National Oceanographic and Atmospheric Administration (NOAA) in a study undertaken at the request of DOE to determine the effects of brine disposal connected with the SPR program (U.S. Dept. of Commerce, 1977f). The MIT model is a time-dependent model which simulates the transient plume conditions at the diffuser site when wind-driven current speeds and direction are input to an electronic computer for analysis. The analysis utilizes results from diffuser performance studies conducted by the U.S. Corps of Engineers Waterways Experiment Station to determine the mathematical dilution factors in the near and intermediate fields (0 to 1000 feet from the diffuser). Salinity concentrations in the far-field region were calculated using the MIT Transient Plume Model, which has been calibrated through thermal discharge studies.

The regions of analysis for the MIT Model are shown in Figure G.3-1. In the near-field region, dilution is affected by turbulent jet mixing and is a function of diffuser design, ambient current velocity, and possibly water depth. The trajectory of each plume, and the lateral spreading of each plume after it falls to the bottom, are strongly



SOURCE: U.S. Department of Commerce, 1977f.

FIGURE G.3-1. Regions of analysis for the MIT Model.

affected by the (negative) buoyancy flux of the discharge. The near field region is assumed to extend downstream until the plumes from adjacent nozzles merge to form a continuous plume, a distance on the order of 100 feet.

The intermediate field is characterized primarily by buoyant lateral spreading and vertical collapse of the plume. Ambient diffusion acts to further dilute the plume, but its importance, initially, is secondary to buoyant spreading. The intermediate field is assumed to end (and the far field to begin) at about 1000 feet corresponding to the point at which vertical collapse of the plume due to buoyancy is comparable with vertical growth due to diffusion.

The far field is the largest of the three regions and is characterized by the ambient processes of advection and diffusion. These processes are essentially independent of diffuser design and are the ones which ultimately control any accumulation of effluents.

G.3.1.2 Brine Plume Salinity Analysis

G.3.1.2.1 Estimated Baseline Conditions

A plume analysis was initially conducted (U.S. Dept. of Commerce, 1977f) using historical current data to determine the excess salinity values at the bottom, mid-depth, and surface for various scenarios of current speed, direction, and duration including stagnant conditions.

Computations were made for the four combinations of water depths and estimated current sequences shown in Table G.3-1. The brine disposal site was assumed to be located approximately 5 nautical miles off the coast in water having a depth (H) of 50 feet; Run 5 (depth = 20 feet) was included to demonstrate the effect of water depth on brine diffusion.

Several current sequences were assumed in the model. For one calculation (Run 3), a steady alongshore current was assumed. For the others (Runs 4, 5, and 6) a combination of tidal and, for the alongshore component only, wind driven components were assumed as:

$$u = u_T \qquad \text{(inshore component)}$$

$$v = v_T + v_W \qquad \text{(alongshore component)}$$

TABLE G.3-1 Far field run parameters for the MIT Model.

Run	H (ft)	Currents	Times (hrs)	Depths Shown for Each Time[a] (B = bottom; M = mid-depth; S = surface)
3	50	Steady, alongshore (u = o; v = -0.5 ft/s)	6	B
			12	B
			18	B
			24	B
4	50	Tidal + 4-day wind-driven cycle (T = 96 hr)[b]	309	B, M
			333	B, M
			357	B, M
			381	B, M
5	20	Tidal + 4-day wind-driven cycle (T = 96 hr)[b]	309	B, M, S
			333	B, M, S
			357	B, M, S
			381	B, M, S
6	50	Tidal + 16-day wind-driven cycle (T = 384 hr)[b]	477	B
			573	B
			669	B, M
			765	B, M, S

[a]For each run and time, calculations were performed for all depths. Calculations are only shown for those depths at which excess salinities exceeded 0.1 ppt. See U.S. Department of Commerce, 1977f for concentration profiles.

[b]See Figure B-2 for wind-driven current cycle imposed.

Rotary tidal components were specified in the form:

$$u_T = 0.3 \cos\left(\frac{2\pi}{24}\, t\right)$$

$$v_T = 0.6 \cos\left(\frac{2\pi}{24}\,(t + 6)\right)$$

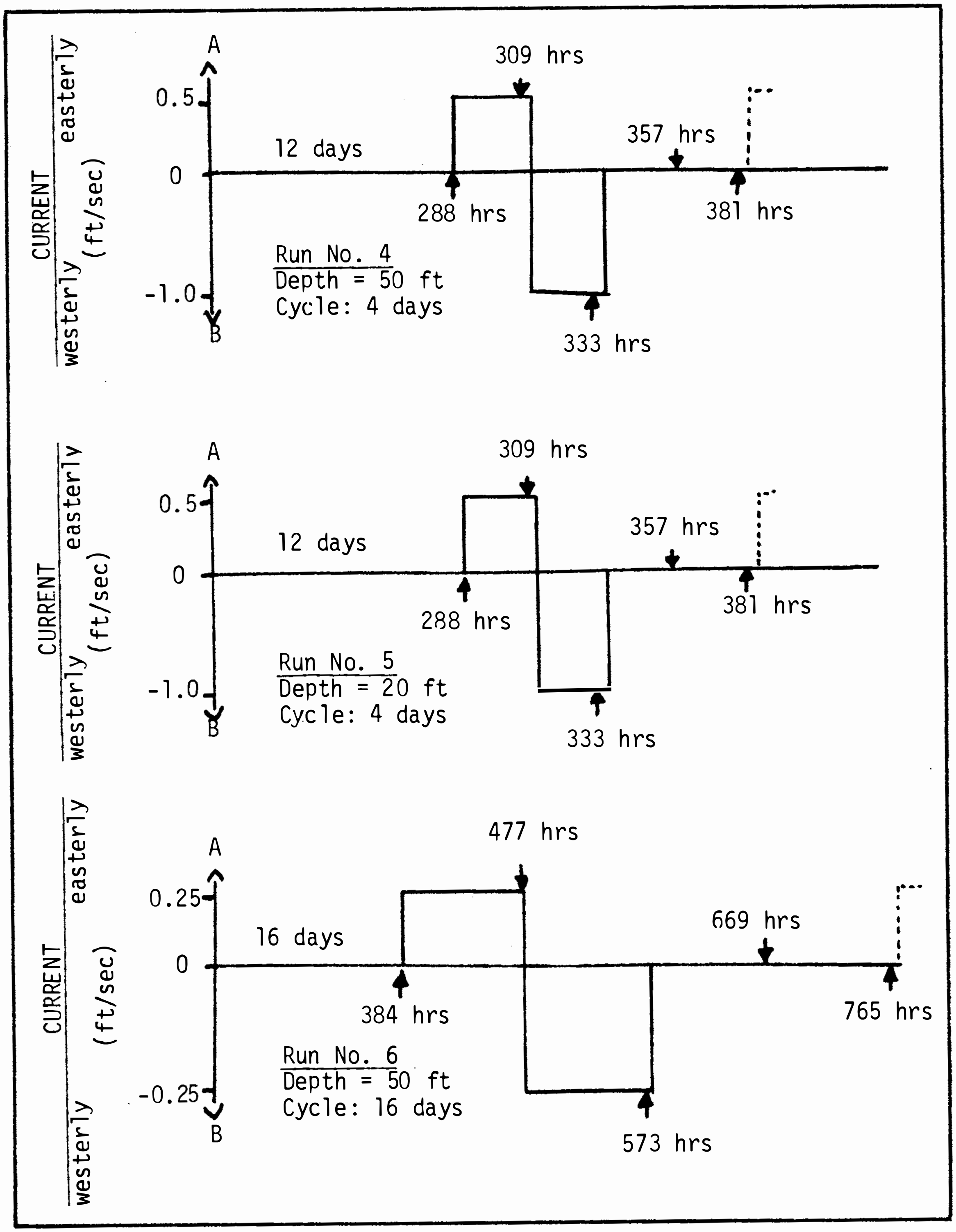
where t is in hours and u_T and v_T are in ft/sec. The wind driven current for Runs 4, 5, and 6 was assumed to fit the schematic cycle described in Figure G.3-2. Although idealized, this sequence reproduces the observed pnenomena of wind reversals following the passage of a front, coupled with periods of stagnation. The 4-day wind-driven cycle was selected to simulate conditions of moderate wind and current. The 16-day wind-driven cycle was selected to simulate the buildup of salinity concentrations with time during periods of stagnation.

G.3.1.2.2 Results and Conclusions (Estimated Currents)

For each run, excess concentrations were calculated four times within the current sequence and at three depths (bottom, mid-depth and surface). Isoconcentration plots for those depths and times (shown in Table G.3-1) at which predicted excess concentrations exceeded 0.1 ppt are presented in "Analysis of Brine Disposal in the Gulf of Mexico, Bryan Mound" (U.S. Dept. of Commerce, 1977f).

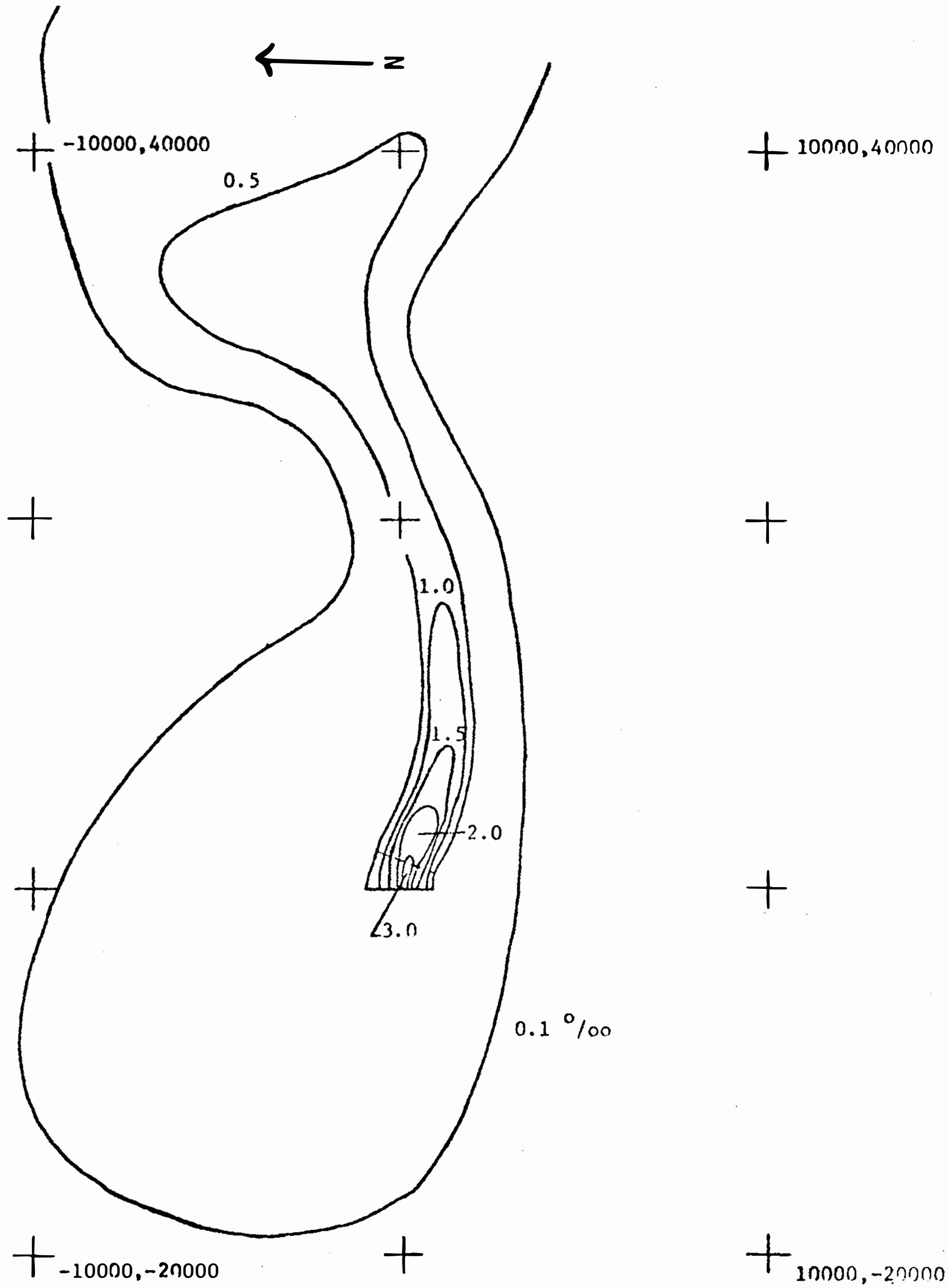
The sequence of excess concentration profiles obtained for Run 4 at the ocean bottom is shown in Figures G.3-3, G.3-4, G.3-5 and G.3-6. Figure G.3-3 shows profiles which result after 13 days of tidal cycles and 21 hours of steady easterly currents of 0.5 ft/sec. The area of 0.5 ppt excess salinity extends for more than 7.5 miles alongshore and up to 1.1 miles toward shore. Figures G.3-4 and G.3-6 show profiles resulting after 21 hours of a 1.0 ft/sec westerly current and 21 hours of no alongshore currents, respectively. Figure G.3-6 shows bottom concentration profiles after 45 hours of stagnant currents (alongshore). Buildup of excess salinities in a pool inshore of the brine diffuser can be observed. Dimensions of the 0.5 ppt excess isoconcentration are approximately 1.9 miles north-south and 3.75 miles east-west.

Several conclusions can be drawn from these calculations. Run 3, which treats the transient development of a plume in a steady current,



SOURCE: U.S. Department of Commerce, 1977f.

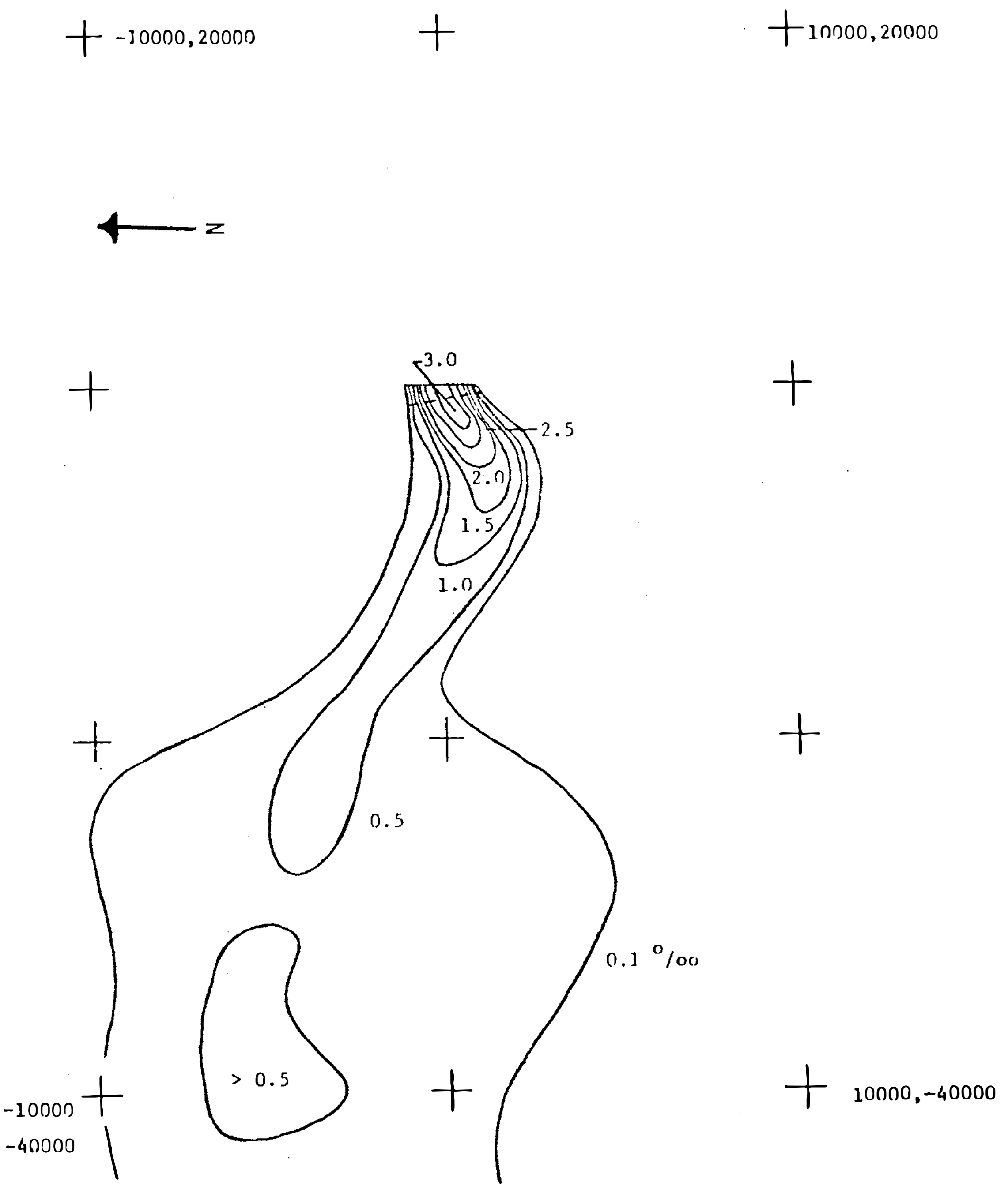
FIGURE G.3-2. Schematic representation of wind driven cycles assumed for computer simulation.



Distance from brine source given in feet; excess salinity above ambient given in ppt.
Run 4 at the Bottom for time = 309 hrs. (See Table G.3-1 and Figure G.3-2)

SOURCE: U.S. Department of Commerce, 1977f.

FIGURE G.3-3. Predicted far field excess salinity, T=309 hours, bottom profile.

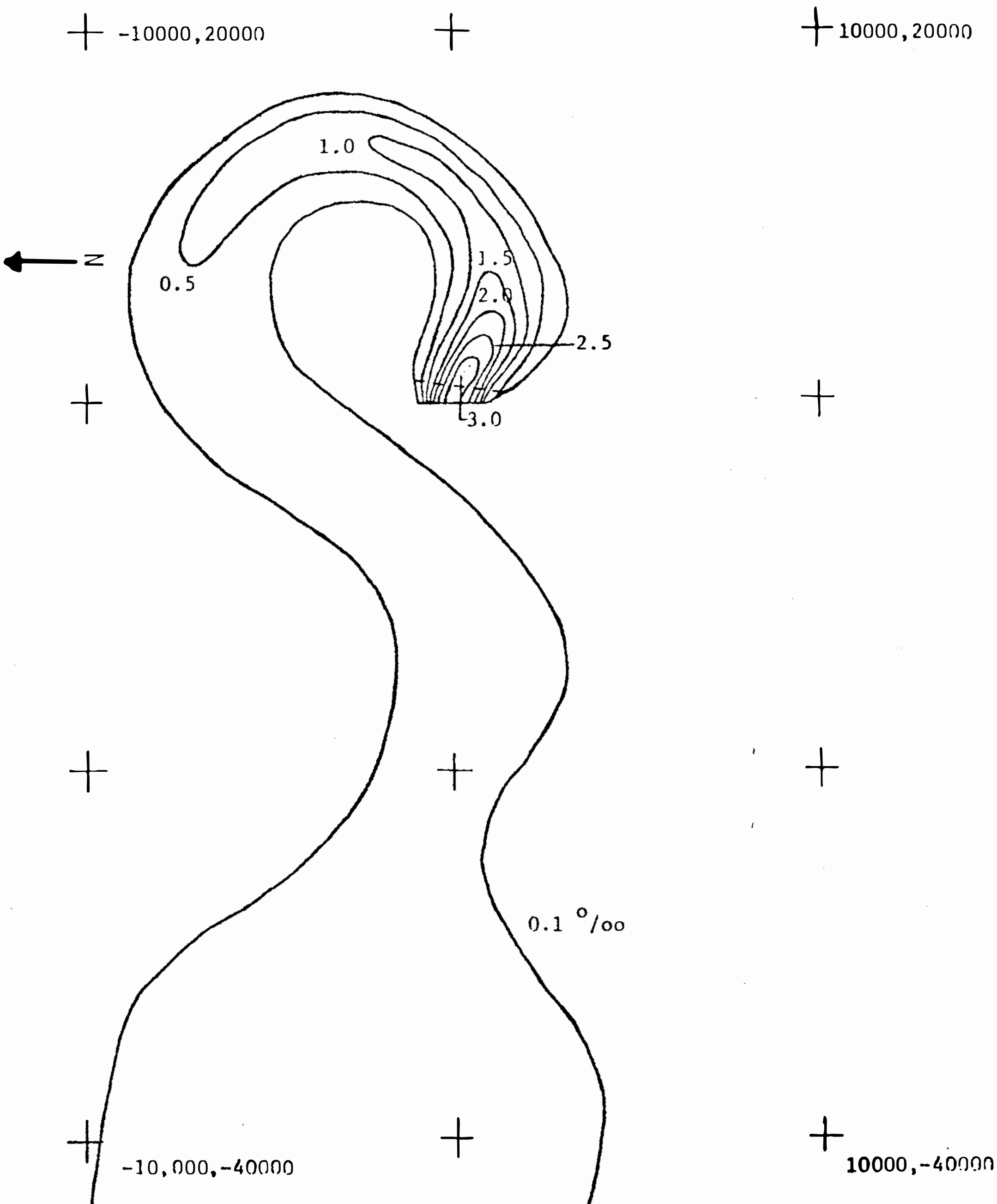


Distance from brine source given in feet; excess salinity above ambient given in ppt.

Run 4 at the Bottom for Time = 333 hrs.(See Table G.3-1 and Figure G.3-2)

SOURCE: U.S. Department of Commerce, 1977f.

FIGURE G.3-4. Predicted far field excess salinity, T=333 hours, bottom profile.



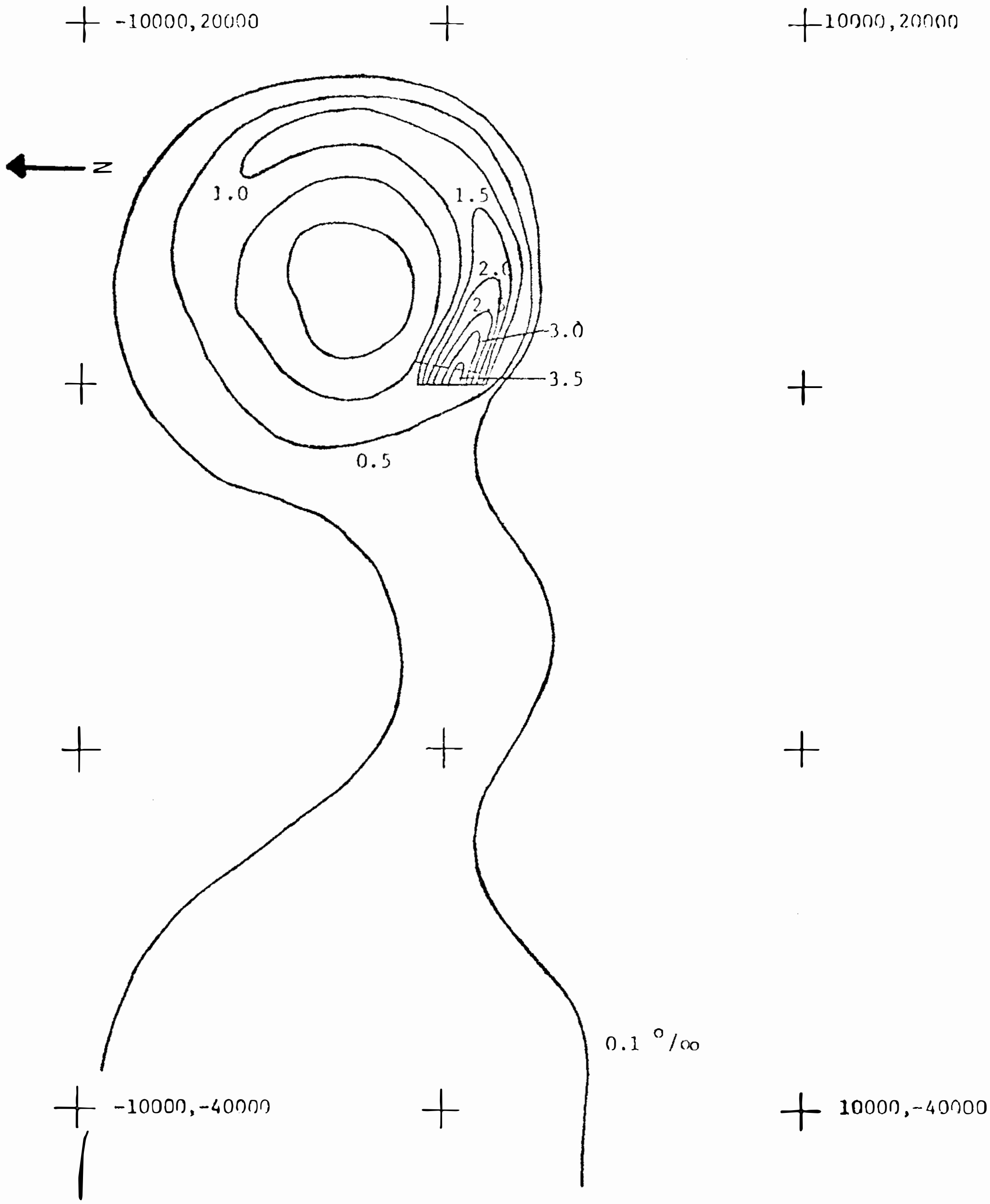
Distance from brine given in feet; excess salinity above ambient given in ppt.

Run 4 at the Bottom for Time = 357 hrs.

(See Table G.3-1 and Figure G.3-2).

SOURCE: U.S. Department of Commerce, 1977f.

FIGURE G.3-5 Predicted far field excess salinity, T=357 hours, bottom profile.



Distance from brine given in feet; excess salinity above ambient given in ppt.
Run 4 at the Bottom for Time = 381 hrs.
(See Table G.3-1 and Figure G.3-2).

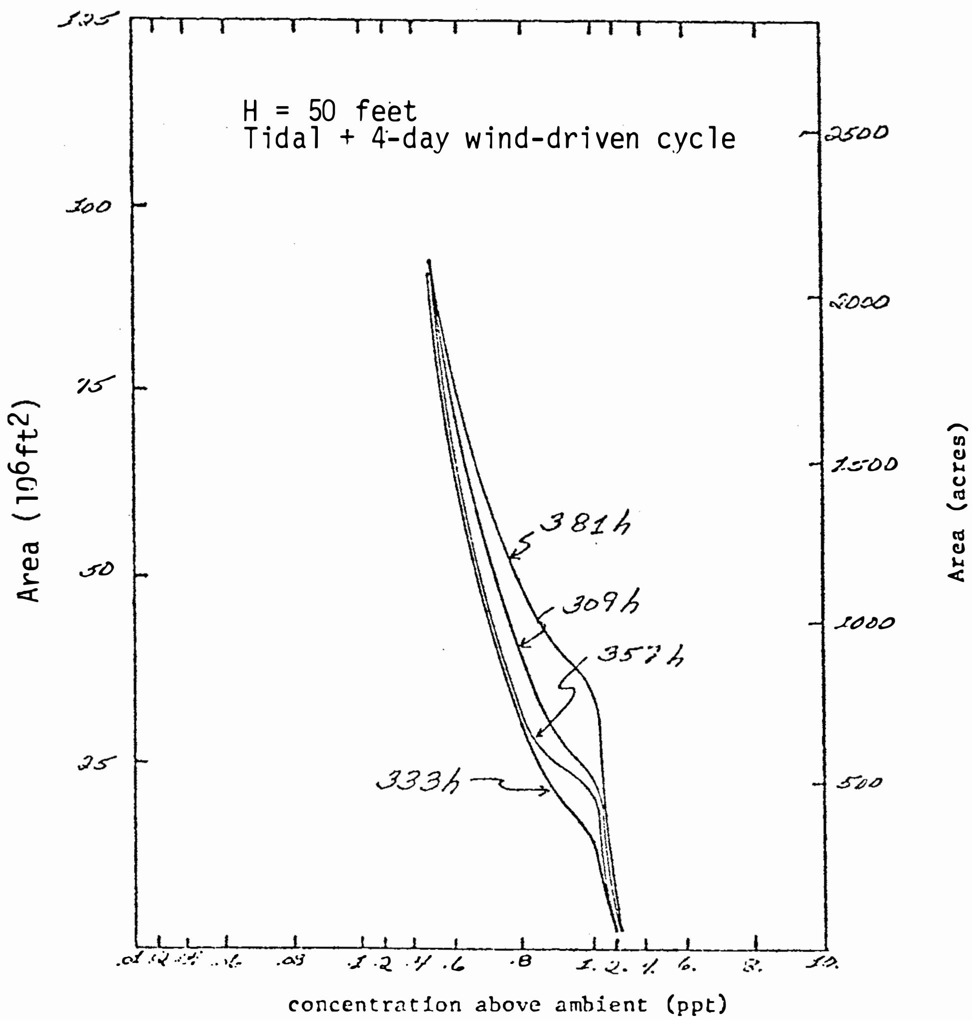
SOURCE: U.S. Department of Commerce, 1977f.

FIGURE G.3-6 Predicted far field excess salinity, T=381 hours, bottom profile.

indicates that the length of time required for a plume to approach steady state is a function of the level of concentration which is considered. For instance, steady state for excess concentrations down to the 1.5 ppt contour requires 18 hours; steady state for excess concentrations below 1.0 ppt requires considerably longer. In this respect, a model which assumes steady currents will be most successful in predicting the extent of the higher levels of concentration.

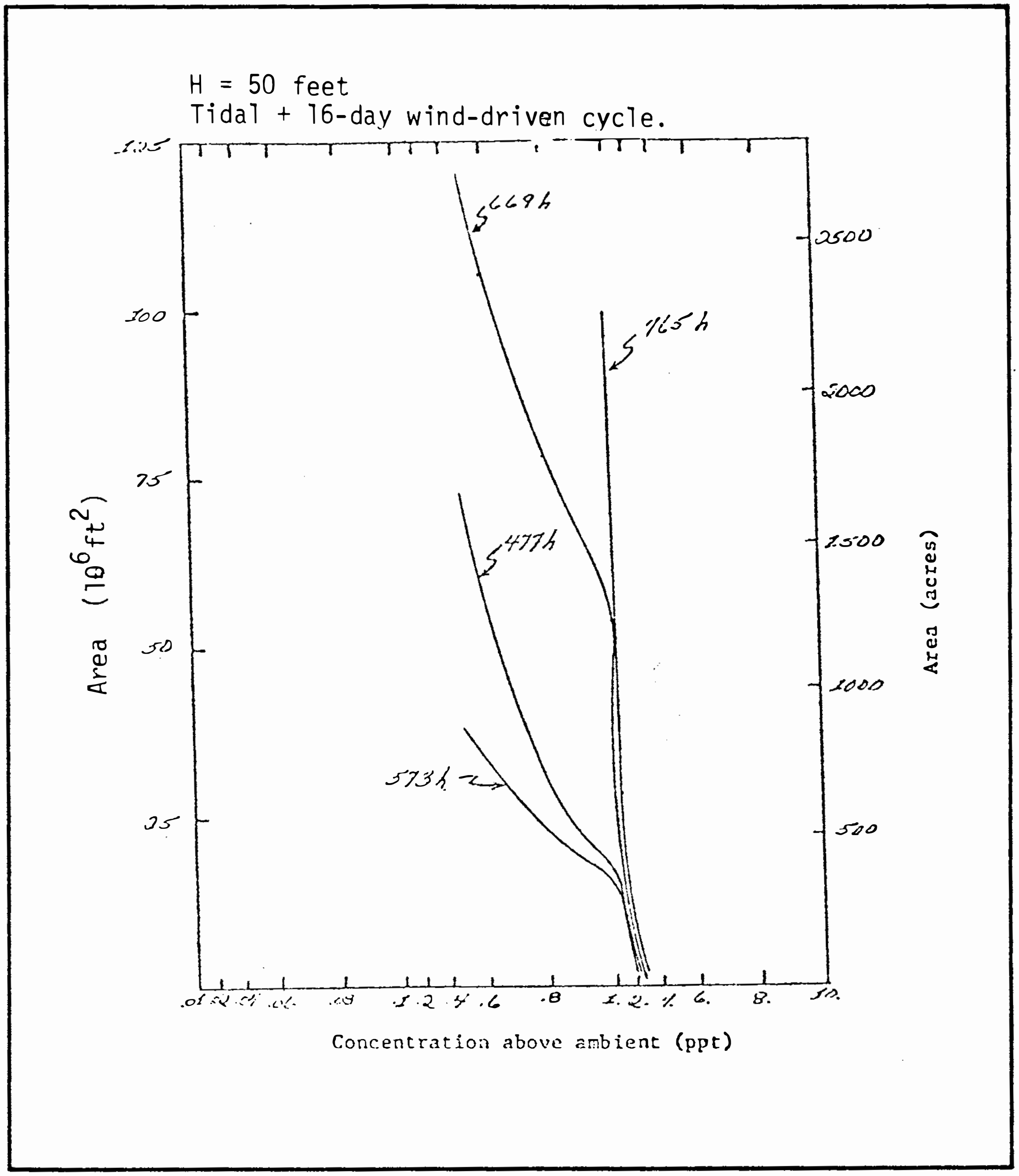
Runs 4 through 6 show that, while the current sequence has only a moderate effect on the maximum predicted concentration in the far field ($\sim$2 to 5 ppt), it has a substantial influence on the shape of the calculated concentration distribution. Periods of strong ambient current (e.g., the second time period for each run) produce long, narrow plumes. Concentrations near the diffuser are relatively low due to the positive dependence of near field dilution on current speed. During periods of little net drift (e.g., the third and fourth time period for each run), the plumes remain close to the diffuser; concentrations near the diffuser are generally higher than for the strong net current cases due to concentration buildup and the poorer near field dilution at the lower ambient velocities. The first time period for each run represents an intermediate situation where the current is instantaneously strong, but the effects of prior stagnation and/or a current in the reverse direction can be seen.

Figures G.3-7 and G.3-8 summarize the results of the analysis for the water depth of 50 feet and the tidal plus 4-day and 16-day wind-driven cycles, respectively. The buildup of concentration with time during periods of stagnation can be seen on Figure G.3-3 at 357 and 381 hours, which shows bottom concentrations after periods of stagnation lasting for 1 and 2 days; also on Figure G.3-4 at 669 and 765 hours, which shows bottom concentrations after periods of stagnation lasting for 3 and 4 days. Using a diffuser of the adopted design and under conditions of moderate wind and current, a characteristic model output predicts a plume with salinities of greater than 1 ppt above ambient at the bottom covering less than 500 acres. Under stagnant conditions, a characteristic plume of such salinities would cover up to 2000 acres.



SOURCE: U.S. Department of Commerce, 1977f.

FIGURE G.3-7 Bottom areas vs. excess salinity at various times for Run 4.



SOURCE: U.S. Department of Commerce, 1977f.

FIGURE G.3-8 Bottom areas vs. excess salinity at various times for Run 6.

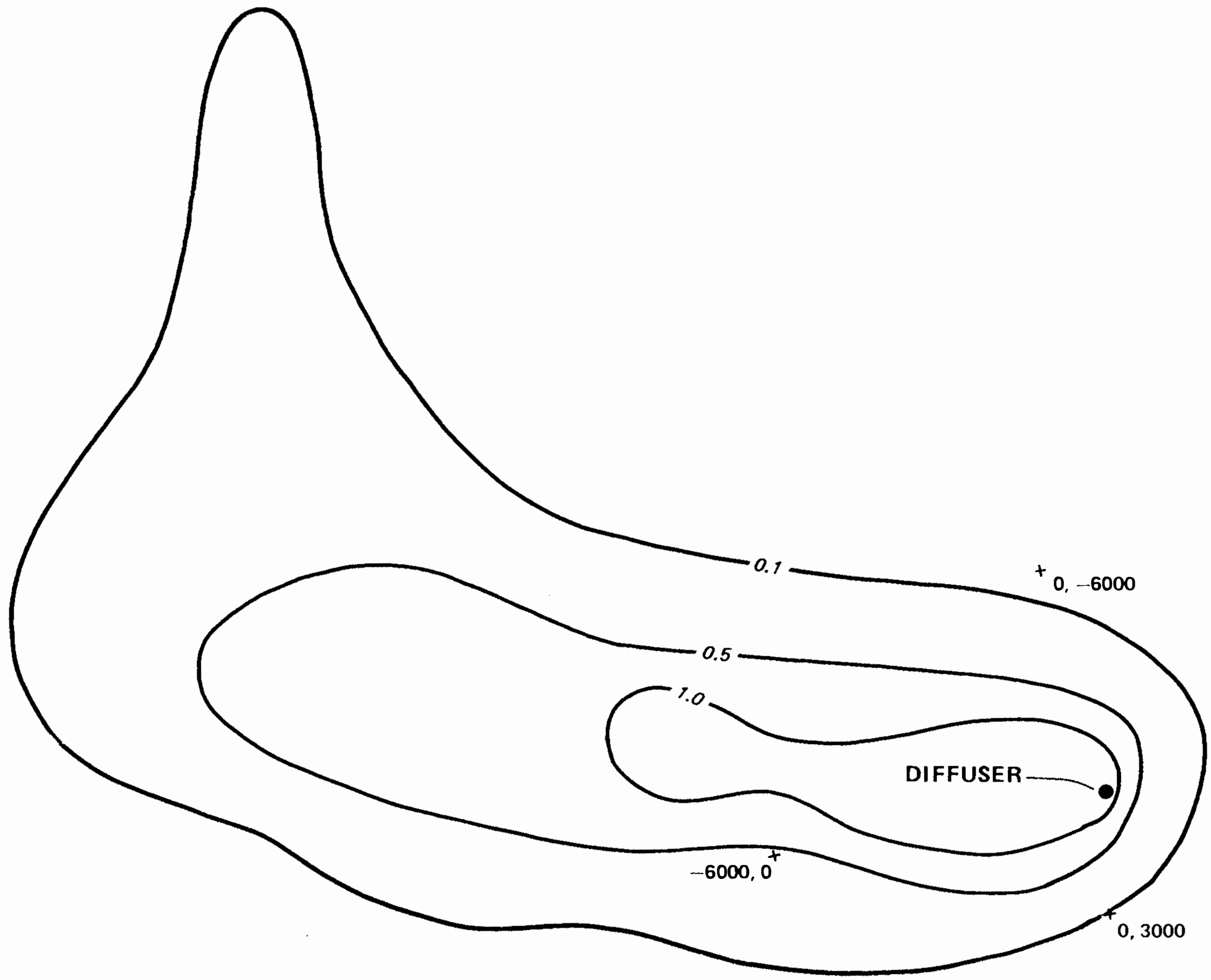
It is also interesting to note that, while areas associated with the larger concentrations are generally greater for cases with low net current than for cases with strong net currents, the areas associated with the smaller concentrations are often smallest for the cases with low net current. This is explained by the fact that for distances greater than the tidal excursion and during periods of low net current, transport is effected mainly by diffusion which acts radially (and hence, in both horizontal directions), while for periods of strong net current, only diffusion in the lateral direction is effective in mass transport.

Comparison of Runs 5 and 6 show that, for the cases considered, the depth of water has little influence on bottom concentrations and only a moderate effect on the surface concentrations. Perhaps the biggest difference between the two runs is the fact that in Run 5 (H = 20 feet), the excess salinities extend past the location of the shoreline while in Run 6 (H = 50 feet), they remain offshore.

G.3.1.2.3 Observed Baseline Conditions, Results and Conclusions

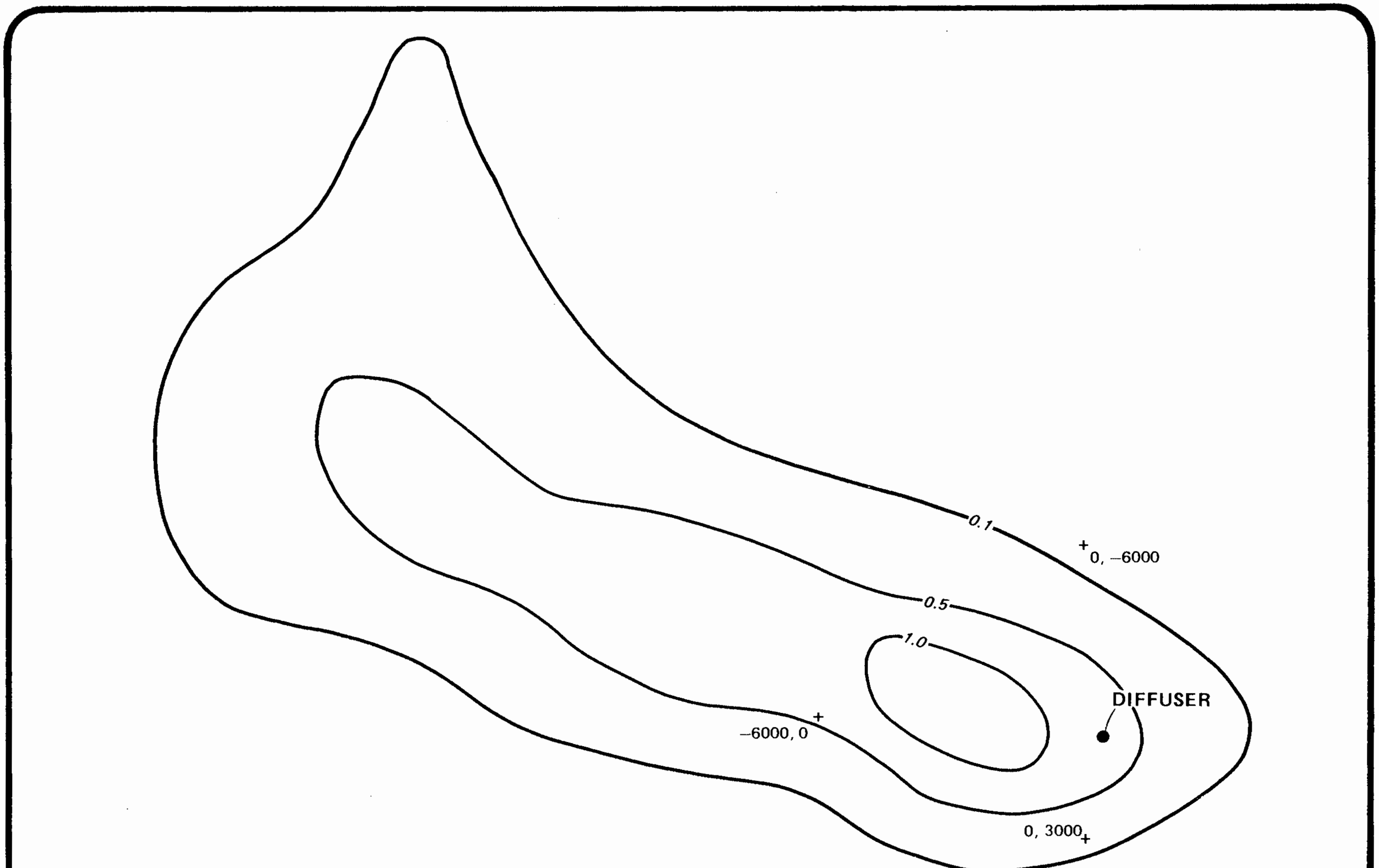
A second plume analysis was conducted (U.S. Dept. of Commerce, 1978b) using *in situ* current data collected at the alternative diffuser site between December 4, 1977 and January 5, 1978 (see Figure G.2-24 and G.2-25). Figures G.3-9 through G.3-12 depict contours of the far-field salinity patterns eminating from the proposed diffuser at 3-hour intervals during a tidal cycle. A total of 310 hours of data on observed currents was input to the model prior to outputting the salinity contours shown. The figures represent an instant time analysis of the plume as it would dynamically change in response to changes in the tidal and wind-driven currents found in the proposed diffuser area.

The new current data indicate that the currents in the area are stronger than previously estimated and therefore the expected dilution effect of the currents would also be higher. This higher dilution would reduce the observed excess salinity and temperature values at the site.



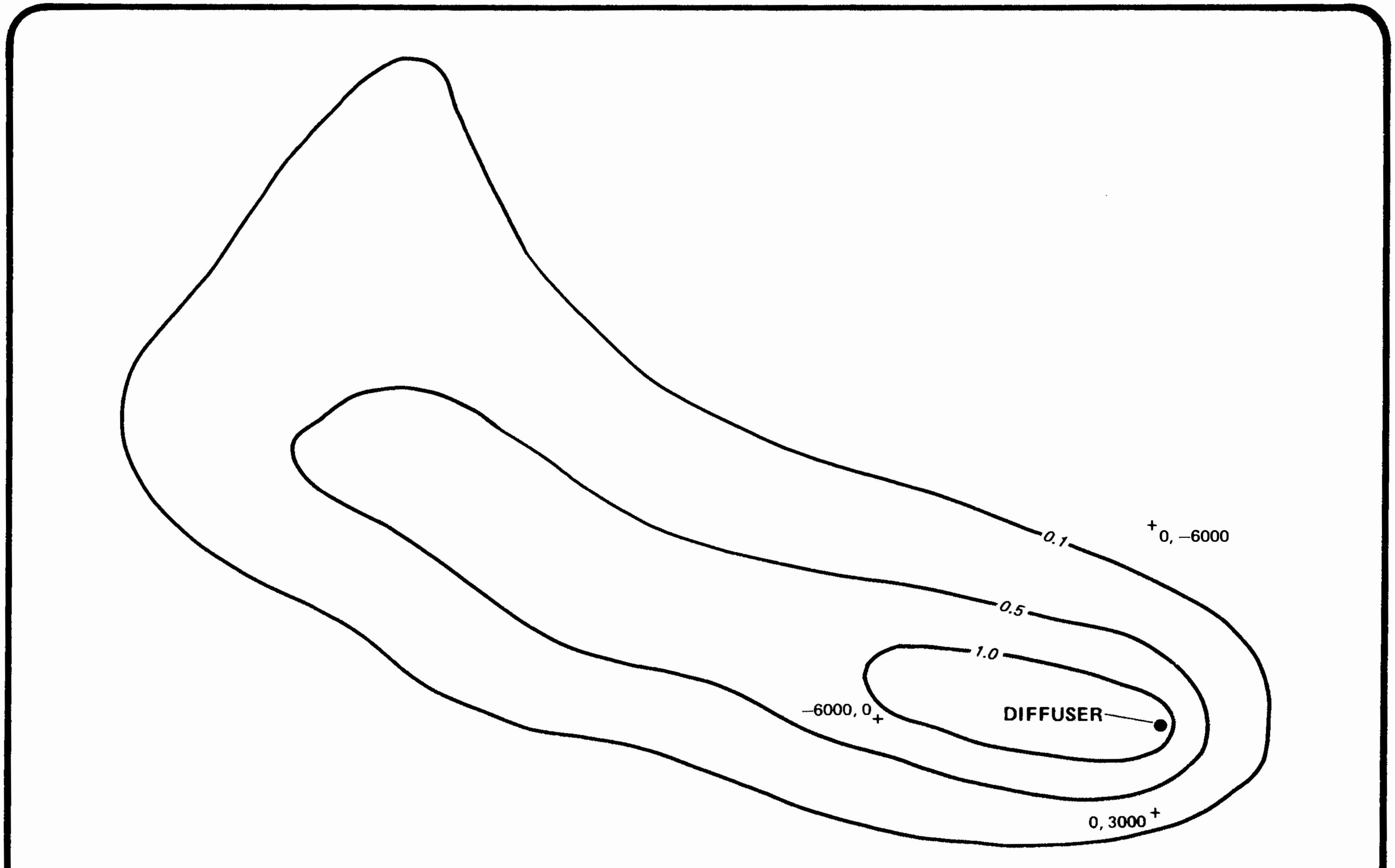
SOURCE: U.S. Department of Commerce, 1978b.

FIGURE G.3-9. Contours of excess salinity concentrations (ppt) at various distances (feet) from the center of the proposed diffuser using observed currents at T=310 hours.



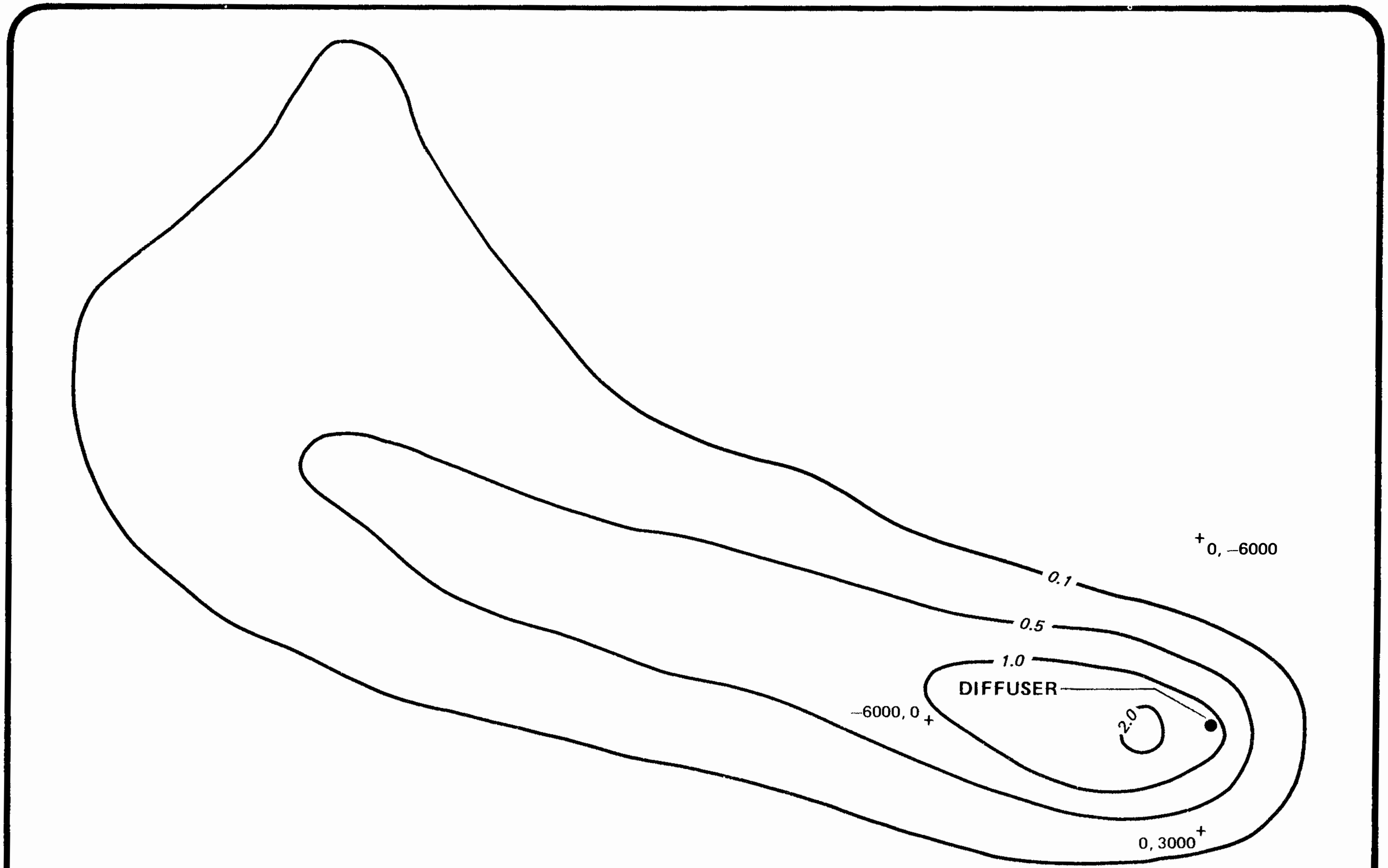
SOURCE: U.S. Department of Commerce, 1978b.

FIGURE G.3-10. Contours of excess salinity concentrations (ppt) at various distances (feet) from the center of the proposed diffuser using observed currents at T=313 hours.



SOURCE: U.S. Department of Commerce, 1978b.

FIGURE G.3-11. Contours of excess salinity concentrations (ppt) at various distances (feet) from the center of the proposed diffuser using observed currents at T=316 hours.



SOURCE: U.S. Department of Commerce, 1978b.

FIGURE G.3-12. Contours of excess salinity concentrations (ppt) at various distances (feet) from the center of the proposed diffuser using observed currents at T=319 hours.

The expected plume patterns, using the observed current data, closely parallel the patterns predicted by inputting estimated current data. The isopaths of salinity in the figures are plotted where the predicted excess salinity contours exceed 0.1 ppt. With the exception of the 0.1 ppt isohaline, the four predicted plumes are similar, reflecting the effects of ambient currents in the area on the shape of the plume pattern. For example, it would be expected that strong ambient currents would produce a long narrow plume. In this case, the plume pattern reflects the northwesterly drift at the time of analysis. Excess far field salinity concentrations do not exceed 2 ppt for any of the plumes described; this is also consistent with predictions using estimated currents. Salinity concentrations near the diffuser head are relatively low due to the positive dependence of the nearfield dilutions on current speed.

G.3.1.3 Brine Plume Thermal Analysis

The brine which would be discharged from the Seaway Group diffuser at Bryan Mound (Figure G.3-13) would originate either from the initial leaching of caverns or from water displacement of stored oil during a cavern fill period. Because of the earth's thermal influence in these deep caverns, the effluent brine would be elevated in temperature. The temperature of the brine before disposal in the Gulf of Mexico would thus be influenced by this geothermal heating and is related to the depth of the leached caverns in the earth, the residence time in the caverns, the temperature of the displaced oil, the retention of the brine in the holding pits and any heat loss or gain in the pipeline to offshore. Although it has been conservatively estimated that the temperature of the brine will be 130^{o}F, observations made for various flow rates at several operational salt domes show that the temperature of the brine before injection into a brine holding pit will be more realistically at a temperature of 120^{o}F or less.

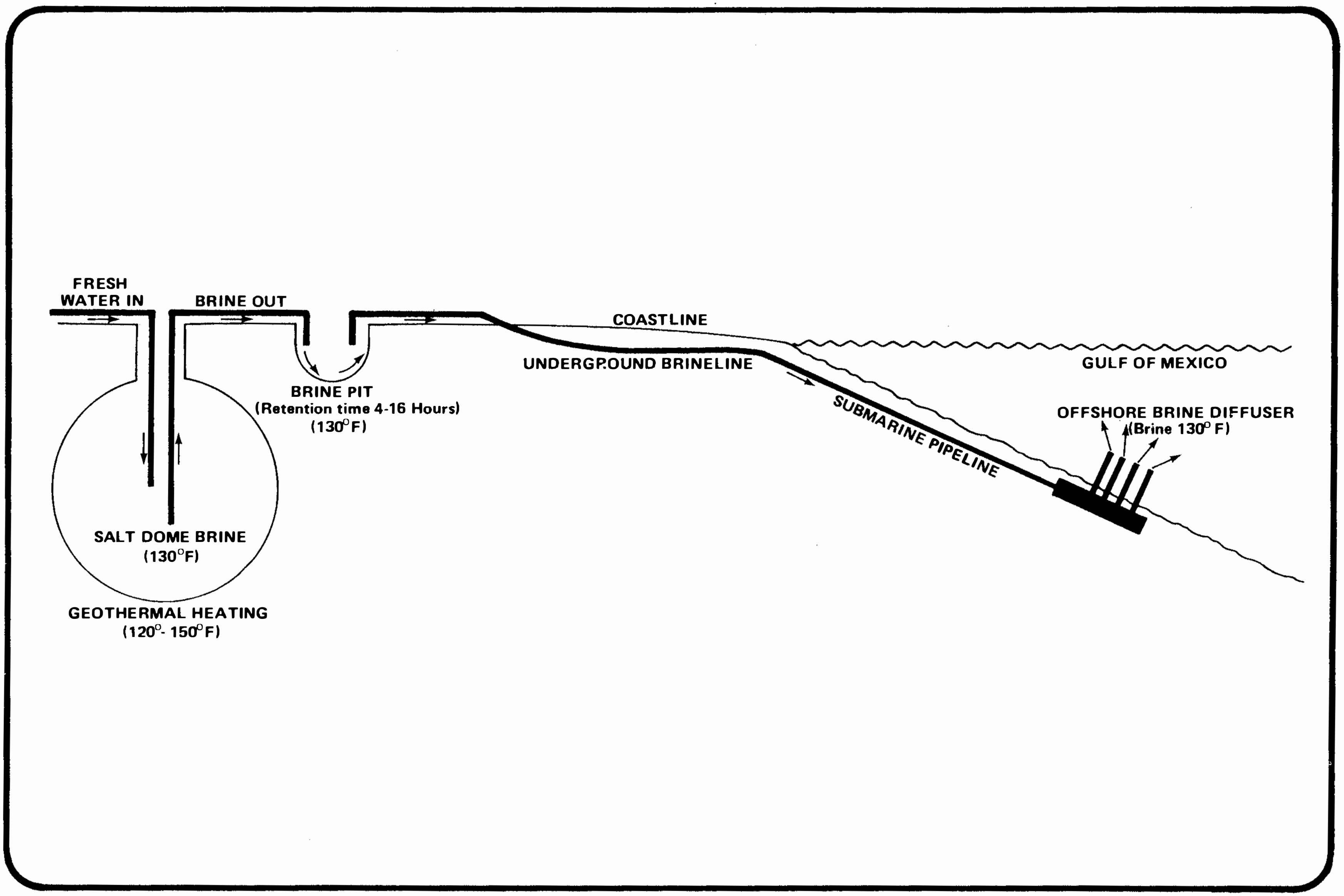


FIGURE G.3-13. Schematic model for brine temperature analysis.

Observed Temperature and Flow Rates for Brine at Several Gulf Coast Salt Domes

Salt Dome	Brine Temperature (^{o} F)	Oil Temperature (^{o} F)	Flow Rate (BPH)	Well Number
Bryan Mound	120	80	1500	2
			1000	4
Bayou Choctaw	80-90	80	1250[a]	15
West Hackberry	80-90	80	1500	6
			1000	11

[a]Fill at Bayou Choctaw is intermittent; the average is 1250 BPH but actual injection rate is 2200 BPH.

An analysis of heat transfer properties in the proposed brine disposal pipeline was conducted to determine the expected heat loss in the disposal when the brine is pumped from the brine pit to the Bryan Mound diffuser head (Figure G.3-13). This analysis was carried out for conditions where the temperature of the brine at the inlet ranged from 70^{o}F to 140^{o}F and ambient ground temperatures ranged from 50^{o}F to 70^{o}F. The results of this analysis in the table below indicate that the maximum temperature differential (ΔT) between the inlet and the outlet (i.e., the diffuser ports) would occur for the case when the inlet temperature was 140^{o}F and the ground temperature was 50^{o}F, but this difference would only amount to 3.2^{o}F. Therefore the temperature of the brine at the diffuser head considered below should conservatively remain within the temperature range of about 115^{o} to 120^{o}F.

Brine Temperature (^{o}F) at the Proposed Diffuser Ports as a Function of Ground Temperature and Brine Temperature at the Pipeline Inlet

Brine Inlet Temperature (^{o}F)	Ground Temperature (^{o}F) 50	60	70
140	136.8	137.2	137.6
130	127.2	127.6	128.1
110	108.1	108.5	108.9
90	88.9	89.3	89.6
70	69.6	69.9	70.0

G.3.1.3.1 General Approach

To estimate the potential impacts from excess temperatures which might result from discharge of brine to the Gulf of Mexico through the Seaway Group diffuser at Bryan Mound, a simplistic heat flow model (Figure G.3-14) was evaluated and analyzed. A correlation was made between excess temperature and excess salinity profiles, assuming 90^{o}F seawater (probable maximum) and brine temperatures varying from 90^{o}F to 150^{o}F. The brine dispersion model as discussed in Section G.3.1.1 provided a basis for applying this correlation to expected mixing conditions in the Gulf of Mexico at the diffuser site. The simplified analysis presented here does not account for buoyancy effects in the water column due to elevated brine temperatures. The analysis should be reasonably accurate within the mixing zone which is located close to the brine diffuser.

Since the temperature of the brine within the salt dome is not accurately known and temperature will vary with residence time and the other factors described above, a parametric analysis was used to relate the difference in the temperature in the brine plume compared to the ambient water temperature (ΔT_1) with the temperature of the brine (T_b) (see Figure G.3-14).

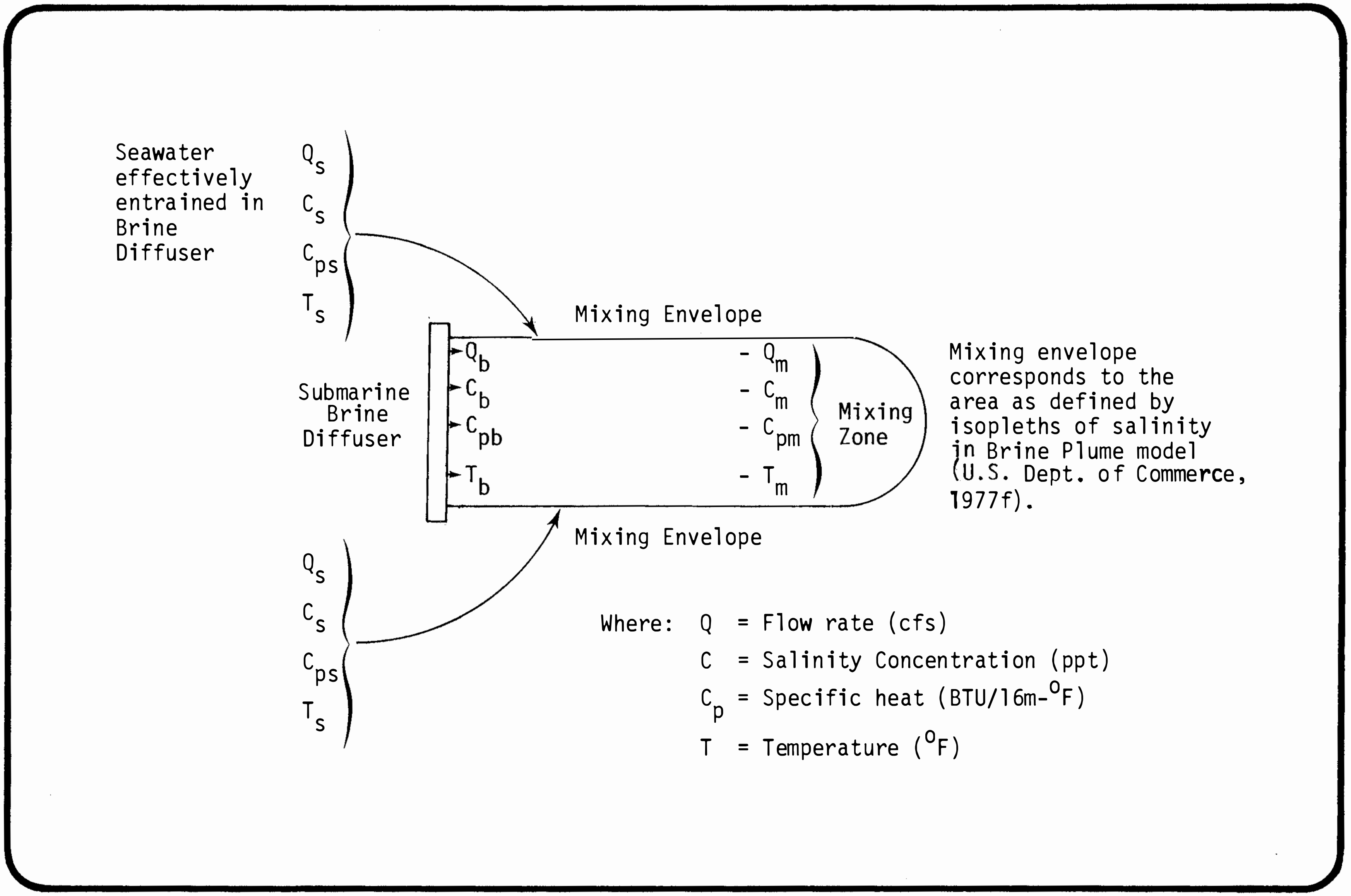


Figure G.3-14. Schematic model of mixing zone relationships for brine plume temperature analysis.

G.3.1.3.2 Salinity Dilution Calculation

The basic analysis for the salinity dilution effects corresponds to the area at the diffuser site defined by the MIT model (Section G.3.1.1) above; in this analysis salt is conserved throughout mixing zones such that:

$\rho_m Q_m C_m = \rho_b Q_b C_b + \rho_s Q_s C_s$; where $\rho_m Q_m = \rho_b Q_b + \rho_s Q_s$, and ρ is the specific gravity of the corresponding fluid.

$$\therefore C_m = \frac{\rho_b Q_b C_b + \rho_s Q_s C_s}{\rho_b Q_b + \rho_s Q_s}$$

Define: $$\Delta C_1 = C_m - C_s = \frac{\rho_b Q_b C_b + \rho_s Q_s C_s}{\rho_b Q_b + \rho_s Q_s} - C_s$$

Or $$\Delta C_1 = \frac{\rho_b Q_b (C_b - C_s)}{\rho_b Q_b + \rho_s Q_s}$$

Solve for Q_s: $$Q_s = \frac{\rho_b Q_b (C_b - C_s) - \rho_b Q_b (\Delta C_1)}{\rho_s \Delta C_1}$$

Define: $C_b - C_s = \Delta C_2$ = constant

Then $$Q_s = Q_b \left(\frac{\Delta C_2}{\Delta C_1} - 1 \right) \left(\frac{\rho_b}{\rho_s} \right) \qquad (1)$$

G.3.1.3.3 Heat Dilution Calculation

Assume conservation of energy in mixing zone:

$\therefore \rho_m Q_m C_{pm} T_m = \rho_b Q_b C_{pb} T_b + \rho_s Q_s C_{ps} T_s$; where

$\rho_m Q_m = \rho_b Q_b + \rho_s Q_s$ and within most of mixing zone,

$C_{pm} \approx C_{ps}$ (i.e., substantial dilution)

Also, heat capacity per unit volume is nearly independent of salinity, or $\rho_s C_{ps} \approx \rho_b C_{pb} \approx \rho_m C_{pm}$

then:

$$T_m = \frac{\rho_b Q_b C_{pb} T_b + \rho_s Q_s C_{ps} T_s}{(\rho_b Q_b + \rho_s Q_s) C_{pm}} = \frac{\rho_s C_{ps} (Q_s T_s + Q_b T_b)}{C_{pm} (\rho_b Q_b + \rho_s Q_s)}$$

Define:

$$\Delta T = T_m - T_s = \frac{\rho_s Q_b T_b - \rho_b Q_b T_s}{\rho_s Q_s + \rho_b Q_b}$$

Using equation (1): $\Delta T = \frac{\Delta C_1}{\Delta C_2} \left(\frac{\rho_s}{\rho_b} T_b - T_s \right)$ (2)

Using equations (1) and (2) and site specific data for Q_b, C_b, C_s, ρ_s, ρ_b, and T_s, we can solve for Q_s and ΔT, as a function of T_b and ΔC_1.

G.3.1.3.4 Application to Seaway Group Diffuser

The following data have been applied to the diffuser at Bryan Mound:

Q_b = 42 cfs

ΔC_w = 240 ppt; $C_b \cong$ 270 ppt; C_s = 30 ppt

T_s = 32^oC = 90^oF

ρ_s = 1.02

ρ_b = 1.2

Then, from Equation (1):

$$Q_s = 42\left(\frac{240}{\Delta C_1} - 1\right)\left(\frac{1.2}{1.02}\right) = f\ (\Delta C_1)$$

and from Equation (2):

$$\Delta T = \frac{\Delta C_1}{240}\ (0.85\ T_b - 90) = f\ (\Delta C_1,\ T_b)$$

Therefore, using the salinity change profiles (ΔC_1) as calculated in Section G.3 above, we can calculate Q_s, and for various assumed brine temperatures, T_b, we can correlate ΔT with ΔC_1.

Table G.3-2 lists correlations calculated between ΔC_1, and ΔT, for a range of T_b from 150^oF to 90^oF and for an assumed T_s = 90^oF. These correlations are plotted on Figure G.3-15.

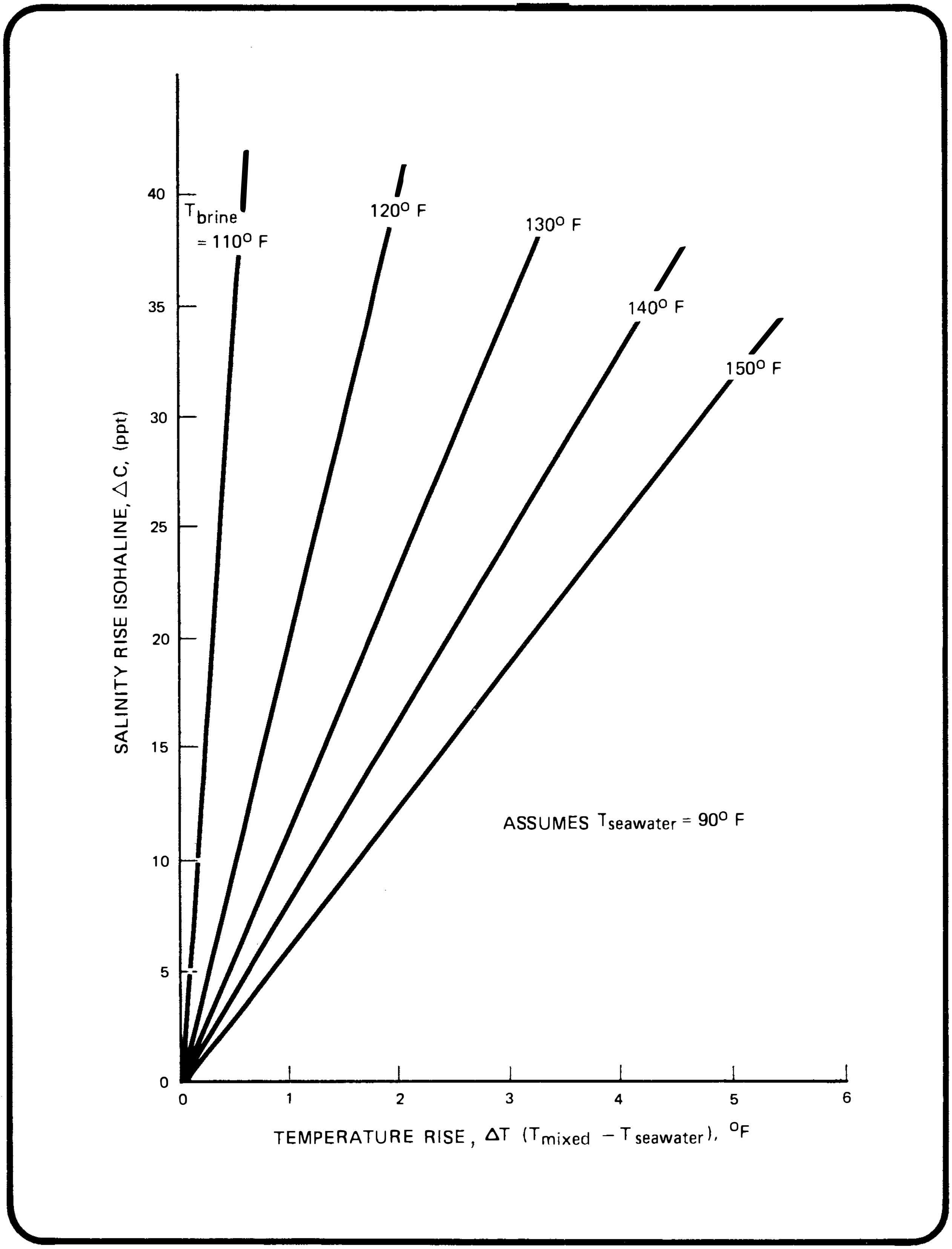


FIGURE G.3-15. Temperature rise (ΔT) versus salinity rise (ΔC) correlation.

To apply these results, the profiles of excess salinity which appear in Section G.3-1 above can be replotted for excess temperature profiles. Within the range of ΔC_1 as plotted, ΔT, will be less than 0.6^{o}F, which indicates a very small area will be affected by elevated brine temperatures. Concentration profiles of salinity excess would be needed in the near field to show the area of possible thermal impact. Therefore under most case conditions it is expected that at the boundary of the 25-acre mixing zone an increase in temperature of less than 1^{o}F would occur during summer temperature maxima.

The presence of a strong thermocline or halocline at the proposed diffuser site might possibly inhibit the vertical movement of the plume discharge water and thus increase the area affected by elevated temperatures. The condition would most likely occur in the spring when freshwater inflow, due to high river flow, is a maximum, and the surface waters are beginning to warm due to solar heating.

TABLE G.3-2 Salinity - thermal correlations for proposed brine diffuser.

Salinity Rise Isohaline ΔC_1 (ppt)	Rate of Seawater Entrainment Q_s (cfs)	Temperature Rise in Surrounding Seawater, $\Delta T(^oF)$, for Various Brine Temperatures, T_b, at the Diffuser[a]						
		150°F	140°F	130°F	120°F	110°F	100°F	90°F
0.1	118,511	0.0156	0.012	0.0085	0.0050	0.0015	0	0
0.2	59,240	0.0313	0.024	0.017	0.0100	0.0029	0	0
0.3	39,471	0.0469	0.036	0.026	0.0150	0.0044	0	0
0.5	23,663	0.0781	0.060	0.043	0.0250	0.0073	0	0
1.0	11,807	0.1563	0.121	0.085	0.0500	0.0146	0	0
1.5	7,855	0.2343	0.181	0.128	0.075	0.0437	0	0
2.0	5,879	0.3125	0.242	0.171	0.10	0.029	0	0
3.0	3,903	0.467	0.363	0.256	0.15	0.044	0	0
4.0	2,915	0.625	0.483	0.342	0.20	0.058	0	0
5.0	2,322	0.781	0.604	0.427	0.25	0.073	0	0
7.5	1,531	1.17	0.905	0.640	0.37	0.109	0	0
10.0	1,137	1.56	1.21	0.853	0.50	0.146	0	0
15.0	741	2.34	1.81	1.28	0.75	0.218	0	0
20.0	543	3.13	2.42	1.71	1.00	0.292	0	0
25.0	425	3.91	3.02	2.14	1.25	0.365	0	0
50.0	188	7.81	6.04	4.27	2.50	0.73	0	0

[a] Assuming an ambient seawater temperature of 90°F.

G.3.2 IMPACTS ON WATER QUALITY

G.3.2.1 Brine Chemistry

Brine samples taken from the Bryan Mound salt dome, were analyzed for chemical components (Table G.3-3). It was determined that approximately 99 percent of the salt solution consists of sodium chloride; the other principal constituent is calcium sulfate. Magnesium is low and variable. The brine is saturated (317 g/l or 263 ppt) with respect to sodium chloride; this saturation level would be expected to occur only during refill operations. During the initial solution mining process, residence time for the brine would be comparatively short and therefore salt levels would be less than the levels discharged during refill periods (270 g/l or 230 ppt). Other salt domes considered as alternative sites for Seaway Group expansion would be anticipated to produce brine similar to that at Bryan Mound.

Aside from absolute salt concentration, an appropriate and convenient way to compare the chemistry of brines and natural waters is by examination of ion ratios to determine relative excesses and deficits of specific ions. Ion ratios for the bulk constituents (major ions) of Bryan Mound brines using data from Table G.3-3 are expressed in Table G.3-4 relative to the respective average ratios of "normal" seawater, i.e., seawater of 35 ppt from the open sea beyond any direct influence of land.

The normalized ratios of Table G.3-4 show that only sodium is in excess in Bryan Mound brines, ranging from 14 to 17 percent higher in brine than seawater relative to chloride. The remaining ions in brine are deficient by one to three orders of magnitude, magnesium being the most deficient.

Of the trace elements analyzed in the brine, only zinc, manganese, barium and iron occur in appreciable amounts (Table G.3-3). In all cases, these metals are within the acceptable standards established for public drinking water supplies (U.S. Environmental Protection Agency, 1973) (Table G.3-5). However, heavy metal concentrations in the Brazos River (Table G.3-6) must also be considered as constituents of the brine discharge since this water is the proposed source for the solution

TABLE G.3-3 Chemical analysis of Bryan Mound brines.

CAVERN NUMBER	(a) C-5	(b) C-5	(b) C-1	(b) C-2	(b) C-2	(b) C-2	(b) C-4	(c) SEAWATER
SALINITY (ppt)	254	262	264	263	263	264	265	35
MAJOR CONSTITUENTS (mg/l)								
Na	117,600	123,802	124,623	124,097	124,037	124,287	124,764	10,760
K	296						113	387
Ca	720	235	280	305	310	280	247	413
Mg	9.2	14	33	31	32	26	N.D.	1,294
Cl	184,100	190,067	191,245	190,174	190,030	190,531	190,672	19,353
SO_4	1,960	2,000	2,300	2,700	2,600	2,350	3,220	2,712
MINOR CONSTITUENTS (µg/l)								
Cd	<2	3	8*	3	2	N.D.	N.D.	
Cr	<2	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	
Cu	2	N.D.	3,920*	N.D.	N.D.	140	N.D.	
Pb	2	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	
Hg	<0.2	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	
Ni	2	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	
Zn	30	N.D.	90*	N.D.	30	30	N.D.	
Ba	<400	800	800	900	700	N.D.	<1.0	
Fe		1,350	8,200	900	1,200	1,000	10	
Mn	100	60	130	70	30	10	N.D.	
Se	<2							
Ag	<10							
As	2							
Sb	<2							

[a] Brine analysis conducted by U.S.G.S. National Water Quality Laboratory, Denver.

[b] Analysis of a refereed brine sample conducted by DOE.

[c] Myers, Holm and McAllister, 1969.

N.D. Not detected.

*Contamination suspected from sampler equipped with brass seals.

TABLE G.3-4 Bryan Mound brine ion ratios[a] relative to seawater (S = 35 ppt).

Source/Date		Na/Cl	K/Cl	Ca/Cl	Mg/Cl	SO_4/Cl	Ca/Mg	K/Na
		$(X^{y\pm}$ / Cl) Seawater = 1.000						
C-5	1/4/77	1.1487	0.0781	0.1841	0.00075	0.0761	246	0.068
C-5	9/30/77	1.1714	-	0.0582	0.00111	0.0752	52.8	-
C-4	12/2/77	1.1766	0.0301	0.0610	-	0.1207	-	0.024
C-2	9/29/77	1.1734	-	0.0755	0.00244	0.1015	30.8	-
C-2	10/6/77	1.1737	-	0.0768	0.00252	0.0978	30.5	-
C-2	10/20/77	1.1730	-	0.0692	0.00204	0.0881	34.0	-
C-1	9/29/77	1.1717	-	0.0689	0.00258	0.0860	26.7	-

[a] All ratios are weight-to-weight.

TABLE G.3-5 Proposed EPA numerical criteria for water quality.

Parameter	Public Water Supply Intake (μg/l)	Marine Water Constitutents (Aquatic Life) (μg/l)	Freshwater Aquatic Life (μg/l)
Arsenic	50	50	---
Cadmium	10	10	30 (hardness >100 μg/l) 4 (hardness <100 μg/l)
Chromium	50	100	50
Copper	1000	50	1/10 LC 50
Lead	50	50	30
Mercury	2.0	1.0	0.2
Nickel	---	100	1/50 LC 50
Zinc	5000	100	5/1000 LC 50
Cyanides	200	10	1/20 LC 50 (.005 μg/l)
Aldrin	1	5.5	0.01
DDT	50	0.6	0.002
Dieldrin	1	5.5	0.005
Chlorodane	3	---	0.04
Endrin	0.2	0.6	0.002
Heptachlor	0.1	8	0.01
Heptachlor epoxide	0.1	---	---
Lindane	4	5	0.02
Phenols	1.0	---	1/20 LC 50 (0.1 μg/l)
Oil and Grease	---	1. Not detectable as a visible film, sheen discoloration of the surface, or by odor. 2. Does not cause tainting of fish or invertebrates or damage to biota. 3. Does not form an oil deposit on the shores or bottom of the receiving body of water.	1. None visible on surface. 2. 1000 μg/kg hexane extractable subtances in sediments. 3. 1/20 LC 50.
pH	---	6.5 - 8.5	6 - 9
Ammonia	---	400	1/20 LC 50 (20 μg/l)
Hydrogen Sulfide	---	10	---
Sulfides	---	---	2
Dissolved Oxygen	---	6.0 mg/l	4.0 mg/l(>31°C)
Phosphorus	---	0.1	---
Diazinon	---	---	0.009
Malathion	---	---	0.008
Parathion	---	---	0.001
Suspended and settleable solids	---	---	80 μg/l
Turbidity and light penetration	---	---	10% change in compensation pT
Color	---	---	10% change in compensation pT
Toxaphene	5	0.10	0.1

SOURCE: U.S. Environmental Protection Agency, 1973.

TABLE C.3-6 Brazos River Diversion Channel dissolved heavy metal burden of 7/7/77.

HEAVY METAL (μg/l)	EXPECTED INTAKE WATER QUALITY		
	SURFACE	MIDDEPTH	BOTTOM
Cd	<1	<1	<1
Cr	1.6	2.5	3.0
Cu	4.0	4.4	5.2
Pb	3	2	3
Hg	0.30	0.23	0.30
Ni	2	<1	1
Zn	17	17	21
Sb	<10	<10	<10
Mn	60	55	53
Se	<20	<20	<20
Ag	<0.5	<0.5	<0.5
As	<20	<20	<20

SOURCE: FEA, 1977b.

water. Five metals (Cd, Sb, Se, Ag, and As) were undetectable in all samples. The remaining metals were significantly higher than the brine and slightly higher than Gulf of Mexico waters (Table G.2-10).

G.3.2.2 Impacts

The most obvious impact of brine discharge to the Gulf of Mexico would be increased salinity levels within the plume (Section G.3.1.2). Subtle elevation of certain ions and decrease of others may also have an impact. Engineering and modeling studies (FEA, 1977b) estimate an immediate dilution from the jet of 50 to 100 times in the brine plume. Using the conservative figure (dilution factor of 50 times), the effluent from the diffuser would then be expected to amount to 2 percent brine, and 98 percent seawater within the near field of the plume.

For the case of an effluent of 2 percent brine at the edge of the jet, mixing calculations performed on the data of Tables G.3-3 and G.3-4 show that the salinity of the plume will still be greater than 5 ppt above ambient, but the Ca/Mg ratios will be reduced to within 1 to 3 percent of that for average seawater. In coastal waters, because of salinity variations, this is probably statistically insignificant.

In contrast to Ca/Mg, the K/Na ratio of a plume of 2 percent brine will still be 15 to 19 percent lower than that of normal seawater. The slower response of the K/Na ratio to mixing is due to the dominance of sodium in the brine, especially relative to potassium. Hence, the K/Na ratio will not approximate that of normal seawater until the excess salinity above ambient falls to less than 1 ppt.

The significant distortion of Ca/Mg and K/Na ratios in brine, relative to seawater, is of biological interest since the proportions of these ions in ambient waters have been shown to be an important ecological factor in the physiological function of several aquatic organisms. Thus, imbalance may be as significant a concern in brine dispersion as osmotic stress (Section G.3.3.3).

A model used to predict the concentration of chemical components at various excess salinity contours for the Texoma brine disposal project (FEA, 1977c) forecasts that many of the free chemical components would assume near normal levels within the 10 ppt excess salinity contour. The number and types of precipitates predicted would remain constant as excess salinity increased. However, concentrations of most of these precipitates would increase with increasing excess salinity. The increased dissolved and precipitated solids which would form would tend to have an affinity for the surface of existing particulates. Formation and possible settling of these particulates could have an influence on the sessile marine life in the disposal area (FEA, 1977c).

Trace metals resulting from dissolution of the brine would remain well below EPA marine discharge criteria (Table G.3-5). During either low river flow or flood conditions at the raw water intake in the Brazos River, heavy metal levels would be expected to increase greatly. Under these conditions, concentrations of certain heavy metals (Pb, Hg, Zn, and Mn) in the brine discharge could exceed the EPA recommended discharge guidelines. Except for mercury, these heavy metal levels would be expected to decrease to below the recommended EPA discharge values as a result of sedimentation of particulate heavy metals in the salt cavern. Under normal river conditions, little increase above ambient levels in the Gulf should be anticipated from trace metals discharged along with the brine.

A predictive model for the amount of petroleum which could be dissolved in the brine (FEA, 1977c) estimated that the maximum theoretical equilibrium concentration would be 31 ppm; the average amount of dissolved oil during initial fill with a gradient of from 0 to 31 ppm. During oil fill and withdrawal, it is expected that there would be insufficient time, turbulence and circulation to allow the dissolved oil to reach the theoretical equilibrium concentration. Furthermore, vaporization and oil skimming during subsequent refills should reduce the maximum oil concentration at the discharge to less than 15 ppm, averaging 6 ppm (FEA, 1977b; US DOE, 1977). This level is higher than the observed ambient Gulf hydrocarbon levels, but it is expected that local mixing and dispersal mechanisms would have a moderating effect on the area of impact.

To test the validity of the above oil in brine model, historical data on the content of hydrocarbons discharged from similar brine cavern oil storage operations were collected. In Manosque, France, discharged oil-in-brine levels were 4.6 ppm (Range: 0.0-13.8 ppm) in operational caverns and 3.3 ppm (Range: 0-10 ppm) in the solution mining of new caverns. In Etzel, Germany, the hydrocarbon concentration of the brine discharge was less than 1 ppm (FEA, 1977b).

The expected salinity (230 to 264 ppt) and temperature (120^{O}F) of the brine in the cavern would result in its deoxygenation. When discharged during worst case stagnant conditions, the dissolved oxygen in the surrounding seawater would decrease by 0.1 to 0.2 mg/l from the normal 6 mg/l within the 4 ppt excess salinity contour. Under normal conditions of wind mixing because of the shallow (<50 feet) depths involved, reoxygenation of the plume would be expected to occur rapidly.

The pH of the water column should not be altered, since none of the constituents analyzed in the brine should affect pH levels.

G.3.3 IMPACTS TO THE BIOLOGICAL ENVIRONMENT

Salinity and temperature are crucial to living marine organisms. The range of salinity which will permit life is from natural freshwater with a minimal salt content (nearly approching zero), to saturated salt water with a salt content approaching 270 ppt. Water temperature is generally more important to the distribution of individual organisms and faunal assemblages than is salinity. Water temperature controls the lives of most aquatic animals; since they are poikilo-thermus, their body temperatures are at or near the temperature of the water environment and their temperature varies with changes in the water column. In the Gulf of Mexico, the average maximum surface water temperature rarely exceeds $85^{O}F$ and at a depth of about 1000 feet the temperature remains at about $41^{O}F$. These two physico-biological parameters and their potential for change are important to the development of the proposed diffuser site. Their impact on biological assemblages at the diffuser site are discussed in the following sections.

Aquatic organisms are best suited, physiologically, to an optimum salinity range. Fauna and flora having limited salinity tolerance ranges are termed stenohaline; those having a wide salinity tolerance, euryhaline. Even though these organisms exhibit optimum salinity ranges, they often live in waters outside these ranges. Within the estuarine and neritic ecosystems, aquatic organisms may encounter a wide range of salinity regimes. Estuaries and other coastal water bodies, where seawater is measurably diluted with freshwater, seasonally undergo wide salinity variations.

An organism's response to salinity stress will vary during particular stages of its life cycle. The adult stages may show a tolerance to wide salinity regimes, whereas narrow ranges are required for spawning and rearing of larvae. Hence, a species may change from stenohaline to euryhaline during its life cycle, and even within a certain life stage may tolerate different and often non-optimum growth salinity ranges. This is exemplified by the life cycle of many Gulf of Mexico marine species which alternate between environments of low and high salinity.

Much of the spawning activity occurs in the Gulf, which indicates a need for water of higher salinity and stability during this phase of the life cycle.

Environmental temperature changes have pronounced effects on an organism's response to variations in salinity. Aquatic organisms exhibit maximum tolerance to salinity variations when the temperature of their environment is within their optimum physiological temperature range. Within the Gulf coast estuaries and coastal waters, seasonal variations in water temperatures may be extreme, particularly in the summer and winter months when temperatures approach or exceed some organisms' temperature limits. During these months, slight variations in salinity may cause excessive stress on these organisms.

At the proposed diffuser site, a variety of environmental variables, including temperature, salinity, currents, depth, bottom topography, precipitation, and evaporation (Section G.2.2), would continually modify and influence the brine discharge plume. For discussion purposes, however, the plume can be defined to consist of two general areas: the near and intermediate-field discharge, covering up to 25 acres and having a salinity range of 5 ppt to 264 ppt above ambient, and a far-field area which will extend over several thousand acres with salinities ranging from less than 5 ppt to 0.1 ppt above ambient. Because the discharged brine will be denser than the ambient seawater, the plume will be confined, for the most part, to the lower half of the water column. During nonstagnant periods, the long ends of the plume will be generally parallel in the direction of the prevailing water currents.

G.3.3.1 Impacts to Plankton

The planktonic organisms encountered within these coastal Gulf waters (as discussed in Section G.2.4.2) have limited powers of mobility and therefore, in general, float passively; hence plankton cannot actively avoid an impacted region. Plankton in the upper half of the water column, in the region of the brine discharge, would probably not encounter the plume and would not be impacted. Those planktonic organisms in the lower half of the water column encountering the mid-section of the plume's axis would be entrained in the plume. The duration of exposure to (or "residence time") of the plankton in this plume should not exceed several hours. Only a small portion of this time would be spent in the extreme salinities and temperatures of the near-field sector of the plume. Recovery of the plankton from saline or temperature shock would commence when the plankton are carried out of the plume by the prevailing currents and encounter ambient salinities or temperatures. It is estimated that the extent of the plume having salinities or temperatures which might induce severe physiological stress on the entrained plankton would be relatively small. The plankton biomass encountering this section of the plume would likewise be comparatively small.

The salinity tolerances of several plankton species anticipated to occur at the diffuser site are presented in Figure G.3-16. Within the given range, each species has a smaller physiologically optimum salinity range. Above and below this smaller range, life processes may be adversely modified.

Bioassay analyses have been reported by the U.S. Department of Commerce (1978). These studies were undertaken to assess the impact of brine disposal in the marine environment on selected plankton and nekton species. Three phytoplankton species comprised the study, of which only one, Skeletonema costatum was collected in the study area. The other species assayed were Hymenomonas carterae and Tetraselmis chuii. The response of these species to various brine concentrations at 72^{o} and $86^{o}F$ was assessed over a period of 9 days. Several conclusions drawn from those bioassay studies were:

(1) Each algal species exhibited characteristic responses to various concentrations of brine:

T. chuii - most tolerant
H. carterae - tolerant
S. costatum - most sensitive

(2) No growth occurred in 40 percent (143 ppt) brine solution in any species, but a concentration of 20 percent (94 ppt) and 10 percent (64 ppt) was inhibiting in varying degrees according to the species as follows: (+++ = Better than control; ++ = similar to control, + = less than control, - = no growth).

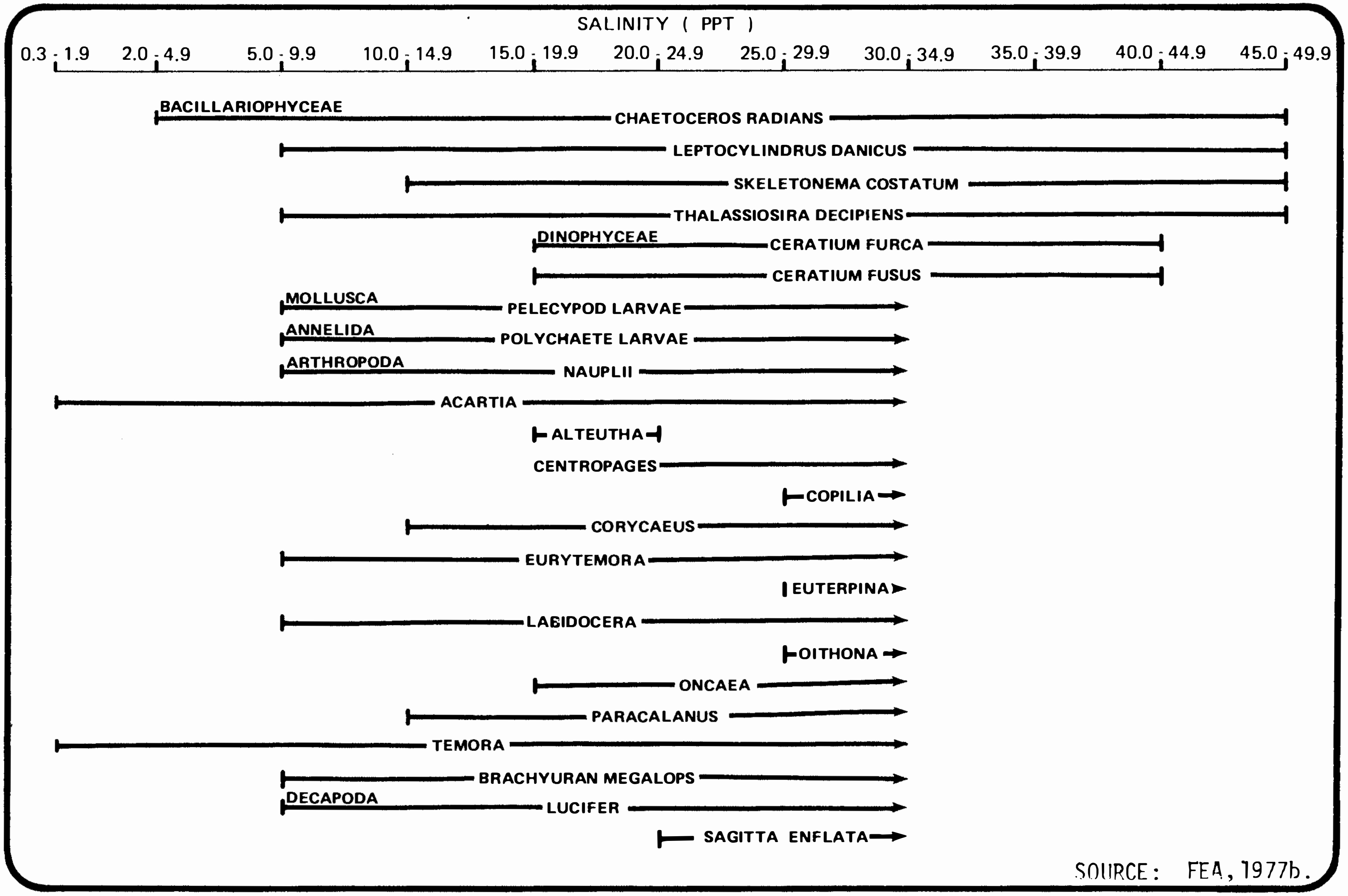


FIGURE G.3-16. Distribution of several organisms which may be encountered in the waters at the proposed diffuser site.

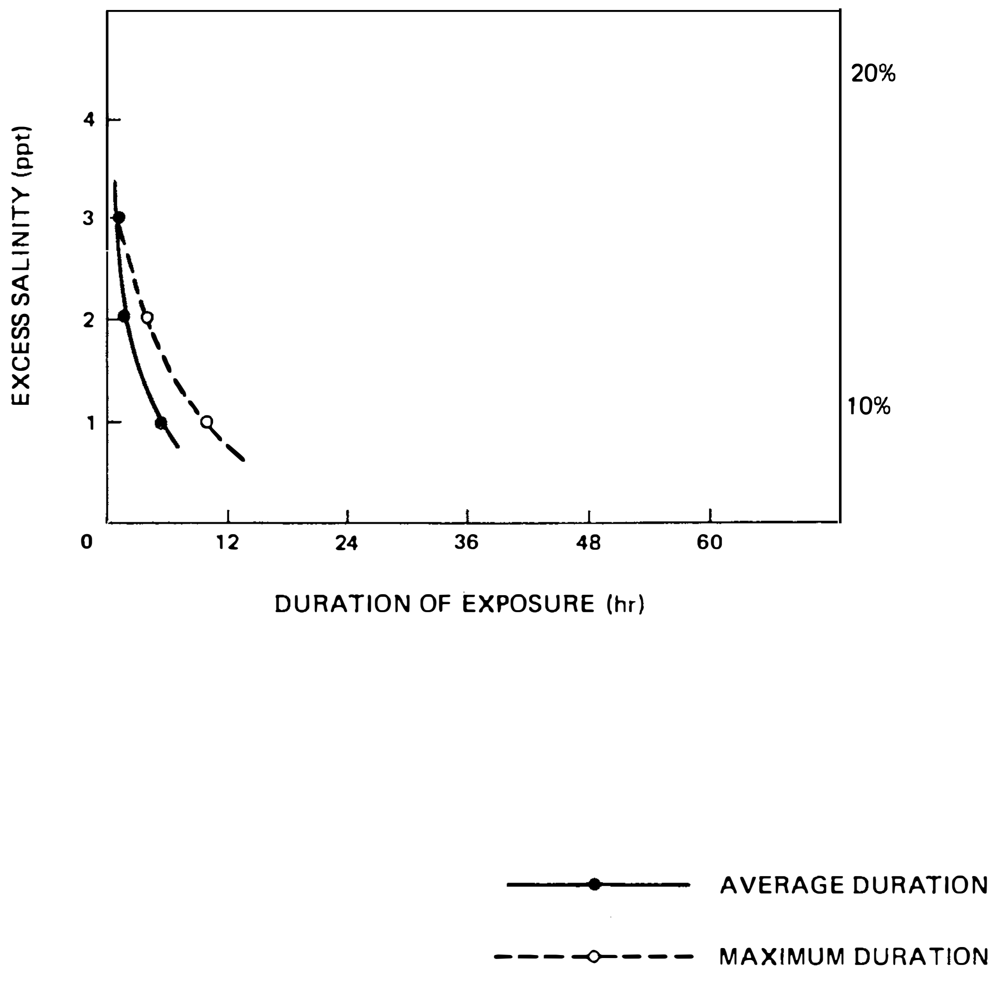
% Brine	Salinity (ppt)	*H. carteral*	*S. costatum*	*T. chuii*
0.0	30.0	++	++	++
0.1	31.0	++	+++	++
0.2	31.5	++	++	++
0.5	32.0	++	++	++
1.0	34.0	++	++	++
2.0	39.0	++	+	+
5.0	46.0	++	+	+
10.0	64.0	--	--	+
20.0	94.0	--	--	--
40.0	143.0	--	--	--

(3) A concentration of 5 percent (46 ppt) is the highest acceptable amount of brine that should be released at the outlet to permit a stand of phytoplankton in the near-field.

(4) Increase in temperature (from 72°F to 86°F) had no significant effect on the growth of any of the algae tested in concentrations up to a 5 percent brine concentration.

Assessment of the impact of the brine disposal on the marine phytoplankton in the study area should consider two points: (1) because of the relatively small size of the (bottom flowing) plume in comparison to the coastal shelf region under study, a proportionately small percentage of the total phytoplankton biomass would be entrained and impacted by the plume; and (2) the residence time of phytoplankton entrained in the plume is short.

A Lagrangian model output based on currents considered characteristic of the study site is shown on Figure G.3-17. The excess salinity calculations (above 30 ppt) are shown with the modelled average and maximum exposure durations. The initial entrainment of planktonic organisms in the brine plume is considered to be a region within 300-400 feet from the diffuser (U.S. Department of Commerce, 1978a).



SOURCE: U.S. Department of Commerce, 1978a.

FIGURE G.3-17. Excess salinity versus duration of exposure for drifting planktonic species entrained in the brine plume.

Severe physiological stress would be anticipated for plankton entrained in the high salinity-temperature sector of the plume near the brine diffuser. In this region, excess salinities would range from approximately 5 ppt to almost 264 ppt above ambient, while temperatures at the 5 ppt isohaline will be less than $1^{o}F$ above ambient during both the summer and winter months (Section G.3.1). As noted in Section G.2.4.2.1, the yearly average phytoplankton concentration of approximately 4.1×10^{5} cells per liter is characteristic of the coastal zone of this area. Therefore, for each liter of water entrained in the high salinity-temperature sector of the plume, a yearly average of 4.1×10^{5} cells would probably be destroyed. Phytoplankton entrained in the plume sector having salinities less than 5 ppt above ambient and reduced temperatures would probably be stressed; however, recovery should commence once the plankton are carried out of the impacted area. While in this sector of the plume, primary productivity would probably be substantially reduced. No substantial long term impacts to the phytoplankton community would be anticipated as a result of the brine and thermal discharge.

As a result of brine discharge into the Gulf of Mexico, localized chemical impacts would be anticipated (Section G.3.2.2). Ion ratios within the plume would be expected to be altered and might induce physiological stress on the entrained phytoplankton community. Periodic increases in the concentration of several heavy metals (Pb, Hg, Zn and Mn) above the EPA recommended discharge guidelines may occur. Phytoplankton entrained in the plume may selectively adsorb or absorb these metals, thus making these metals accessable to higher levels of the food web. Local turbidity increases may be anticipated. If turbidity were to increase, light penetration would be locally reduced, thus potentially reducing productivity. Oxygen levels may decrease, leading to further reduction in productivity. The estimated oil concentrations in the discharged brine would be about 6 ppm. Various phytoplankton species including Chlorella vulgaris, Asterionella japonica and Phaeodactylum tricornutum, when exposed to single or successive coatings of several crude oils in concentration of 0.1 to 38 ppm, illustrate depression of growth rates (delay in cell division) or reduction in photosynthesis. Mixed phytoplankton samples when exposed to 10 to 20 mg/l (ppm) of Venezuelan crude, and No. 2 and No. 6 fuel oils show the following sublethal response: photosynthesis is stimulated at concentrations of 10 to 30 ppb; whereas, a decrease is noted at 100 to 200 ppb for the No. 2 fuel oil (Hyland and Schneider, 1976). Phytoplankton entrained in the plume having oil concentrations of 6 ppm could experience short term adverse environmental conditions. Dramatic changes in plankton as a result of oil contamination have not been observed.

Outside of the high salinity-temperature sector, no single chemical constituent introduced into these waters by the plume may be present in sufficient concentrations to be toxic. The presence of these chemicals together may act synergistically to produce adverse impacts on the biological environment.

During the brine discharge period, temporary stagnation periods in the longshore nontidal currents are anticipated. In consideration of a very conservative eight day slack in the longshore currents, the region of the plume within the 5 ppt isohaline (above ambient) would increase to almost 25 acres. Concurrently, the area covered by the $1^{o}F$ isotherm (above ambient) would increase as well. Therefore, the area of the plume having a high temperature-salinity regime and inducing severe physiological impacts on the biota would increase during this period.

Segments of the zooplankton community congregate along pycnoclines (lines of equal water density). The introduction of a bottom-flowing brine plume into the marine environment would probably result in density discontinuities. It is possible that zooplankton might be attracted to the pycnoclines resulting from the brine plume, but the qualitative and quantitative aspects of these impacts,. are largely unknown. Zooplankton (e.g. copepods) entrained in the plume in the vicinity of the diffuser where extreme temperature and salinity values persist would probably be killed.

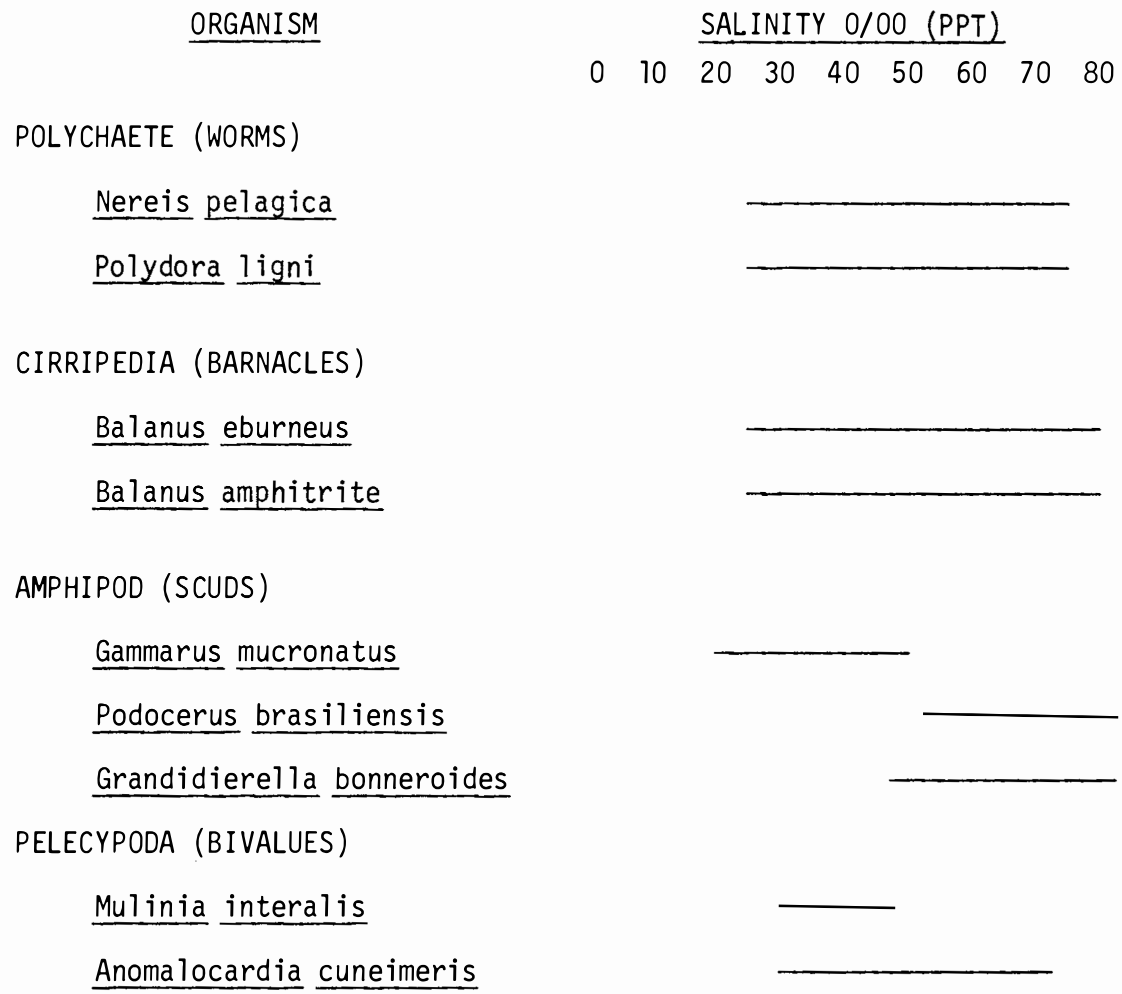
G.3.3.2 Impacts to Benthos

Brine disposal in the Gulf of Mexico would have a significant effect on certain components of the benthic invertebrate community, since the dense brine will sink towards the bottom. The area of greatest stress to the benthic organisms would be within the 5 ppt isohaline. Many of the sessile (nonmotile) organisms living within the range of this contour would be killed (U.S. Department of Commerce, 1977f), particularly in areas near the diffuser where salinities may approach values of up to 264 ppt and temperatures may be as high a 120^{o}F. Assuming total mortality, about 1.3 x 10^{8} benthic invertebrates would be killed per acre, based on mean density values (Figure G.2-36; Stations A3, A4, A5, D2 and E2). This value would vary with seasons but is likely to be greater in the summer during periods of highest productivity. Based on conservative estimates, only about 25 acres would be covered by the 5 ppt isohaline during an eight day slack period in longshore nontidal currents.

Away from the diffuser, little or no significant adverse effects to benthic organisms would occur. Although an excess salinity gradient of greater than 0.5 ppt could extend up to 6.5 nautical miles (FEA, 1977b) from the diffuser site under various combinations of environmental conditions, the salinity increase (less than 5 ppt) in the far field is unlikely to have a significant adverse impact on the benthic community near the site.

Only limited data are available on the salinity tolerance of marine benthic invertebrates or infauna. Salinity ranges of 24 to 82 ppt (Table G.3-7) have been reported by Hedgpeth (1967) for several species of benthic invertebrates and these data indicated that invertebrates, and in particular polychaetes, are capable of quick recovery even after large communities are killed by adverse salinity changes (Gunter, Ballard, and Venkatarmiah, 1974). Bioassay studies (Neff, 1978) of the polychaete Neanthes arenaceodentata revealed this benthic species was able to withstand salinities of 40 to 53.3 ppt. A Eulerian approach (hypersaline exposure at fixed locations affected by the plume) was

TABLE G.3-7 Salinity ranges for benthic invertebrates in the northwestern Gulf of Mexico having a recorded occurrence in salinities above 45 ppt.



Source: Hedgpeth, 1967

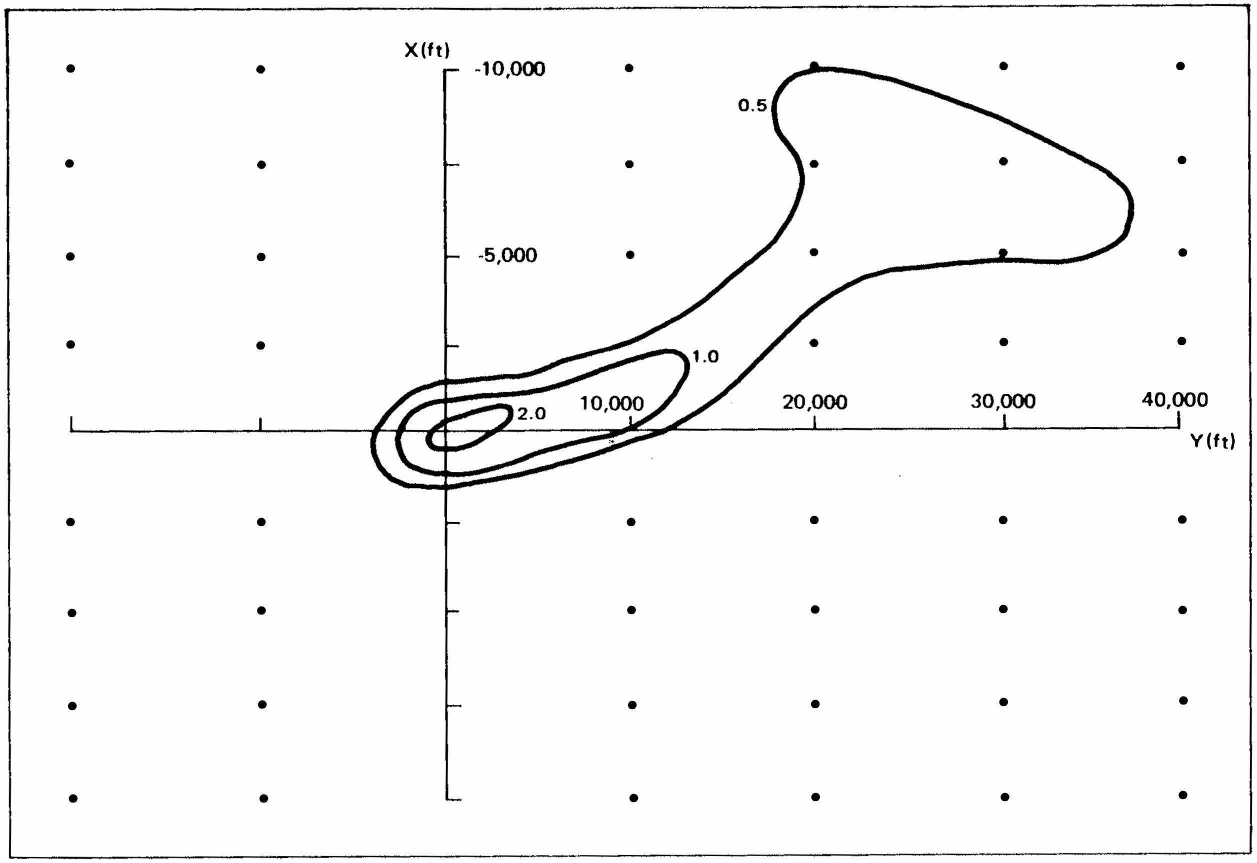
utilized in a analysis using the MIT Transient Plume Model (U.S. Department of Commerce, 1978a). An idealized brine plume, Figure G.3-18, was determined from currents typical of the area, Figure G.3-19. As noted in the resulting graph of exposure conditions for spotted sea trout (Figure G.3-20), salinities would not be high enough to cause significant mortalities in the far field (therefore, plots were not made for polychaetes). These studies also showed that Neanthes was better able to tolerate high brine concentrations at a temperature of 68^{O}F than at either 59^{O}F or 86^{O}F. Although adult Neanthes seem well adapted to withstand stress from high salinity levels, the younger developmental stages of this species cannot. Similar trends in salinity tolerance levels and temperature interaction may be expected for many other polychaete species and related benthic invertebrate infauna taxa.

Although many of the benthic invertebrates are of little or no direct economic value to man, the infauna occupy important trophic positions in the food web. The benthic invertebrate data analyzed for the proposed diffuser site (Section G.2.4) do not reveal the presence of either threatened or endangered species or unique communities within the excess 5 ppt isohaline at the site. On a regional basis, the environmental loss of the benthic community within this brine plume is not expected to be significant.

G.3.3.3 Impacts to Nekton

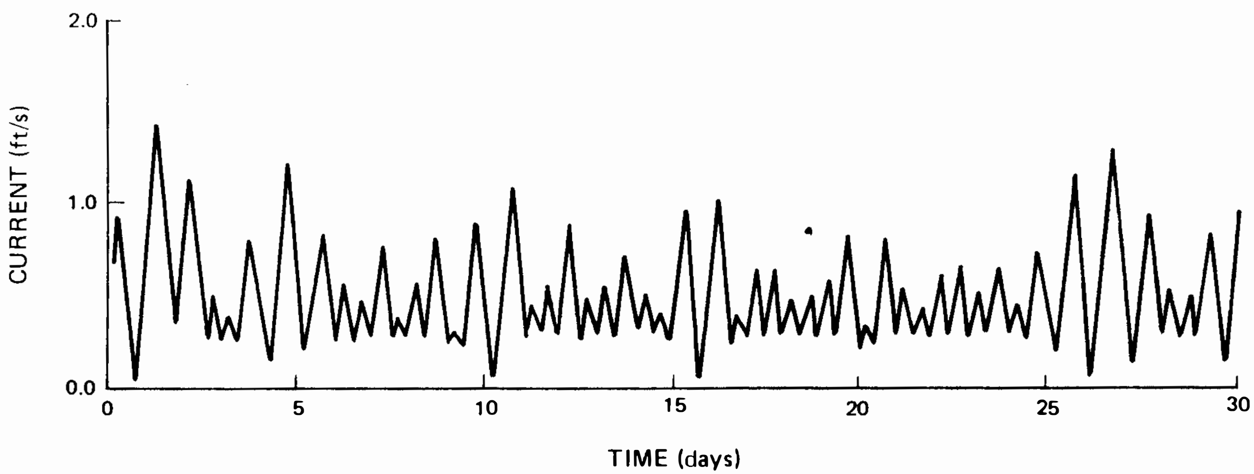
G.3.3.3.1 General

The tolerance of the more important components of the nekton community (shrimp, crabs and fish) to brine discharge at the proposed diffuser site is highly variable, depending upon the season of the year, the species involved, and the life stage of the organism. Generally the impacts of brine disposal would be expected to be minimal on the adult members of the nekton community, because the active swimmers in this group could avoid the regions of unacceptable water quality within the plume. Those nektonic organisms which partially depend on the bottom, including shrimp, crab and sciaenid fish would be excluded from most of the high salinity stress area within the 5 ppt isohaline. Outside of



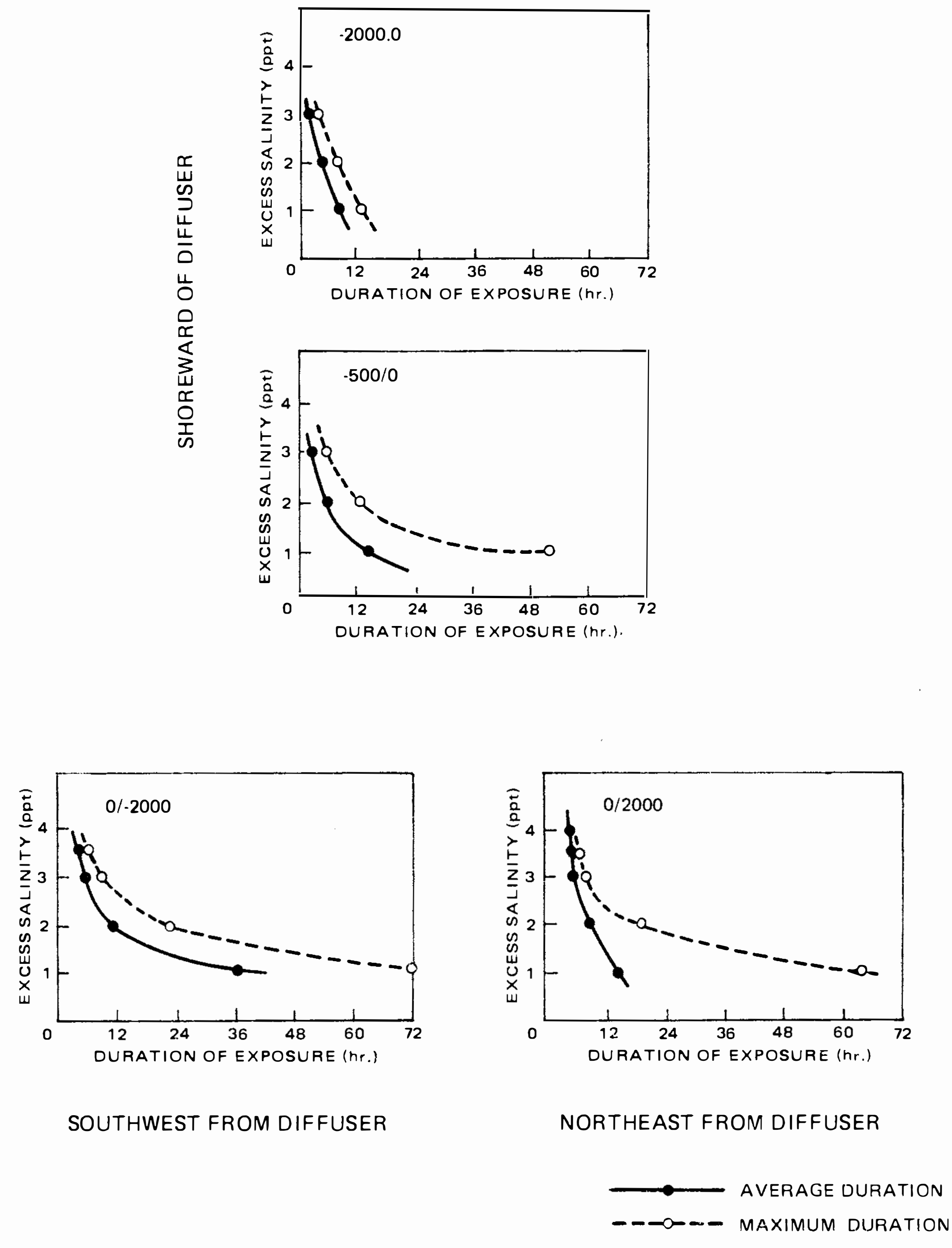
SOURCE: U.S. Department of Commerce, 1978a.

FIGURE G.3-18. Idealized brine plume and analysis region shoreward (X direction) and alongshore (Y direction) from the diffuser. Excess salinity contours in ppt.



SOURCE: U.S. Department of Commerce, 1978a.

FIGURE G.3-19. Typical current magnitudes used in Transient Plume Model.



SOURCE: U.S. Department of Commerce, 1978a.

FIGURE G.3-20. Excess salinity versus duration of exposure at indicated grid points.

this area, no one water quality component of the brine may be in high enough concentrations to be lethal, but a number of compounds may act synergistically to impact the regions near the diffuser site. Seasonal factors such as temperature and river input may also act synergistically with the brine plume.

The greatest environmental impact of brine disposal would be expected on the eggs, larval stages, and reproductive potential of nektonic organisms which might be affected by small increases in ambient salinity or temperature levels. This impact could be locally significant because under certain conditions, an excess salinity gradient of 0.5 ppt may extend as a bottom plume more than 6.5 nautical miles from the diffuser site (FEA, 1977b).

Commercial fishery activities, particularly for white shrimp, would likely not be disturbed by the diffuser ports as non-snag feature would be incorporated into the design.

Sport fishing in the region should be unaffected by the brine disposal except in the immediate area around the diffuser (25 acres) where most sport fish would be excluded. Red drum spawning areas (reefs and wrecks) may be subject to slight salinity increases, however, it is not known if spawning success would be affected.

G.3.3.3.2 Factors Influencing Impacts On Nekton

Certain alterations in water quality as a result of the brine plume could have an impact on nekton in the vicinity of the proposed diffuser, including increased salinity, increased turbulence, particulates and hydrocarbon levels, and decreased dissolved oxygen. Excess salinity would have the greatest impact, especially to those organisms which are locally abundant or of local commercial importance, including shrimp, anchovies and sciaenid fish (seatrout, drum and croaker). Bioassays on the effects of discharged brine on various stages of white shrimp and spotted seatrout (U.S. Dept. of Commerce, 1978a), are presented in subsequent sections.

Of the toxins which may be released with the brine, trace metals would be expected to be within EPA criteria for marine life. However, hydrocarbons which would be released with the brine only during the oil refill phase of the project, could occur in levels much higher than those of ambient. Bioassay data on a wide variety of marine organisms reveal a lethal level range of 1 to 100 ppm soluble petroleum fractions for adult stages and 0.1 to 1.0 ppm for larval and juvenile life stages. Adverse sublethal physiological impacts have been found to occur from 1 to 10 ppb (Hyland and Schneider, 1976).

The exit velocity of brine from the diffuser port has been estimated to be 25 ft/sec. The resulting turbulence would probably cause mortalities among fish and macroinvertebrate eggs and larvae. Furthermore, salinities and temperatures would be high where the discharge velocity is great, compounding the impact of turbulence. The increased amounts of dissolved and precipitated solids could have an indirect effect on the nekton. Increased turbidity could result in decreased productivity, leading to decreased availability of food sources. Possible settling of the particulates could have an influence on benthic life, another food source for the nekton.

Lower dissolved oxygen levels would effect sessile organisms thus decreasing food sources for nekton, and also have a direct effect on the nekton. However, since these marine organisms could avoid the depleted areas and since oxygen levels are expected to assume near normal levels rapidly, this impact should not be great.

Hydrocarbons have been predicted to be released from the brine discharge at 6 ppm; yet dilution would be expected to decrease these levels rapidly. However, physiological dysfunction may occur to nekton which have not avoided or rapidly traversed from the region. These include disruption of normal feeding and reproductive patterns perhaps due to interference with chemotaxsis. Low level hydrocarbon pollution has been found to result in decreased growth, delayed hatching and abnormal behavior and development in fish and macroinvertebrate eggs and larvae (Hyland and Schneider, 1976). Incorporation of petroleum hydrocarbons in marine organisms may also result in tainting of edible species.

In general, nektonic populations affected by hydrocarbons, would likely recover quickly since larval and adult immigrants would replace individuals eliminated during the one to two years of oil refill. Nektonic organisms dependent on the benthos would be affected to a greater extent since hydrocarbons tend to accumulate in sediments to higher levels for longer periods of time.

G.3.3.3.3 Shrimp

Brine bioassays were performed on three life stages of white shrimp: eggs and postlarval nauplii and early protozoeal stages. The concentrations of brine at 82^{o}F that were lethal to the embryonic shrimp were between 2.45 and 3.2 percent by volume (36.5 to 38.0 ppt) (Wilson *et al*., 1978).

Results indicated that the 82^{o}F, 24 hour LD_{50} of postlarvae was between 6.3 and 6.5% brine (49 ppt). At 87.8, 89.6 and 91.4^{o}F, the 24 hour LD_{50} were 5.9, 4.75 and 4.4 percent, respectively (approximately 48, 43 and 42 ppt). It appeared that salt dome brine is less toxic to nauplii than to the embryos or early postlarvae. Although the nauplii survive, they may not metamorphose to the first protozoeal stage after exposure to concentrations of 3.0 percent brine (39 ppt). Furthermore, if exposed from the time of egg cleavage to the protozoeal stage, development may be inhibited at concentrations of 3.0 percent brine (Wilson, Harrison and Aldrich, 1978).

In other studies (FEA, 1977b), the salinity preference of the postlarvae of brown shrimp and white shrimp (Table G.3-8), have been examined in gradient tanks with salinity ranges from 0 to 70 ppt and 0 to 50 ppt, respectively. The results indicate that the shrimp preferred lower salinity levels than those normally expected in the open Gulf. It was hypothesized that the shrimp key on salinity gradients to navigate during their migration to the less saline onshore nursery grounds. It was concluded from statistical analysis of the data that there was a seasonal variation in salinity preference by the postlarvae, especially by the brown shrimp, which preferred highest salinities in the spring. White shrimp postlarvae showed a seasonal preference only when exposed to low salinities.

At temperatures of 73^{o} to $78^{o}F$, postlarvae of brown shrimp grew equally well at salinities of 2 to 40 ppt. Postlarvae of white shrimp produced twice as much tissue at intermediate salinities (10 to 15 ppt) compared to conditions at 20 and 35 ppt and temperatures above $77^{o}F$. Postlarvae of brown shrimp produced the most tissue at salinities of 30 ppt and $90^{o}F$, (FEA, 1977b). These data indicate that postlarval penaeid shrimp are tolerant of both salinity and temperature variations.

Several studies have indicated that adult white shrimp generally were less tolerant of high salinity than adult brown shrimp, although other studies showed no differences in salinity preference of the post-larval stages of the two penaeid shrimp species. Adult white shrimp have been collected under conditions where the salinities ranged from 0.2 ppt to more than 47 ppt; brown shrimp have been taken in areas where salinities range from 0.1 ppt to 69 ppt. This wide range of salinity values indicates that these two penaeid shrimp are euryhaline species (FEA, 1977b). The preferred temperatures (based on catch data) for adult white and brown shrimp are 68^{o} to $86^{o}F$ and 68^{o} to $95^{o}F$, respectively (Copeland and Bechtel, 1974).

Experiments on the susceptibility of the white shrimp to oilfield brine showed that for one case all shrimp died within two hours of exposure to an oil field brine concentration of 42 ppt. White shrimp

TABLE G.3-8 Salinity preference of postlarvae of brown and white shrimp[a].

SEASON	P5[b]	P25	P50	P75	P95	P75-P25	P95-P5
SUMMER							
Brown	41.4	28.9	20.6	13.9	7.2	15.0	34.2
White	43.5	34.5	28.0	21.1	11.1	13.4	32.3
FALL							
Brown	47.3	36.0	27.4	19.2	10.0	16.8	37.3
White	41.0	28.5	21.1	13.6	5.8	14.9	35.2
SPRING							
Brown	49.1	38.1	29.9	21.9	11.4	16.2	37.7

[a]Salinity values (ppt).

[b]P5 represents the salinity value at or above which the top 5% of the most salinity tolerant members are found. P50 would be the medial value where 50% of the members are above and 50% are below the indicated salinity values.

Source: Keiser and Aldrich (1976).

survived indefinitely when similarly exposed to evaporated bay water with salinities of 45 ppt. The conclusion was that the ionic composition of the brine may exert a greater influence on organisms than the high concentrations (FEA, 1977b).

Little information is available about the way ionic composition affects shrimp. It is suspected that locomotory activity of penaeid shrimp may be inversely correlated to their respective blood serum magnesium levels (FEA, 1977b).

In summary, it has been reported that high salinity waters will favor the brown shrimp over the white shrimp. In areas where the salinity exceeds a level of about 36 ppt white shrimp embryos are unlikely to survive. Because the brine diffuser is near the center of the white shrimp spawning grounds (at the 48-foot depth contour), it is likely that major losses to the shrimp population in the immediate vicinity of the diffuser could occur. The actual effects produced by different salinities can be modified by various other physiochemical factors, the most significant of which is temperature. Warm water temperatures (for example, 91^{o}F compared to 82^{o}F) appear to enhance the ability of shrimp to adjust to changes in salinity.

G.3.3.3.4 Blue Crabs

The proposed brine disposal area is unlikely to have any significant effects on the regional blue crab populations. Regional data (Section G.2.4.4) indicate that crabs are most abundant in estuarine areas and in shallow coastal waters. Adult blue crabs have a wide range of salinity tolerance (0.7 to 88 ppt) and spawn in waters with relatively high salinity levels (Jaworski, 1972). However, 5 percent brine (44 ppt) at 82^{o}F has been found to be lethal to blue crabs zoea (Johnson and Williams, 1978). Thus, brine disposal would exclude blue crab from the immediate area of the high salinity zone and would have a greater impact on the larval stages.

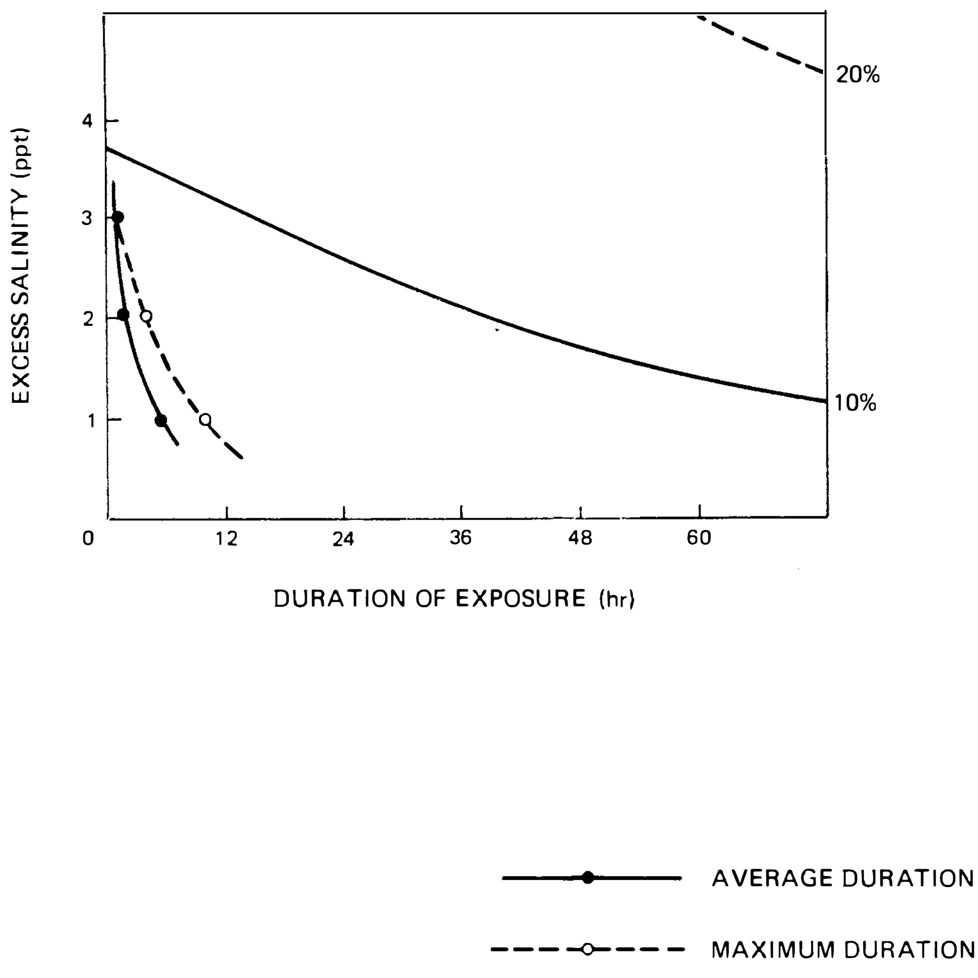
G.3.3.3.5 Fish

Brine disposal at the proposed site would be expected to have minimal impact on adult fish, which generally avoid areas with adverse salinity concentrations. The area within the high salinity stress zone in the vicinity of the diffuser would be lost to the fish; their food source of benthic invertebrate would also be scarce in the immediate disposal area.

Although salinity tolerances for marine fish vary between species, it is usually the younger developmental stages that would be expected to be less tolerant to salinity changes. The local redfish spawning grounds (such as reefs and wrecks) in the area (Figure G.2-29) may be subjected to increased salinities, however, they are not within the projected high salinity zones (i.e., 5 ppt isohaline). Some marine teleost eggs can tolerate wide ranges of salinity. For example, Atlantic herring eggs have hatched under laboratory conditions in salinities up to 90 ppt, and the eggs of the sheepshead minnow have hatched in salinities of 110 ppt in situ. Yolk sac larvae of the Atlantic herring survive and remain active for at least 24 hours at 60 to 65 ppt. The larvae of Gulf menhaden have metamorphosed in the laboratory at salinities of 25 to 40 ppt (FEA, 1977b).

Bioassays conducted on spotted seatrout eggs and larvae when exposed to Bryan Mound brine for 48 hours at 80.6^{o}F results in significantly increased mortalities at a concentration equivalent to approximately 40 ppt. These mortalities did not differ from those of comparable salinities using artificial seawater, indicating that brine alteration of ionic composition may not have an impact (Johnson and Williams, 1978). The planktonic life stages will be entrained into the plume, but will only be exposed to excess salinities for a relatively short period of time. Using observed currents at the alternative brine diffuser site and assuming that these organisms are entrained within a region 300 to 400 feet from the diffuser, the two curves in Figure G.3-21 represent estimates of average and maximum exposure durations (U.S. Dept. of Commerce, 1978a).

Since the fish eggs and larvae will be entrained for much less than 48 hours, brine bioassays of 1 and 2 hour exposures were performed (Table G.3-9) on larval spotted seatrout. The LC_{50} of a 1 hour exposure after 24 hours was greater than 55 ppt and after 48 hours was approximately 51.5 ppt. Upon a 2 hour exposure, after 24 hours the LC_{50} was



SOURCE: U.S. Department of Commerce, 1978a.

FIGURE G.3-21. Excess salinity versus duration of exposure for drifting planktonic species entrained in the brine plume. Area above the 10% line denotes environmental conditions lethal to at least 10 percent of laboratory tested specimens. (Data for larval spotted seatrout).

TABLE G.3-9 Average mortality of 1 hr posthatch larval spotted seatrout to short-term exposure to Bryan Mound brine (based on 4 replicates).

Percentage Volume/Volume[a]	Exposure Time (hr)	Total Test Time (hr)	Mortality[b]	Exposure Time (hr)	Total Test Time (hr)	Mortality[b]
10.0 [55]	1	24	3.00 (2.57)	1	48	58.83 (16.91)
5.0 [44]	1	24	2.07 (2.11)	1	48	25.65 (11.87)
2.0 [36]	1	24	2.56 (0.76)	1	48	16.40 (8.50)
1.0 [34]	1	24	2.47 (2.48)	1	48	12.03 (3.27)
0.5 [33]	1	24	2.85 (2.33)	1	48	4.53 (1.33)
0.0 [30]	1	24	0.68 (0.78)	1	48	4.90 (1.24)
10.0 [60]	2	24	80.55 (8.33)	2	48	98.75 (1.50)
5.0 [48]	2	24	10.13 (1.44)	2	48	53.90 (7.94)
2.0 [42]	2	24	3.78 (1.03)	2	48	48.75 (28.69)
1.0 [39]	2	24	4.18 (2.19)	2	48	17.25 (14.80)
0.5 [38]	2	24	4.00 (2.14)	2	48	6.75 (2.33)
0.0 [36]	2	24	2.35 (1.65)	2	48	4.83 (1.54)

LC_{50} = 1 hr - 24 hr = <10% V/V, 1 hr - 48 hr = 8.4 ± 2.2% V/V
2 hr - 24 hr = 7.5 ± 2.5% V/V, 2 hr - 48 hr = 3.5% V/V

[a] [ ] = measures salinity in o/oo

[b] ( ) = 1 standard deviation

54.5 ppt and after 48 hours, 44.5 ppt (Johnson and Williams, 1978). When entrained under the conditions of Figure G.3-21, the brine discharge exposures are expected to be lethal to less than 10% of spotted seatrout larvae (U.S. Dept. of Commerce, 1978a).

Supranormal salinities may cause changes in growth rates and energy expenditure, lead to tissue damage of asphyxiation, and affect metabolic rate, activity, and neuromuscular functions. Since the dissolved oxygen level decreases as salinity increases, the physiological effects may be indirect. This is revealed by growth rate experiments involving desert pupfish. As salinity increased, a progressive retardation of development was observed. These results were attributed to lower oxygen levels in the water (FEA, 1977b). Several investigators have reported that the size distribution of fish is directly related to salinity.

The expenditure of energy in marine organisms may result from both direct and indirect effects of salinity. It has been shown that within a certain optimum salinity range a minimum amount of energy needs to be expended in order to maintain osmotic gradients; thus, large amounts of energy can then be directed to growth. Above the optimum salinity range an increase in metabolic process occurs and is generally accompanied by an increase in uptake of oxygen. Above 35 ppt, the oxygen uptake rate in the starry flounder increased 15 percent. In order to sustain osmotic and ionic regulation at above-optimal salinity regimes, additional energy is expended (FEA, 1977b).

Changes in density of the water column will result from alterations in salinity or water temperature. Consequently, fish characteristically preferring one part of the water column to another, must expend either greater of lesser amounts of energy to maintain their relative position in the water column depending upon the _in situ_ density levels (FEA, 1977b).

Damage to epithelial gill tissue has been recorded due to high salinities and this damage may cause asphyxiation by blocking oxygen transfer. Reduced oxygen uptake may also lead to decreased activity in fish. Other behavioral responses in fish, such as avoidance, may be reduced because of the inability to detect small salinity fluctuations of as little as 0.06 ppt (FEA, 1977b).

The majority of fish encountered in the study area off the Texas coast are euryhaline and have a high tolerance to wide salinity ranges (Table G.3-10). Generally the upper limit of this tolerance is 75 to 80 ppt; the lower limit is that of freshwater, less than 5 ppt. The sheepshead minnow has been reported in waters with salinities ranging up to 142.4 ppt (FEA, 1977b).

G.3.3.4 Impacts to Threatened or Endangered Species

It is not expected that the endangered species which have been listed for the northern Gulf of Mexico (Section G.2.4.5) would be significantly affected by the brine discharge. Although data concerning the salinity and temperature tolerances of these species are sparse, these highly mobile organisms would probably avoid regions of the plume they found undesirable. If these organisms moved through the plume, they would probably experience only temporary salinity-temperature stress and would move to more favorable areas in the water column either above or to the side of the plume. Because of the short duration of this stress, recovery should commence soon after they encounter their preferred, ambient temperature-salinity regimes.

G.3.3.5 Impacts to Unique or Important Habitats

The unique or important habitats in the vicinity of the proposed brine diffuser (discussed in Section G.2.4.6) include three coral heads: one is 1.6 nautical miles to the south-southeast of the proposed brine diffuser site; the other two are 3.3 and 5.0 nautical miles southwest of the proposed site, respectively.

Based on the characteristics of the discharge plume (Section G.3.1) it is possible that, under anomalous current conditions, the coral head 1.6 nautical miles south-southeast of the proposed diffuser site could be intermittantly affected by the far-field region of the plume, where salinities exceeding 0.1 ppt above ambient would be expected. The coral head 3.3 nautical miles to the southwest of the diffuser site may also

TABLE G.3-10 Salinity tolerances of some common Texas marine fishes.

	SALINITY (PPT)				
	RANGE	GREATEST ABUNDANCE	HIGHEST RECORDED SALINITY TOLERANCE	REFERENCE[a]	COMMENTS
Ladyfish			75	Gunter 1967	Die at 100 ppt
Gulf menhaden	0-30	5-24.9		LWL&FC 1971	
	<1->60			Reintjes and Pacheco 1966	Die at 80 ppt
Striped anchovy	>29.9	>15		LWL&FC 1971	
			75	Gunter 1967	Die at 100 ppt
Gizzard shad			60	Copeland and Moseley 1967	Brine dominated system
Sea catfish	0->30	>10		LWS&FC 1971	
	2-36.7	>30		Gunter 1945	
Sheepshead minnow			75	Gunter 1967	Die at 100 ppt
			60	Copeland and Moseley 1967	Brine dominated system
			142.4	Simpson and Gunter 1956	
Gulf killifish			55.1-58.6	Renfro 1969	
Longnose killifish			75	Gunter 1967	Die at 100 ppt
Tidewater silverside			75	Gunter 1967	Die at 100 ppt
			55.1-58.6	Renfro 1960	
Rock seabass	>5->30			LWL&FC 1971	
Pinfish			75	Gunter 1967	Die at 100 ppt
	15-26[b]			U.S. Corps of Engineers 1976	
Sand seatrout	0.2->30			LWL&FC 1971	
Spotted seatrout			75	Gunter 1967	Die at 100 ppt
		15-35	77	Tabb 1966	
	15-45[b]			U.S. Corps of Engineers 1976	
Banded drum	5->30	>15		LWL&FC 1971	
Spot	0.2->30	>10		LWL&FC 1971	
	0-33.9			Nelson 1969	
Southern kingfish	2->30	10		LWL&FC 1971	
Atlantic croaker	0->30			LWL&FC 1971	
			75	Simmons 1957	
			75	Gunter 1967	Die at 100 ppt
	15-35[b]			U.S. Corps of Engineers 1976	
Black drum	0.2-24.9			LWL&FC 1971	
			75	Gunter 1967	Die at 100 ppt
			80	Simmons and Breuer 1962	Eyes are glazed
	15-45[b]			U.S. Corps of Engineers 1976	
Red drum	5-29.9			LWL&FC 1971	
	0.8-37.6			Kilby 1955	
			50	Simmons and Breuer	
	15-40[b]			U.S. Corps of Engineers 1976	
Striped mullet	0->30	5-19.9		LWL&FC 1971	
			60	Copeland and Moseley 1967	Brine dominated system
			75	Gunter 1967	Die at 100 ppt
			55.1-58.6	Renfro 1969	
	25-85[b]			U.S. Corps of Engineers 1976	
Atlantic threadfin	1.6-29.9	20		LWL&FC 1971	
Atlantic cutlassfish	0.2->30	>15		LWL&FC 1971	
Blackfin searobin	10-24.9			LWL&FC 1971	
Fringed flounder	5-29.9	20		LWL&FC 1971	
Southern flounder	0->30			LWL&FC 1971	
	0-50			U.S. Corps of Engineers 1976	
	12-35[b]			Ibid.	
Blackcheck toungfish	0.3-29.9	>10		LWL&FC 1971	
		>30		Gunter 1945	

[a]LWL&FC - Louisiana Wildlife and Fisheries Commission.

[b]Ideal salinity range.

Source: FEA, 1977b.

be intermittantly encompassed by the plume in areas where the excess salinities of the plume could be from 0.1 to 0.5 ppt above the ambient salinities. This impact would occur in the fall and winter when the net current flow is to the southwest. The coral head furthest (5.0 nautical miles) from the diffuser probably would not be affected by the brine plume because of its large distance from the expected field of the brine plume.

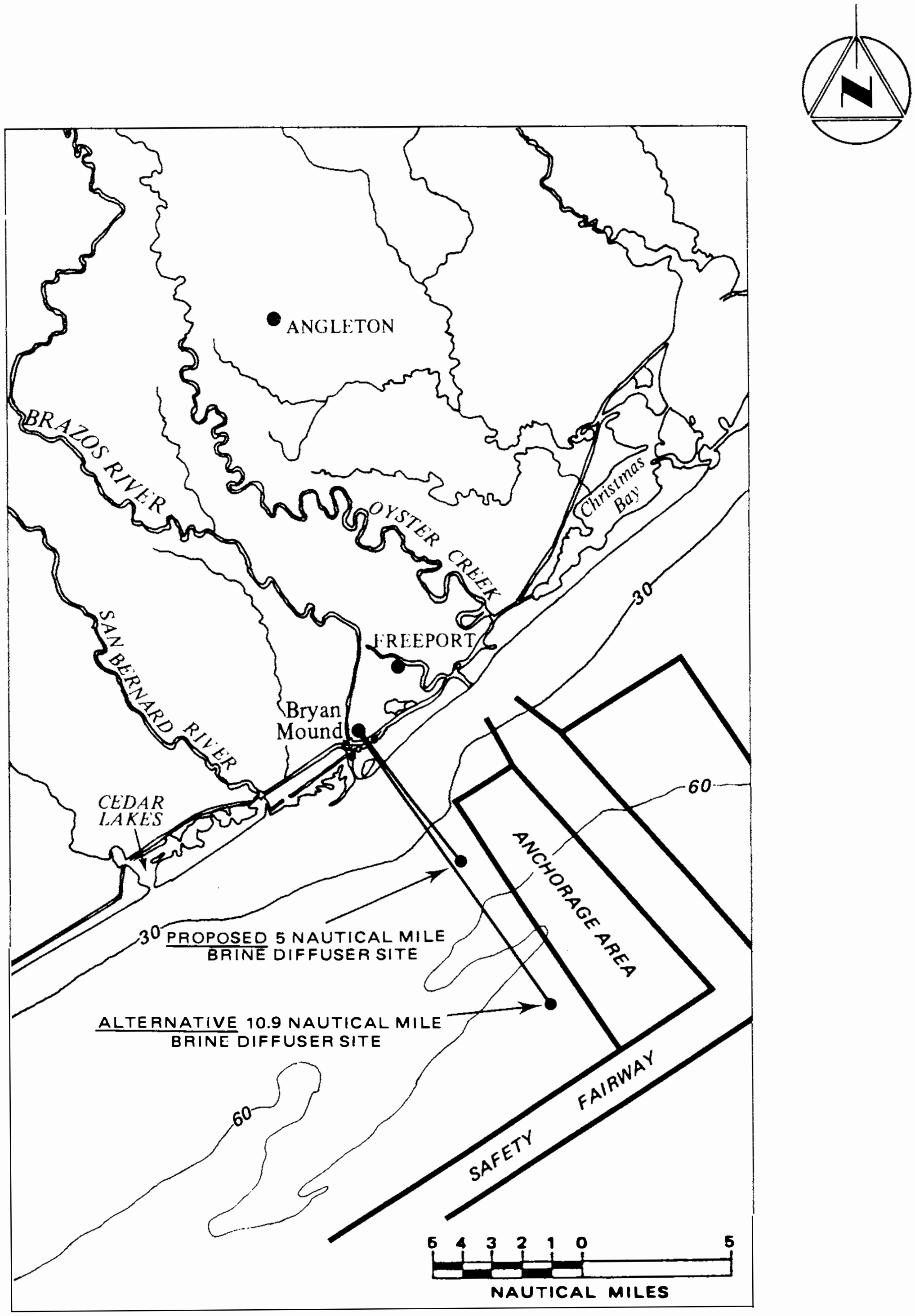
Little information is available concerning either the species composition of these unique coral head habitats or their tolerances to salinity and temperature variations. The shallow waters of the Texas coastal region undergo rather wide seasonal variations in both salinity and temperature (Section G.2), especially during the rainy season when salinities and temperatures are usually low and also in the late summer when temperatures and salinity can approach the upper tolerance limits for many of the organisms found near the diffuser site. Due to this high variability of environmental parameters in these coastal waters, many of the resident species tolerate wide fluctuations in these parameters and thus would be expected to be euryhaline and eurythermal. Even if the coral head closest to the diffuser is entrained in the brine discharge during a period when ambient salinities approach the upper tolerance limit for this community, only temporary excess physiological stress may be imposed on segments of the coral reef community. The coral reef 3.3 nautical miles from the diffuser may be the only reef intermittantly entrained in the discharge; however, little if any impact on this reef community is anticipated under normal conditions.

G.4 ALTERNATIVE DIFFUSER SITE AREA

Using engineering, environmental, and economic criteria, an offshore diffuser site area 10.9 nautical miles off Bryan Beach, Texas, was defined late in 1977 as an alternative to the proposed diffuser site located five nautical miles from the beach (Figure G.4-1). This alternate site at latitute 28^{o} 44.45'N and longitude 95^{o} 14.67'W has a sandy bottom and is in about 68 feet of water.

The alternative area was selected to determine if any of the anticipated environmental impacts of the brine discharge at the proposed nearshore site could be mitigated by relocating the diffuser further offshore in deep water. The location of the offshore site was, in part, restricted by a shipping safety fairway about 0.9 nautical miles to the east and 2.6 nautical miles to the south of the area (Figure G.4-1). The U.S. Army Corps of Engineers will not approve permits for the placement of structures in these shipping safety fairways.

Baseline environmental conditions and anticipated impacts, as described in the previous sections of this appendix, were based on data mostly obtained from the nearshore (proposed) site from September through December, 1977. In January 1978, a supplementary field sampling program was initiated at the offshore alternative site. Data from the offshore area to describe the alternative site is limited and preliminary. A report will be prepared subsequently to provide a description of the baseline environmental conditions at the offshore site, and the anticipated impacts of a brine discharge for this area, together with a comparison of the nearshore site with the alternative offshore area.



SOURCE: TEXAS A&M, 1978.

FIGURE G.4-1 Proposed and alternative brine diffuser sites (depth contours in feet).

G.4.1 PHYSICAL OCEANOGRAPHY

G.4.1.1 Baseline Conditions

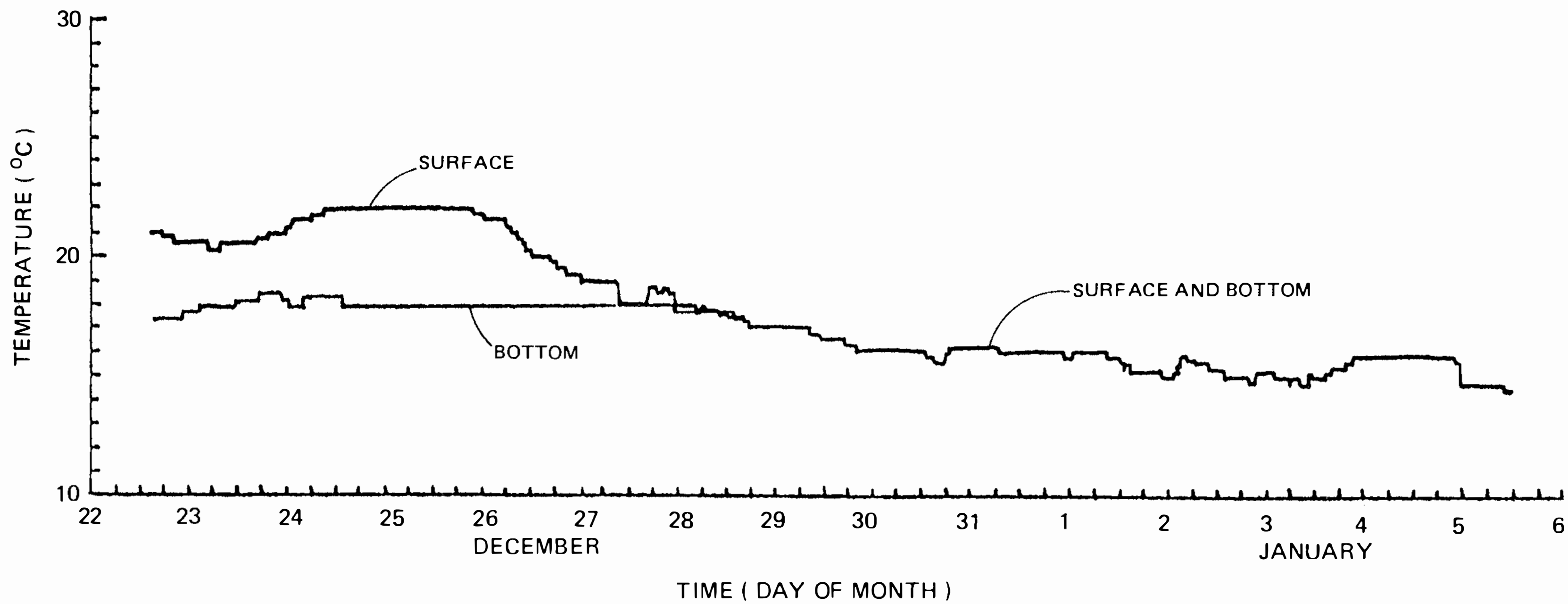
The physical oceanography and sediment distribution at the alternative offshore site are expected to be similar to those at the proposed brine diffuser site. The bathymetric contours at the offshore site trend parallel to the coastline in a northeast-southwest direction and reach a depth of 68 feet at the site of the alternative diffuser. The continental shelf in the immediate vicinity of this disposal area is a flat plain which gently slopes to the southeast. The offshore site lies beyond the inner fishing banks and bottom obstructions such as coral heads as discussed by Mattison (1948) and Decca Survey Systems, Inc. (1973) (Section G.2.2).

Annual patterns of temperature, salinity and density are similar to those found in the proposed nearshore site (Section G.2.2.2), but because it is farther offshore the alternative site is influenced less by the regional river system.

Continuous temperature data collected at the alternative site (Figure G.4-2) show that on December 27 and December 28, 1977, the bottom waters were warmer than the surface waters, but after this period the water column became well mixed with no apparent difference in water temperature between the surface and bottom.

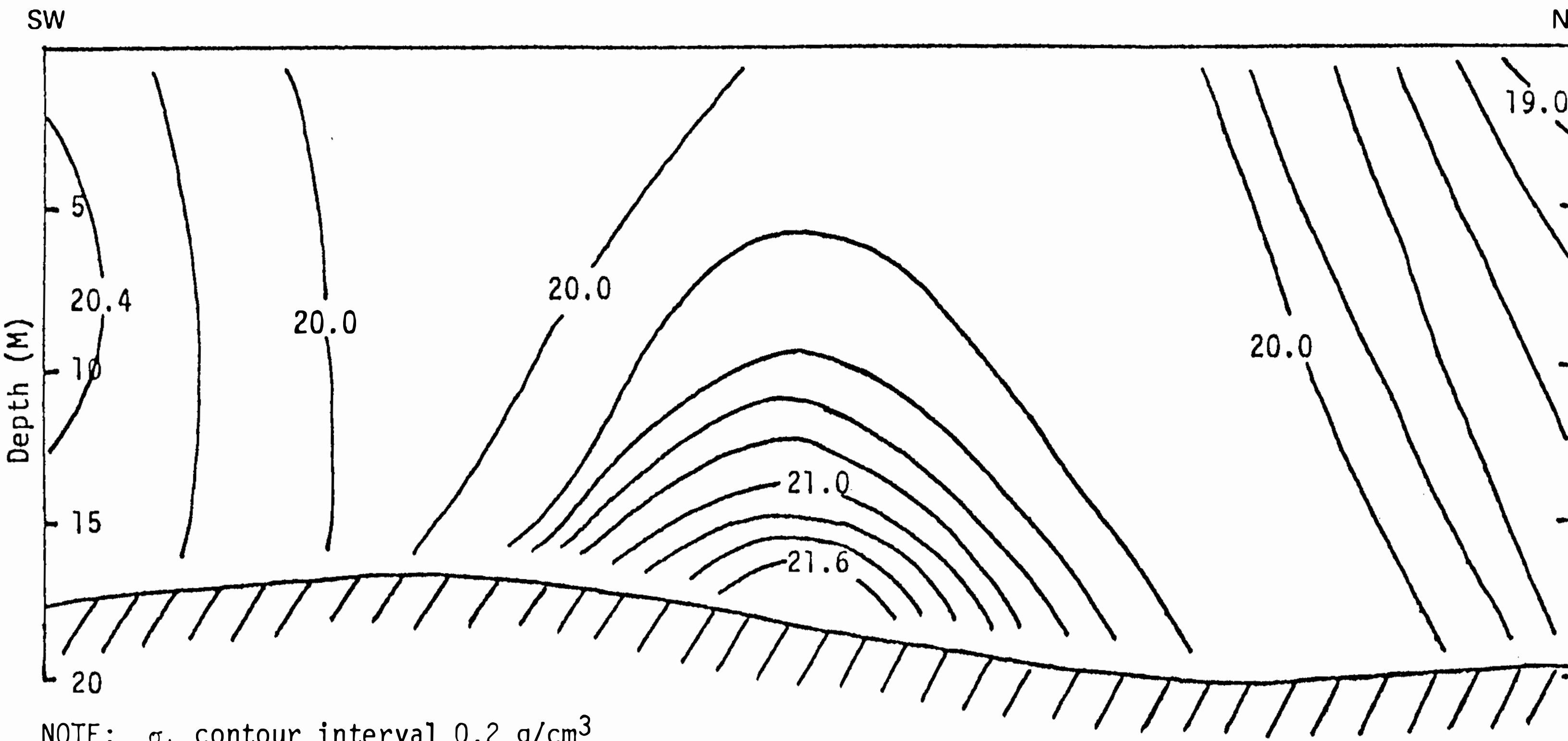
Over-the-side temperature and salinity measurements taken on December 18 and 19, 1977 (See Figure G.1-2) detected a warmer but more saline bottom water mass at the alternative site than at the proposed site. The thermograph records showed that this water mass retreated farther offshore between December 26 and 31, 1977. The mechanism for this offshore movement may be wind-driven currents.

Longshore density profiles constructed from the over-the-side temperature and salinity measurements taken from September through December (Figures G.4-3 and G.4-4) also show that during September a relatively dense tongue of water had stratified the water column from 5 meters below the surface to the bottom, while the water column to the northeast and southwest was well mixed. In December (Figure G.4-4),



SOURCE: Texas A & M, 1978.

FIGURE G.4-2 Continuous thermograph data for the surface (10 foot depth) and bottom water (7 feet above bottom) at the alternative offshore brine disposal site (December, 1977 to January 1978).



NOTE: σ_t contour interval 0.2 g/cm^3

SOURCE: Texas A & M, 1978.

FIGURE G.4-3. Longshore vertical density stratification for stations 27 through 6 (September 15-17, 1977).

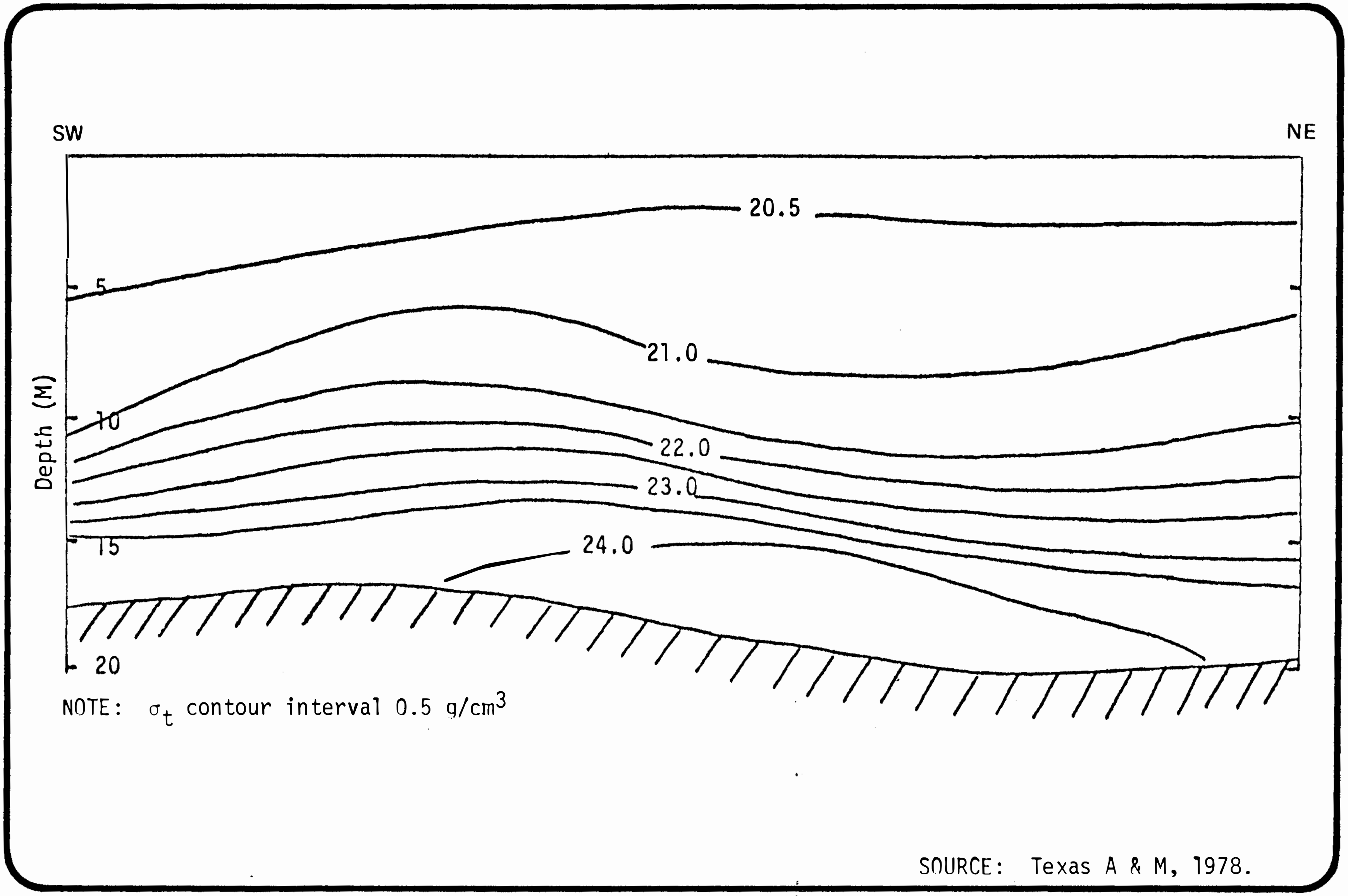


FIGURE G.4-4. Longshore vertical density stratification for stations 27 through 6, December 18 and 19, 1977.

stratification of the entire offshore alternative site area was readily apparent. The four monthly cross sections taken normal to the shoreline, but terminating approximately one mile shoreward of the alternative site (Section G.2.2.2; Figures G.2-14, G.2-15, G.2-16 and G.2-17), reflect a dense, highly stratified water column at the offshore diffuser site compared to the proposed site. In September and October the area was relatively homogeneous and only slightly stratified, but in November and December the average density of the water increased due to an influx of warm highly saline water from offshore, and the eastern half of the area was highly stratified.

Current measurements taken at a depth of 68 feet (December 22, 1977 to January 5, 1978) confirmed that during this period the:

1. currents in the area were primarily wind-driven and their maximum speeds did not exceed 53 cm/sec (1.0 knot);
2. mean current direction was parallel to the isobaths and to the southwest; and
3. tidal currents in the area were generally weak and usually masked by the mean drift current.

A more detailed analysis of the current meter data including scatter plots, averaged velocity stick diagrams, and progressive water diagrams, is presented in Section G.2.2.3.

Because of the proximity of the sites to one another, distribution of wave heights is expected to be comparable at both sites. Wave height records collected by the National Climate Center from 1884 through 1973 show that a medium wave height average of 3.4 to 5.0 feet would be anticipated for the months of November through May and from 1.5 to 3.5 feet for June through October.

Factors that influence tidal fluctuations for the area are contained in Section G.2.2.4. Tidal ranges are expected to be similar for both sites.

No textural analysis of the sediment samples collected at the offshore site has yet been conducted, although approximately 20 to 30 2-foot long cores were collected for later analysis of sediment chemistry.

These cores were visually described as primarily sand to sandy mud; some patches of clay and silt were encountered. A thin veneer of silt overlaid the firmer sediments, depending on preceding weather conditions at the site.

G.4.1.2 Impacts to Physical Environment

A complete impact analysis of the diffusing brine as predicted by the MIT Transient Plume Model has been discussed in Section G.3. Input to the model (ENDECO current meter data) originated from the offshore site, therefore, the predicted brine plumes presented in Figures G.3-3 through G.3-6 also apply to this alternative site. Figures G.3-7 and G.3-8 predict bottom areas impacted by various combinations of ambient conditions. Under normal current conditions, the area of major impact defined by the 5 ppt excess salinity isohaline would be limited to approximately 100 feet on either side of the diffuser and would cover an area of about 9 acres.

An analysis of heat transfer properties in the alternative brine disposal pipeline was conducted to determine the expected heat loss in the line when the brine is pumped from the brine pit to the alternative diffuser. This analysis was carried out for conditions where the temperature of the brine at the inlet ranged from $70^{o}F$ to $140^{o}F$ and ambient ground temperatures ranged for $50^{o}F$ to $70^{o}F$. The results of this analysis in the table below indicate that the maximum temperature differential (ΔT) between the inlet and the outlet (i.e., at the diffuser ports) would occur for the case when the inlet temperature was $140^{o}F$ and the ground temperature was $50^{o}F$, but this difference for the 10.9 nautical miles would only amount to $3.5^{o}F$. This difference is very close to the ΔT of $3.2^{o}F$ determined for the proposed nearshore diffuser site (Section G.1.3). Therefore, it is expected that the brine plume thermal analysis and impacts for this alternative site would be very similar to those as described for the proposed 5 mile site.

Brine Temperature (^{o}F) at the Alternative Diffuser Ports as a Function of Ground Temperature and Brine Temperature at the Pipeline Inlet.

Brine Inlet Temperature (^{o}F)		Ground Temperature (^{o}F) 50	60	70
140		136.4	136.8	137.3
130	Temperature	126.9	127.3	127.8
110	(^{o}F) of Brine	107.8	108.3	108.7
90	at Diffuser	89.2	89.5	89.8
70	Ports	69.6	69.9	70.0

However density gradients (i.e., stratification) in the bottom waters (Section G.2.2.2.2) in the vicinity of the alternative offshore site could inhibit diffusion to a limited degree.

There is approximately an 18 to 20 foot difference in water depth between the proposed diffuser site and the alternative offshore site. Topographically, the proposed site is more complex with several coral reef heads and other bottom obstructions located to the south and southwest (Section G.2.2.5). Although the shelf in the vicinity of the alternative site is relatively flat and featureless, a shallow trough trends in a northeast-southwest direction just seaward of the alternative site location. This trough could possibly be a scour feature and as such could be accompanied by high current velocities.

The density profiles show the presence of warmer and more saline bottom water in the vicinity of the alternative site during September and October from an offshore source. The stratification present in the deeper waters offshore could thus inhibit vertical diffusion of the brine at this alternative site and therefore the plume, being restricted by the stratified water column, could extend over an area larger than the predicted excess salinity zone.

A reasonable degree of homogeneity in the flow field between the two sites can be expected because of their proximity to one another. Small variations in direction may be manifested at the inshore site due to its shallow depth, and the influence of irregular topographic features (coral reef heads and other bottom obstructions). Mean flow, however, averaged through time and vertically over the water column, is not expected to vary significantly between the two sites.

Waves at the proposed brine diffuser site tend to be choppier than at the alternative site due to its decreased water depth. Normally, incoming swells or waves of a given size will "feel bottom" and produce more surface turbulence at the shallower proposed site than will a similar size wave passing over the deeper offshore alternative diffuser site.

No significant differences would be expected for the tides at either of the two sites.

Sediment distribution maps (Curray, 1960) show both sites having similar sediment types. Negligible impacts would be expected on the sedimentary features if either site were developed.

G.4.2 CHEMICAL OCEANOGRAPHY

G.4.2.1 Baseline Conditions

The alternative offshore area would be expected to have water and sediment chemistry characteristics similar to the proposed site. However, because it is further offshore, the alternative site might not be as highly influenced by river inflow, and therefore the transparency of the water at the alternative site might be higher than at the proposed site. This transparency was reflected at an offshore area 16 miles south of the alternative site (SEADOCK, 1975), wherein Secchi Disk Readings ranged in depth from 13.4 to 18.3 meters. Turbidity, at the same area ranged from 0.3 to 1.6 Formazin Turbidity Units (FTU) and 7.4 to 11.0 FTU in top and bottom waters respectively during the spring and 0.2 to 0.6 FTU throughout the water column in the summer.

Dissolved oxygen values at the alternative site would also be expected to be similar to the SEADOCK site, which averaged 10.67 mg/l during the winter, but decreased during the spring and summer to within a range of 2.0 to 7.1 mg/l; three measurements in the bottom water were below 5.0 mg/l. Oxidation-reduction potentials of the sediment decreased from a positive oxidizing value in the winter to negative reducing values in the summer. The sediment pH ranged from 7.0 to 8.6 with values decreasing in spring and summer (SEADOCK, 1975).

Inorganic nutrient levels in the water column of the offshore area were low, with NH_3, NO_2, NO_3 and PO_4 usually being below 0.01, 0.01, 0.03 and 0.1 ppm respectively, during the spring and summer, and NH_3 and PO_4 rising slightly during fall and winter. In the sediments, NO_2 values were similar to the values measured in the water column, NO_3 averaged two orders of magnitude higher, and PO_4 averaged one order of magnitude higher. Total organic carbon in the water column and percent volatile solids in the sediment were similar at SEADOCK to values at the proposed diffuser site (SEADOCK, 1975).

Heavy metal concentrations for both the water column and sediment were in the range normally found for coastal waters and were similar at SEADOCK to the levels found at the proposed site. The amount of dissolved oil and grease in the water column (2.4 ppm at the proposed site, 3.2 ppm in the offshore area) increased offshore toward the shipping lanes located about 16 miles from and parallel to the shoreline. These results suggest that a major source of dissolved oil and grease in this region of the Gulf may be the heavy ship traffic in the shipping lanes.

G.4.2.2 Impacts to Chemical Oceanography

Because of the expected similar water quality of the proposed and alternative brine diffuser locations and the similar nature of the plume discharge, impacts to the chemical environment are also expected to be similar for the two sites. The major impact of the proposed brine disposal on the alternative offshore area would be an increase in salinity, resulting mostly from high levels of sodium and chloride. As a result of jet dilution, potassium, calcium and sulfate would assume near-normal levels rapidly. Sodium and chloride would be in excess of natural Gulf water fluctuations and magnesium levels would be below normal.

Since metal levels in the brine are extremely low, heavy metal concentrations in the discharge water would be highly dependent on the water quality of the intake water from the Brazos River. During normal flow periods, little impact on the environmental conditions at either site should result from trace metals in the discharged brine. However, during either low flow or flood conditions in the Brazos River, when heavy metal levels increase greatly, the concentrations of lead, mercury, zinc, and manganese in the raw water supply could exceed EPA recommended discharge guidelines (Table G.3-5). These metals, with the exception of mercury, would settle out in the salt cavern, resulting in metal levels in the brine at the diffuser which would meet recommended guidelines.

Although the maximum equilibrium concentration of oil in brine would be about 31 ppm, factors such as insufficient mixing time, turbulence, and circulation in the cavern, vaporization, and oil skimming controls would reduce the oil concentration in the discharged brine to an estimated 6 ppm (FEA, 1977b). This level is higher than ambient Gulf hydrocarbon levels, but since oil and grease levels are greater in the alternative offshore area than at the proposed site, the hydrocarbon discharge would not contribute proportionally as great an increase at the alternative site.

As at the proposed site, the increased salinity and temperature of the discharged brine could result in decreased ambient dissolved oxygen levels and an alteration in the heavy metal chemical equilibrium between various interfaces such as between the water column and suspended particulates, the sediment and the pore water, and the sediment and the water column. These impacts would be expected to be of a minor nature.

Comparison of the baseline data from the proposed and alternative sites indicates that potential impacts to the chemical environment at the two locations would be similar. However, because baseline oil levels are greater at the offshore site, brine discharge hydrocarbons would not have as great an impact there as at the proposed site. Although no information is available on turbidity caused by brine discharge, a possible increase in turbidity would impact the higher transparency in the offshore waters to a greater extent than at the proposed area nearer shore.

G.4.3 BIOLOGICAL OCEANOGRAPHY

G.4.3.1 Plankton

G.4.3.1.1 Phytoplankton

In general, the phytoplankton community and population dynamics in the vicinity of the alternative site are similar to those as described for the proposed diffuser site (Section G.2.4.2.1). Diatoms usually dominate the community throughout the year, but dinoflagellates periodically codominate, especially in the warm months of the year. Primary productivity and cell densities are generally highest in the bays and decrease offshore. Productivity and chlorophyll a values are maximum in the late winter-early spring and minimum during the late summer; a slight increase in productivity is usually present in the early fall.

The phytoplankton community in the vicinity of the offshore site may differ from the proposed diffuser site in the following respects: because the offshore area is less influenced by the Texas rivers and bays, a greater number of marine species and fewer estuarine and freshwater species should be present at the offshore site; the density of the phytoplankton cells at the offshore site should on an annual average, be somewhat less than that at the proposed nearshore site; and the average annual phytoplankton productivity would be slightly less in the offshore waters.

To assess the anticipated environmental impacts of locating the brine diffuser in the offshore waters, several assumptions have been made. First, the characteristics of the brine plume should be much the same as for the proposed site except that the alternative diffuser would be located in 68 feet of water rather than 50 feet as for the nearshore site. Secondly, the average annual phytoplankton concentrations in the offshore and inshore areas, 7.8×10^4 cells/liter and 4.1×10^5 cells/liter respectively, correspond to those presented by Van Baalen (1976) for the similar nearshore and intermediate areas. In addition, it has been assumed that all plankton entrained within the 5 ppt isohaline excess where salinities may increase up to approximately 270 ppt above ambient conditions, would be either destroyed or at least undergo severe physiological stress. Based on these assumptions, it is anticipated that for each liter of water entrained in this area, approximately one-fifth the cells would be adversely impacted at the alternative diffuser site compared to the proposed site. Outside of the area enclosed by the 5 ppt isohaline, impacts to the phytoplankton community would be expected to be substantially less and comparable for both locations. It also can be expected that the primary productivity at each of the sites would be markedly reduced; the proposed site would be impacted at a higher rate compared to the offshore site because the expected rate of productivity at the nearshore site is higher than that anticipated for the offshore area.

G.4.3.1.2 Zooplankton

The density of the zooplankton community, and its population dynamics in the vicinity of the alternative offshore diffuser site, are expected to be similar to those described for the proposed diffuser site (Section G.2.4.2.2). In general, zooplankton density, in terms of numbers of organisms per cubic meter, is highest in the nearshore waters and decreases in a seaward direction. Copepods dominate this community and the euryhaline species *Acartia tonsa* is usually the prevalent species in this part of the neritic zone. Further offshore, a greater proportion of stenohaline marine species would be encountered. Zooplankton densities undergo large seasonal variations and attain their maxima in early summer and again in the fall; low zooplankton densities are ususally found in the late summer and winter.

In the region of the alternative site, the zooplankton community may differ from the community at the proposed nearshore diffuser site in the following aspects: the average annual zooplankton density may be somewhat less at the offshore site and a greater proportion of marine species might be found in these offshore waters.

To assess the potential environmental impacts of locating the brine diffuser at the alternative site, several assumptions have been made. First, the plume characteristics at the offshore site would be similar to those defined for the plume at the proposed site, except that the diffuser would be located in deeper water at the alternative site.

Second, due to the lack of data, regional maximum zooplankton concentrations previously reported, have been used to characterize the two sites: 7700 zooplankters/m^3 for the offshore site (Fotheringham, 1977) and 120,000 zooplankters/m^3 for the proposed nearshore site (LOOP, 1975). It is also assumed that all plankton entrained within the high salinity plume area would be either destroyed or undergo severe physiological stress. Based on these assumptions, it is anticipated that for each cubic meter of water entrained in the brine plume, almost 15 times more zooplankton would be impacted at the proposed diffuser site than at the offshore site. Zooplankton entrained in the plume area outside the area are not expected to be severely impacted.

G.4.3.2 Benthos

The alternative offshore brine diffuser site is characterized by benthic invertebrate fauna similar to that observed at the inshore brine diffuser site (Section G.2.4.3). Although site specific data for the offshore location is limited, a comparison of the data collected for SEADOCK (1975) and preliminary data at the offshore site shows that the 44 benthic taxa collected by the SEADOCK survey (Table G.4-1) are apparently not as diverse as the collections taken in December 1977 at the offshore location (Table G.4-2). The number of samples collected at the alternative site in 1977 was five times greater than that collected for Seadock in 1973. Both the SEADOCK collections (Table G.4-1) and the 1977 collections (Table G.4-2) were dominated by polychaetes, (>60 percent) and crustaceans and molluscs (25 percent). These relationships correlate well with regional data (Section G.2.4.3) which indicate that polychaetes were the dominant benthic invertebrates present. Nearly 80 percent of the benthic organisms undergo some degree of seasonal variation, however, the total number of taxa collected during each season showed little variability (Table G.4-1).

Based on samples taken in December 1977 (Table G.4-2), the alternative offshore site has a lower diversity (total number of species) compared to the proposed inshore site, however, relative biomass (in terms of number of individuals per square meter) at the alternative site is more

TABLE G.4-1 Summary of benthic invertebrates collected in the vicinity of the alternative diffuser site (SEADOCK Station 18), 1973.

SCIENTIFIC NAME	COLLECTION PERIOD[a]		
	Winter	Spring	Summer
Hydrozoa	XX	--	--
Nemertea	XX	--	--
Cerebratulus lacteus	--	XX	XX
Sthenelais boa	--	--	XX
Bhawania goodei	XX	--	--
Ancystrosyllis hartmanae	--	XX	--
Sigambra tentaculata	XX	XX	XX
Nereis sp.	XX	XX	XX
Nephtys picta	XX	XX	XX
Glycera americana	--	XX	XX
Diopatra cuprea	--	XX	XX
Onuphis eremita oculata	XX	--	XX
Lumbrineris sp.	XX	XX	XX
Ninoe nigripes	--	--	XX
Aricidea cf. *fragilis*	XX	XX	--
Aricidea cf. *wassi*	--	XX	XX
Ampelisca abdita	XX	XX	XX
Prinospio heterobranchia	--	XX	XX
Prinospio pinnata	XX	XX	XX
Spiophanes bombyx	XX	XX	XX
Spio setosa	--	XX	--
Streblospio benedicti	XX	--	--
Megelona pettiboneae	XX	XX	XX
Megelona sp. (purple banded)	--	XX	XX
Spiochaetopterus oculatus	--	XX	--
Tharyx setigera	--	XX	--
Cossura delta	XX	--	XX
Mediomastus californiensis	XX	XX	XX
Notomastus latericeus	--	XX	--
Owenia fusiformis	XX	--	--
Ampharetidae	XX	--	--
Chone duneri	XX	--	--
Phascolion strombi	XX	XX	--

TABLE G.4-1 continued.

SCIENTIFIC NAME	COLLECTION PERIOD[a]		
	Winter	Spring	Summer
Squilla empusa	--	xx	--
Callianassa sp.	--	xx	--
Chasmocarcinus mississippiensis	--	xx	--
Pinnixa sayana	--	--	xx
Crepidula fornicata	xx	--	--
Natica pusilla	--	--	xx
Vitrinella helica	--	--	xx
Anadara transversa	xx	--	--
Tellina versicolor	--	xx	--
Phoronis architecta	--	xx	--
Hemipholis elongata	xx	--	--
Total taxa collected	23	27	22

Source: SEADOCK, 1975.

[a] xx indicates presence in collection; -- indicates not collected.

TABLE G.4-2 Summary comparison of benthic invertebrates (infauna) collected at the proposed and alternative brine diffuser sites, December 1977.

	Proposed	Alternative
Total number of species	67	59
Average number of species per station	16	21
Average number of individuals/m^2 per station	902	2092
Number of polychaete species	34	32
Number of crustacean species	10	13
Number of mollusk species	6	8
Number of miscellaneous species	17	6
Percentage of polychaetes	75	92
Percentage of crustaceans	3.8	4.4
Percentage of mollusks	3.6	1.0
Percentage of miscellaneous groups	17.5	2.4

SOURCE: Texas A & M, 1978.

than twice that of the proposed site. The distribution of major taxons (polychaetes, crustaceans and mulluscs) is similar although polychaetes are by far the dominant species at the alternative site. The greater abundance of individuals at the offshore location is apparently associated with the sandy substrate found at this site. Several studies (Harper, 1977; SEADOCK, 1975) indicate that the density of benthic macroinvertebrates tends to be higher in substrates with a moderate to large quantity of sand than in softer mud or silty substrates.

The possibility of heavy predation of benthic organisms at the proposed site, and changes in the relative density of organisms at the two sites due to seasonal variation, should not be overlooked. Although it appears that the offshore area is more productive, it is possible that the relatively low density of benthic invertebrates inshore may be due to heavy predation by shrimp and other benthic feeding organisms.

The salinity in the discharge area of the alternative diffuser site would be the same as that expected for the proposed site, however, because of the deeper water depth at the alternative site, temperatures are expected to be slightly lower than those at the proposed site. The overall impacts of the brine discharge would generally be similar to the proposed site (Section G.3.3.2). Assuming that the density of benthic invertebrates is higher (Table G.4-2) at the alternative site, the impact to the benthos would be greater by a similar magnitude. If complete mortality for the benthic invertebrates within the 5 ppt isohaline occurred, approximately 7.4×10^8 benthic organisms would be killed (based upon density ratio determined from Table G.4-2) compared to 3.2×10^8 at the proposed site (from Figure G.2-35).

G.4.3.3 Nekton

The alternative diffuser site is expected to be characterized by nektonic fauna similar to the proposed site (Section G.2.4.3). Site specific data for the nekton at the offshore location is limited, however, some preliminary data has been utilized from an ongoing DOE study.

The bathemetry of the alternative area suggests that the site is located in a transition between the white and brown shrimp fishing grounds. Data taken at the offshore site (Section G.2.4.4, Figure G.1-6) indicate that the fauna is more characteristic of the brown shrimp grounds (Tables G.2-16, G.2-18, G.5-3, G.5-4, and G.5-5).

The impacts of the brine discharge on nekton would be similar to those anticipated for the proposed site (Section G.3.3.3) but the magnitude of these impacts would be proportional to the nekton biomass differences between the two sites. Preliminary data indicate that the relative nekton biomass is greater at the proposed site compared to the alternative site (Tables G.2-17, G.2-18, G.5-3, G.5-4, and G.5-5). This relationship is not supported by regional data which indicate that the relative biomass should be higher on the brown shrimp grounds. Two possible explanations for these unexpected differences are the lack of seasonal data for the alternative site (which may show that this site does have a higher relative biomass than the proposed site), and that the alternative site actually is in a transition zone between the two shrimping grounds and thus not representative of the prime brown shrimping grounds.

The proposed area is an important area for white shrimp and redfish spawning (near reefs and wrecks). Although the projected salinity concentrations during disposal are not expected to have a serious adverse impact on the nearshore spawning grounds, there would be even less potential impact from the offshore alternative site which is well removed from this important habitat. Because the inshore proposed site is recognized as prime white shrimp grounds and the alternative site is not, commercial fisheries operations, particularly for white shrimp, might be less hindered at the alternative site.

G.5 SUPPLEMENTARY DATA

TABLE G.5-1 Typical benthic macro-faunal assemblage of the Gulf of Mexico offshore from Freeport, Texas.

Cnidaria

- *Leptogorgia setacea*
- *Paranthus rapiformis*
- *Renilla mulleri*

Annelida

- *Diopatra cuprea*

Gastropoda

- *Anachis obesa*
- *Anachis ornata*
- *Anachis saintpairiana*
- *Antilliphos* sp.
- *Architectonica nobilis*
- *Busycon contrarium*
- *Busycon plagosum texana*
- *Busycon pyrum*
- *Distorsio clathrata*
- *Fasciolaria hunteria*
- *Murex fulvescens*
- *Murex pomum*
- *Nassarius acutus*
- *Nassarius ambiguus*
- *Nassarina glypta*
- *Oliva sayana*
- *Phalium granulatum*
- *Polinices duplicatus*
- *Strombus alatus*
- *Terebra dislocata*
- *Terebra protexta*
- *Thais haemastoma floridana*
- *Tonna galea*

Pelecypoda

- *Aequipecten gibbus gibbus*
- *Aequipecten muscosus*
- *Anadara transversa*
- *Arca campechiensis*
- *Atrina serrata*
- *Chione clenchi*
- *Chione grus*
- *Chione intapurpurea*
- *Corbula swiftiana*
- *Dosinia discus*
- *Gouldia cerina*
- *Lucina sombrerensis*
- *Mulinia lateralis*
- *Dinocardium robustum*
- *Nuculana concentrica*
- *Nucula proxima*
- *Pandora bushian*
- *Pitar cordata*
- *Phylloda squamifera*
- *Quadrans lintea*
- *Semele purpurescens*
- *Solen viridis*
- *Spisula solidissima raveneli*
- *Tellina georgiana*
- *Tellina tayloriana*
- *Varicorbula operaculata*
- *Yoldia solenoides*

Cephalopoda

- *Loligo pealei*
- *Loliguncula brevis*

TABLE G.5-1 continued.

Crustacea

- *Arenaeus cribarius*
- *Calappa springeri*
- *Callianassa latispina*
- *Callinectes danae*
- *Callinectes sapidus*
- *Hepatus epheliticus*
- *Persephona punctata*
- *Petrochirus bahamensis*
- *Penaeus aztecus*
- *Penaeus duorarum*
- *Penaeus setiferus*
- *Portunus spinimanus*
- *Portunus gibbesi*
- *Sicyonia brevirostris*
- *Sicyonia dorsalis*
- *Solenocera vioscai*
- *Squilla empusa*
- *Trachypeneus constrictus*
- *Trachypeneus similis*
- *Xiphopeneus kryeri*

Echinodermata

- *Astropecten antillensis*
- *Clypeaster ravenelli*
- *Luidia alternata*
- *Luidia clathrata*

Source: SEADOCK, 1975

TABLE G.5-2 Invertebrates and fish characteristic of the offshore northern Texas coastal region based upon trawl samples.

Common Name	Scientific Name
Invertebrates	
Sea pansy	Renilla mulleri
Brief squid	Lolliguncula brevis
Mantis shrimp	Squilla empusa
Royal red shrimp	Hymenopenaeus robustus
White shrimp	Penaeus setiferus
Brown shrimp	Penaeus aztecus
Seabob	Xiphopenaeus kroyeri
Rock shrimp	Sicyonia dorsalis
Purse crab	Myropsis quinquespinosa
Purse crab	Persophona crinata
Spider crab	Libinia emarginata
Blue crab	Callinectes sapidus
Swimming crab	Callinectes danae
Brittle star	Ophioderma brevispinum
Fish	
Blacknose shark	Carcharhinus acronotus
Silky shark	Carcharhinus falciformus
Bull shark	Carcharhinus leucas
Spinner shark	Carcharhinus maculipinnis
Smalltail shark	Carcharhinus porosus
Tiger shark	Galeocerdo cuvieri
Smooth dogfish	Mustelus canis
Atlantic sharpnose shark	Rhizoprionodon terraenovae
Scalloped hammerhead	Sphyrna lewini
Bonnethead	Sphyrna tiburo
Atlantic angel shark	Squatina dumerili
Lesser electric ray	Narcine brasiliensis
Roundel skate	Raja texana
Roughtail stingray	Dasyatis centroura
Atlantic stingray	Dasyatis sabina

TABLE G.5-2 continued.

Common Name	Scientific Name
Spotted eagle ray	*Aetobatus narinari*
Cownose ray	*Rhinoptera bonasus*
Lady fish	*Elops saurus*
Blackedge moray	*Gymnothorax nigromarginatus*
Silver conger	*Hoplunnis macrurus*
Pike conger	*Hoplunnis tenuis*
Pike conger	*Hoplunnis* sp.
Conger eel	*Ariosoma bulearicum*
Yellow conger	*Congrina flava*
Margintail conger	*Paraconger caudilimbatus*
Threadtail conger	*Uroconger syringinus*
Stippled spoon-nose eel	*Mystriophis punctifer*
Shrimp eel	*Ophichthus gomesi*
Shrimp eel	*Ophichthus* sp.
Gulf menhaden	*Brevoortia patronus*
Gizzard shad	*Dorosoma cepedianum*
Scaled sardine	*Harengula pensacolae*
Atlantic thread herring	*Opisthonema oglinum*
Spanish sardine	*Sardinella anchovia*
Striped anchovy	*Anchoa hepsetus*
Bay anchovy	*Anchoa mitchilli*
Largescale lizardfish	*Saurida brasiliensis*
Inshore lizardfish	*Synodus foetens*
Offshore lizardfish	*Synodus poeyi*
Sea catfish	*Arius felis*
Gafftopsail catfish	*Bagre marinus*
Toadfish	*Opsanus* sp.
Atlantic midshipman	*Porichthys porosissimus*
Stippled clingfish	*Gobiesox punctulatus*
Singlespot frogfish	*Antennarius radiosus*
Splitlure frogfish	*Phrynelox nuttingi*
Pancake batfish	*Halieutichthys aculeatus*
Roughback batfish	*Ogcocephalus parvus*
Batfish	*Ogcocephalus* sp. A.

TABLE G.5-2 continued.

Common Name	Scientific Name
Batfish	Ogcocephalus sp. B.
Tricorn batfish	Zalieutes mcgintyi
Deepwater codfish	Physiculus fulvus
Southern hake	Urophycis floridanus
Bearded brotula	Brotula barbata
Mottled cusk-eel	Lepophidium jeannae
Cusk-eel	Lepophidium sp.
Crested cusk-eel	Ophidion welshi
American john dory	Zenopsis ocellata
Chain pipefish	Syngnathus louisianae
Bank sea bass	Centropristis ocyurus
Rock sea bass	Centropristis philadelphica
Yellowedge grouper	Epinephelus flavolimbatus
Blackear bass	Serranus atrobranchus
Whitespotted soapfish	Rypticus maculatus
Bigeye	Priacanthus arenatus
Short bigeye	Pseudopriacanthus altus
Twospot cardinalfish	Apogon pseudomaculatus
Blackline tilefish	Caulolatilus cyanops
Bluefish	Pomatomus saltatrix
Cobia	Rachycentron canadium
Sharksucker	Echeneis naucrates
African pompano	Alectis crinitis
Blue runner	Caranx crysos
Crevalle jack	Caranx hippos
Atlantic bumper	Chloroscombrus chrysurus
Round scad	Decapterus punctatus
Bluntnose jack	Hemicaranx amblyrhynchus
Bigeye scad	Selar crumenophthalmus
Lookdown	Selene vomer
Greater amberjack	Seriola dumerili
Almaco jack	Seriola rivoliana
Florida pompano	Trachinotus carolinus
Rough scad	Trachurus lathami

TABLE G.5-2 continued.

Common Name	Scientific Name
Atlantic moonfish	Vomer setapinnis
Red snapper	Lutjanus campechanus
Lane snapper	Lutjanus synagris
Wenchman	Pristipomoides aquilonaris
Vermilion snapper	Rhomboplites aurorubens
Silver jenny	Eucinostomus gula
Barred grunt	Conodon nobilis
Tomtate	Haemulon aurolineatum
Pigfish	Orthopristis chrysoptera
Sheepshead	Archosargus probatocephalus
Whitebone porgy	Calamus leucosteus
Pinfish	Lagodon rhomboides
Longspine porgy	Stenotomus caprinus
Silver perch	Bairdiella chrysura
Sand seatrout	Cynoscion arenarius
Silver seatrout	Cynoscion nothus
High-hat	Equetus acuminatus
Banded drum	Larimus fasciatus
Spot	Leiostomus xanthurus
Southern kingfish	Menticirrhus americanus
Gulf kingfish	Menticirrhus littoralis
Atlantic croaker	Micropogon undulatus
Black drum	Pogonias cromis
Red drum	Sciaenops ocellata
Star drum	Stellifer lanceolatus
Red goatfish	Mullus auratus
Dwarf goatfish	Upeneus parvus
Atlantic spadefish	Chaetodipterus faber
Reef butterflyfish	Chaetodon sedentarius
Striped mullet	Mugil cephalus
Guaguanche	Sphyraena guachancho
Atlantic threadfin	Polydactylus octonemus
Lancer stargazer	Kathetostoma albiquatta
Ragged goby	Bollmannia communis
Atlantic cutlassfish	Trichiurus lepturus

TABLE G.5-2 continued.

Common Name	Scientific Name
Little tunny	*Euthynnus alletteratus*
Chub mackerel	*Scomber japonicus*
King mackerel	*Scomberomorus cavalla*
Spanish mackerel	*Scomberomorus masculatus*
Harvestfish	*Peprilus paru*
Gulf butterfish	*Peprilus burti*
Barbfish	*Scorpaena brasiliensis*
Smoothhead scorpionfish	*Scorpaena calcarata*
Hunchback scorpionfish	*Scorpaena dispar*
Spotted scorpionfish	*Scorpaena plumieri*
Horned searobin	*Ballator militaris*
Bandtail searobin	*Prionotus ophryas*
Mexican searobin	*Prionotus paralatus*
Bluespotted searobin	*Prionotus roseus*
Blackfin searobin	*Prionotus rubio*
Blackwing searobin	*Prionotus salmonicolor*
Shortwing searobin	*Prionotus stearnsi*
Bighead searobin	*Prionotus tribulus*
Three-eye flounder	*Ancylopsetta dilecta*
Ocellated flounder	*Ancylopsetta quadrocellata*
Flounder	*Bothus* sp.
Spotted whiff	*Citharichthys macrops*
Bay whiff	*Citharichthys spilopterus*
Mexican flounder	*Cyclopsetta chittendeni*
Spotfin flounder	*Cyclopsetta fimbriata*
Spiny flounder	*Engyophrys senta*
Fringed flounder	*Etropus crossotus*
Gulf flounder	*Paralichthys albigutta*
Southern flounder	*Paralichthys lethostigma*
Broad flounder	*Paralichthys squamilentus*
Shoal flounder	*Syacium gunteri*
Dusky flounder	*Syacium papillosum*
Sash flounder	*Trichopsetta ventralis*
Lined sole	*Achirus lineatus*
Fringed sole	*Gymnachirus texae*

TABLE G.5-2 continued.

Common Name	Scientific Name
Offshore tonguefish	*Symphurus civitatus*
Spottedfin tonguefish	*Symphurus diomedianus*
Pygmy tonguefish	*Symphurus parvus*
Blackcheek tonguefish	*Symphurus plagiusa*
Dotterel filefish	*Aluterus heudeloti*
Orange filefish	*Aluterus schoepfi*
Gray triggerfish	*Balistes capriscus*
Fringed filefish	*Monacanthus ciliatus*
Planehead filefish	*Monacanthus hispidus*
Scrawled cowfish	*Lactophrys quadricornis*
Smooth puffer	*Lagocephalus laevigatus*
Marbled puffer	*Sphoeroides dorsalis*
Least puffer	*Sphoeroides parvus*
Bandtail puffer	*Sphoeroides spengleri*
Striped burrfish	*Chilomycterus schoepfi*

Source: Chittenden and McEachran, 1976; SEADOCK, 1975 (Includes Station Groups A-J).

TABLE G.5-3 Numbers of selected[a] invertebrates and fish collected at each trawl station during October 1977.

	STATION NUMBER[b]																		
Invertebrates	1	2	3A	3B	4A	4B	5A	5B	6A	6B	7A	7B	8A	8B	9	10	11	12	13
Brown shrimp	2	0	21	N[c]	71	N	66	N	88	N	47	N	101	N	92	N	N	N	N
Pink shrimp	0	0	0	N	0	N	0	N	0	N	0	N	0	N	0	N	N	N	N
White shrimp	22	17	129	N	182	N	138	N	106	N	109	N	199	N	9	N	N	N	N
Fish																			
Sea catfish	2	0	5	N	25	N	9	N	28	N	17	N	45	N	28	N	N	N	N
Longspine porgy	0	0	0	N	0	N	0	N	12	N	0	N	0	N	79	N	N	N	N
Southern kingfish	0	0	1	N	0	N	1	N	1	N	0	N	0	N	3	N	N	N	N
Gulf kingfish	0	0	0	N	0	N	0	N	0	N	0	N	0	N	0	N	N	N	N
Atlantic croaker	92	54	506	N	474	N	612	N	706	N	519	N	835	N	142	N	N	N	N
Sand seatrout	1	1	13	N	37	N	42	N	32	N	20	N	24	N	17	N	N	N	N
Silver seatrout	16	72	92	N	64	N	79	N	108	N	62	N	72	N	69	N	N	N	N
Star drum	336	66	69	N	47	N	30	N	244	N	29	N	54	N	0	N	N	N	N
Atlantic threadfin	7	2	6	N	16	N	61	N	42	N	36	N	27	N	24	N	N	N	N
Atlantic cutlassfish	0	0	0	N	0	N	1	N	1	N	0	N	0	N	11	N	N	N	N
Gulf butterfish	60	4	35	N	103	N	139	N	737	N	142	N	277	N	133	N	N	N	N
Total	538	216	877	N	1019	N	1178	N	2105	N	1053	N	1634	N	607	N	N	N	N

[a]Selected invertebrates and fish include those organisms considered to be either of great commercial importance or abundance.

[b]A letter (e.g., A or B) following a station number indicates a replicate sample.

[c]N indicates no collection made.

SOURCE: Texas A & M, 1978.

TABLE G.5-4 Numbers of selected[a] invertebrates and fish collected at each trawl station during November 1977.

	STATION NUMBER[b]																		
Invertebrates	1	2	3A	3B	4A	4B	5A	58	6A	68	7A	7B	8A	88	9	10	11	12	13
8rown shrimp	0	0	10	7	2	13	8	7	5	8	9	10	5	5	2	N[c]	N	N	2
Pink shrimp	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	N	N	N	0
White shrimp	3	11	15	26	74	169	64	94	75	122	84	114	71	98	4	N	N	N	63
Fish																			
Sea catfish	1	0	0	0	0	0	0	0	0	1	0	0	1	1	0	N	N	N	0
Longspine porgy	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	N	N	N	0
Southern kingfish	0	0	0	0	0	2	0	0	0	2	0	1	0	0	0	N	N	N	1
Gulf kingfish	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	N	N	N	0
Atlantic croaker	12	14	9	8	76	53	23	63	5	22	10	29	29	19	1	N	N	N	13
Sand seatrout	17	3	4	6	16	14	9	17	11	11	6	11	20	9	0	N	N	N	3
Silver seatrout	52	62	78	40	170	391	166	582	253	339	219	290	543	496	0	N	N	N	93
Star drum	13	3	0	0	6	1	0	1	0	0	0	0	0	0	0	N	N	N	0
Atlantic threadfin	0	0	0	0	0	1	0	0	2	4	0	2	44	1	0	N	N	N	0
Atlantic cutlassfish	123	23	0	1	23	1	0	2	4	0	7	4	12	11	0	N	N	N	0
Gulf butterfish	42	8	11	37	14	5	120	12	25	18	102	28	159	96	0	N	N	N	0
Total	263	124	127	125	381	650	390	778	380	527	437	489	844	736	7	N	N	N	175

[a] Selected invertebrates and fish include those organisms considered to be either of great commercial importance or abundance.

[b] A letter (e.g., A or 8) following a station number indicates a replicate sample.

[c] N indicates no collection made.

SOURCE: Texas A & M, 1978.

TABLE G.5-5 Numbers of selected[a] invertebrates and fish collected at each trawl station during December 1977.

	STATION NUMBER[b]																		
Invertebrates	1	2	3A	3B	4A	4B	5A	5B	6A	6B	7A	7B	8A	8B	9	10	11	12	13
Brown shrimp	3	2	6	1	4	4	5	2	3	3	4	3	6	3	34	40	0	0	12
Pink shrimp	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
White shrimp	237	243	183	56	82	67	157	146	175	67	140	57	199	86	5	0	0	0	4
Fish																			
Sea catfish	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
Longspine porgy	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	35	83	124	0
Southern kingfish	1	1	0	1	3	1	1	0	0	1	0	0	1	1	0	0	0	0	2
Gulf kingfish	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Atlantic croaker	39	36	19	12	6	13	7	13	12	9	12	18	12	13	19	6	0	0	6
Sand seatrout	19	10	10	8	8	6	6	6	4	4	1	0	6	1	6	0	0	0	3
Silver seatrout	9	16	129	148	207	203	130	81	148	130	142	93	173	106	164	0	0	0	165
Star drum	244	114	29	4	2	1	1	1	0	0	1	0	0	0	0	0	0	0	0
Atlantic threadfin	0	0	3	0	0	4	0	1	1	0	6	0	0	0	0	0	0	0	0
Atlantic cutlassfish	1	0	0	0	4	1	0	0	0	1	0	0	2	0	4	0	0	0	1
Gulf butterfish	0	1	0	2	1	3	0	1	3	0	1	1	1	0	0	0	0	0	1
Total	554	423	379	232	317	303	307	251	346	215	307	172	400	210	232	81	83	124	196

[a] Selected invertebrates and fish include those organisms considered to be either of great commercial importance or abundance.

[b] A letter (e.g., A or B) following a station number indicates a replicate sample.

SOURCE: Texas A & M, 1978.

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APPENDIX H

DEEP WELL INJECTION OF BRINE

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DEEP WELL INJECTION OF BRINE

An alternate method of disposing of brines displaced from the Strategic Petroleum Reserve (SPR) caverns during oil fill and cavern leaching is by deep well injection. Disposal is accomplished by injecting brines under pressure into wells completed in deep sand reservoirs.

Certain physical conditions are prerequisite to successful subsurface disposal operations. A reservoir having sufficient volume and three-dimensional continuity to accommodate injected brine must exist. Further, the hydraulic characterisitics of the reservoir must be such that it will readily transmit injected brines. Finally, the reservoir must be isolated hydraulically to preclude contamination of fresh water aquifers.

The potential impacts associated with subsurface injection of brines are:

- contamination of ground water aquifers
- aquifer fracture
- chemical and physical problems of fluid incompatibility
- interference with oil and gas reservoirs
- earthquake inducement

Contamination of Ground Water Aquifers

Contamination of overlying fresh water aquifers can occur by direct influx of deep-injected brines into shallower horizons, aquiclude fracture, leakage through permeable beds separating the deeper zones from shallower zones, leakage through improperly cased wells, abandoned wells, or wells which are open to both the injection zone, and to the fresh water aquifers.

The geologic section which was considered for disposal is characterized by poorly consolidated sediments, consisting primarily of sands, silts, clays and partially indurated shales. Sand units comprise an estimated 40% of the total section, while the remaining portion of the section consists of relatively impermeable silts, clays and shales, which have characteristically poor transmitting properties, and may serve to preclude the vertical movement of the injected brines. Brines will be injected into deep (greater than 3,000 feet) saline reservoirs, well below the lowermost usable fresh water aquifer.

Assurances that no contamination will result from leakage through wells requires that all wells within the area of influence of the injection field be identified, and properly sealed where necessary. Because the brine disposal reservoirs may be uplifted in the vicinity of the dome, it is essential that abandoned wells completed at depths shallower than the disposal reservoir also be checked. If any wells are found to be improperly plugged, they would be replugged in accordance with accepted procedures. If a substantial number of the wells appear to need replugging, it may be necessary to move the injection site.

Aquifer Fracture

A satisfactory reservoir for subsurface waste disposal must possess adequate volume and have impermeable strata such as shale aquicludes above and below the storage layer. Excessive pressure buildup could lead to aquiclude fracture and loss of containment. Pressure buildup depends upon:

- aquifer size
- injection rate
- quantity of waste fluid
- aquifer porosity
- aquifer permeability
- clogging agents in the waste such as colloids or materials which support bacterial growth

The potential for aquifer fracture exists whenever the pressure conditions within a reservoir exceed the prevailing stress field. The prevailing stress field in the reservoir is the result of the lithostatic weight of overburden materials and the hydrostatic weight of the fluid column existing within and above the reservoir. Experience in the Gulf Coast sediments suggests gradients of 1.0 and 0.5 pounds per square inch per foot of depth (psi/ft) for the lithostatic and hydrostatic gradients respectively. Fracture gradients in the Gulf Coast sediments have been observed in the range of 0.54 to 0.8 psi/ft. Careful monitoring of well-head and bottom hole pressures during injection will be required to insure that fracture pressures are not exceeded.

Chemical and Physical Problems of Fluid Incompatibility

Impacts associated with chemical and physical incompatibility of injected brines with respect to native formation fluids will be confined to the vicinity of the injection well bore where it penetrates the receiving disposal reservoir. Analyses of brines injected at other SPR sites have indicated no significant compatibility problems. The reservoirs considered for injection contain moderately to highly saline waters (on the order of 30,000 to 100,000 ppm total dissolved solids) and should therefore pose no problems with respect to receiving SPR brines, which will range in concentration from 90,000 ppm to an effectively saturated brine (264,000 ppm).

Interference with Oil and Gas Reservoirs

Impacts on oil and gas reservoirs and production can result directly from the influx and flushing of these reservoirs by injected brines. The oil and gas reservoirs can also be impacted indirectly, by the effects of reservoir pressurization attendant to the injection operations. In order that these impacts are minimized or avoided, injection wells must be located such that the area of influence of the disposal operation does not impinge on the oil and gas reservoirs. Vertical and stratigraphic separations between injection depths and the oil and gas reservoirs will further insure that no impacts result from the disposal operation. However, it is possible that pressure buildup in the disposal sands would be accompanied by slight pressure increases in oil and gas strata. This could benefit overall hydrocarbon production by reducing the effect of pressure loss due to oil and gas depletion.

Earthquake Inducement

Earthquakes may be induced when faults are lubricated by injected fluids. There is documented evidence of earthquakes being triggered as a result of subsurface injection of fluid accompanied by an increase in injection reservoir pressure. The two known cases of this phenomenon have occurred in Colorado in an area of high natural rock stresses. One occurred near Denver and was associated with a disposal well containing liquid waste from the Rocky Mountain Arsenal. The other occurred near Rangely, Colorado and was associated with water injection into wells of the Rangely oil field. The mechanisms causing the earthquake are not well understood; however, one possible explanation is that stresses on opposite sides of existing fault planes were not sufficiently large to overcome frictional forces along the plane and cause movement until the waste fluids were injected and acted as a lubricant. Stresses are relieved by plastic deformation or rupture of rocks. If the plasticity of a rock is relatively low, the stress continues to increase until rupture (faulting) occurs. In the Gulf Coast area, the unconsolidated sediments, as opposed to the consolidated rock in Colorado, are very plastic and stress relief comes in the form of plastic deformation. Although faults do exist in the Gulf Coast, movement along these planes due to lubrication by injected brine seems unlikely. Numerous flood water and liquid waste injection sites have been in operation along the Louisiana-Texas Gulf Coast for many years without reported occurrences of earthquakes. In addition, the National Oceanic and Atmospheric Administration has classified this area as having no reasonable expectancy of surface earthquake damage (Figure B.2-7).

APPENDIX I

HYDROCARBON EMISSIONS AND MODEL TO CALCULATE GROUND-LEVEL CONCENTRATIONS

Part I — Summary of Emissions from Tanker and Barge Transfers and Model Used to Calculate Downwind Ground-Level Concentrations

Part II — Description of the Physical and Chemical Basis for Emissions from Marine Vessel Transfer of Crude Oil (Prepared by SAI)

APPENDIX I

Part I

SUMMARY OF EMISSIONS FROM TANKER AND BARGE TRANSFERS AND MODEL USED TO CALCULATE DOWNWIND GROUND-LEVEL CONCENTRATIONS

I.1 EMISSIONS FROM BARGE AND TANKER TRANSFERS

Hydrocarbon emission factors for petroleum loading/unloading were based upon American Petroleum Institute (API) publication 2514A (1976) and Appendix I, Part II. A summary of average and maximum emission factors at crude oil temperatures of 70^{o}F and 120^{o}F are set forth below:

		Emission Factors (lb/1000 gal transferred)			
		Average		Maximum	
		70^{o}F	120^{o}F	70^{o}F	120^{o}F
Ship Loading:	Cleaned	0.30	0.48	0.33	0.56
	Uncleaned	0.79	0.97	0.83	1.05
	Average	0.55	0.73	0.58	0.81
Ship Ballasting:	Cleaned	0.17	0.17	0.17	0.17
	Uncleaned	0.66	0.66	0.66	0.66
	Average	0.42	0.42	0.42	0.42

Average emission factors were based on a Reid vapor pressure (RVP) of 4 psia, while maximum emission factors were based on a RVP of 5 psia. The crude oil temperature was assumed to be 70^{o}F during fill and 120^{o}F during withdrawal operations. The specific emission factors used for the transfer operations in Section 4.3.2.3 (Table 4.3-1) are as follows (lb/1000 gal):

1) Transfer of oil between VLCC and 45 MDWT tankers 25 miles off shore: 0.30 (loading) + 0.42 (ballasting) = 0.72

2) Offloading 45 MDWT tankers at DOE docks: 0 + 0.42 (ballasting) = 0.42

3) Loading 45 MDWT tankers at DOE docks: 0.73 (loading) + 0 = 0.73

Maximum emission factors used in Section 4.3.2.3 were based upon uncleaned tankers and barges. These factors are as follows (lb/1000 gal):

1) VLCC transfer to 45 MDWT tankers in the Gulf: 0.83 (loading) + 0.66 (ballasting) = 1.49

2) Loading 45 MDWT tankers at DOE docks: 1.05 (loading) + 0 = 1.05

A description of the physical and chemical basis for these emission factors is provided in Appendix I, Part II.

I.2 LOSSES IN TRANSIT

Transit losses are estimated at 0.01 percent per psia TVP per week in transit (EPA, 1976e). Transit emission factors were based on an RVP of 4 psia and are 0.0067 lb/hr/1000 gal at 70^{o}F, and 0.01674 lb/hr/1000 gal at 120^{o}F. Transit times for the SEAWAY oil distribution are as follows:

45 MDWT Tanker transit from 25 miles offshore to SEAWAY docks: 3.5 hours
45 MDWT Tanker transit from SEAWAY docks to 12 miles offshore: 2.0 hours

I.3 MODEL USED TO CALCULATE DOWNWIND GROUND-LEVEL CONCENTRATIONS

Downwind concentrations of effluents were calculated using methods recommended by the U.S. Environmental Protection Agency (Turner, 1969).

The equation used for "worst case" concentrations (averaging periods up to 24 hours) is:

$$\chi = \frac{Q \times 10^6}{\pi \sigma_y \sigma_z u} \exp\left[-\frac{1}{2}\left(\frac{H}{\sigma_z}\right)^2\right] \qquad (1)$$

where: χ = downwind concentration ($\mu g/m^3$)
Q = effluent source term (g/sec)
σ_y = horizontal dispersion coefficient (m)
σ_z = vertical dispersion coefficient (m)
u = wind speed (m/sec)
H = stack height (m)

Except for storage tank, brine pond and construction vehicle emissions, continuous point source release was assumed. Ground-level release (H=0) was assumed except for storage tank and power plant emissions. In addition, the model is based upon the following assumptions: The effluents are normally distributed along the plume centerline; there is no removal of pollutants from the plume; and there is complete reflection at the ground. Worst-case assumptions were for stability class "D" and a wind speed of 1.5 meters per second (m/sec) except two m/sec offshore. These conditions occur very infrequently at the site, particularly for durations longer than about one hour.

Values calculated by Equation 1 are peak concentrations assumed to be 10-minute averages. Extrapolation of the peak concentrations to various averaging periods up to 24 hours are determined by a power law correction (Turner, 1969). The equation used is:

$$\chi(t) = \chi(10\text{-minute}) \times \left(\frac{t}{10}\right)^{-0.17} \qquad (2)$$

where t is the averaging interval in minutes.

Equation 2 is applicable only when the average wind direction is constant. Therefore, extrapolation confidence is much less for 24 hours than for 1 hour.

The equation used for annual average concentrations is:

$$\chi = \sum_i \frac{2.032 \times Q}{u_i \sigma_z X} f_i \times 10^6 \exp\left[-\frac{1}{2}\left(\frac{H}{\sigma_z}\right)^2\right] \qquad (3)$$

where: χ = annual average concentration ($\mu g/m^3$)

X = downwind distance (m)

u_i = wind speed for speed class i (m/sec)

f_i = fraction of the time the wind is blowing in the most frequent wind direction sector in wind speed class i.

and Q, σ_z, and H are as defined for equation (1) above.

Based upon the Galveston wind rose (USDC, 1973), the values of u_i and f_i are as follows:

u_i (m/sec)	f_i (%)
1.08	0.72
2.62	2.20
4.48	6.35
6.69	4.29
9.47	0.59
13.00	0.04

The wind speed for a given wind speed class was taken to be the average speed for that class independent of wind direction. Values of f_i above are for south winds, the most frequent wind direction at Galveston.

Since the storage tanks and construction vehicles are multiple point sources, an area source correction was applied. To allow for an area source, a virtual distance X_1 is found that approximates the distance required for a point source to disperse into an area equivalent to that of the area source. The total distance $(X + X_1)$ is then used to determine revised dispersion coefficients (σ_y and σ_z). To maximum storage tank calculations, the wind was assumed to blow parallel to the longer axis of the tanks.

APPENDIX I
Part II
DESCRIPTION OF THE PHYSICAL AND CHEMICAL BASIS FOR EMISSIONS FROM MARINE VESSEL TRANSFER OF CRUDE OIL

I.1 INTRODUCTION

Ships and barges will be used to deliver crude oil to and from the marine terminals for the Strategic Petroleum Reserve (SPR) facility. Hydrocarbon emissions are generated at marine terminals when volatile hydrocarbon liquids are either loaded onto or unloaded from ships and barges.

The magnitude of crude oil transfer emissions are dependent on many factors. Industry testing programs have been conducted recently to evaluate the interrelationship of these and other important factors in developing up-to-date emission factors for ship and barge loading and ballasting emissions. Most of those studies completed have developed emission factors for gasoline. Crude oil transferring operations are under study by the Western Oil and Gas Association (WOGA) (Chevron Research Co., 1976).

This appendix evaluates the existing emission data and proposes an analytical procedure for estimating the probable crude oil emission factors for the SPR facility.[a]

Section I.2 presents the general nature and characteristics of marine transfer emissions. Sources testing data compiled by many industry sources concerning marine transfer emissions are presented in Section I.3. Description of a proposed procedure and assumption required to estimate emission factors for crude oil are presented in Section I.4. The final section concludes the emission factor analysis and presents a summary of emission factors proposed to be used for the SPR facility.

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[a]This appendix derives emission factors for crude handling operations which represent a reduction in emission factors presented in earlier DOE environmental reports. The results reported here represent the best approximations possible with currently existing data.

I.2 EMISSION SOURCES AND CHARACTERISTICS

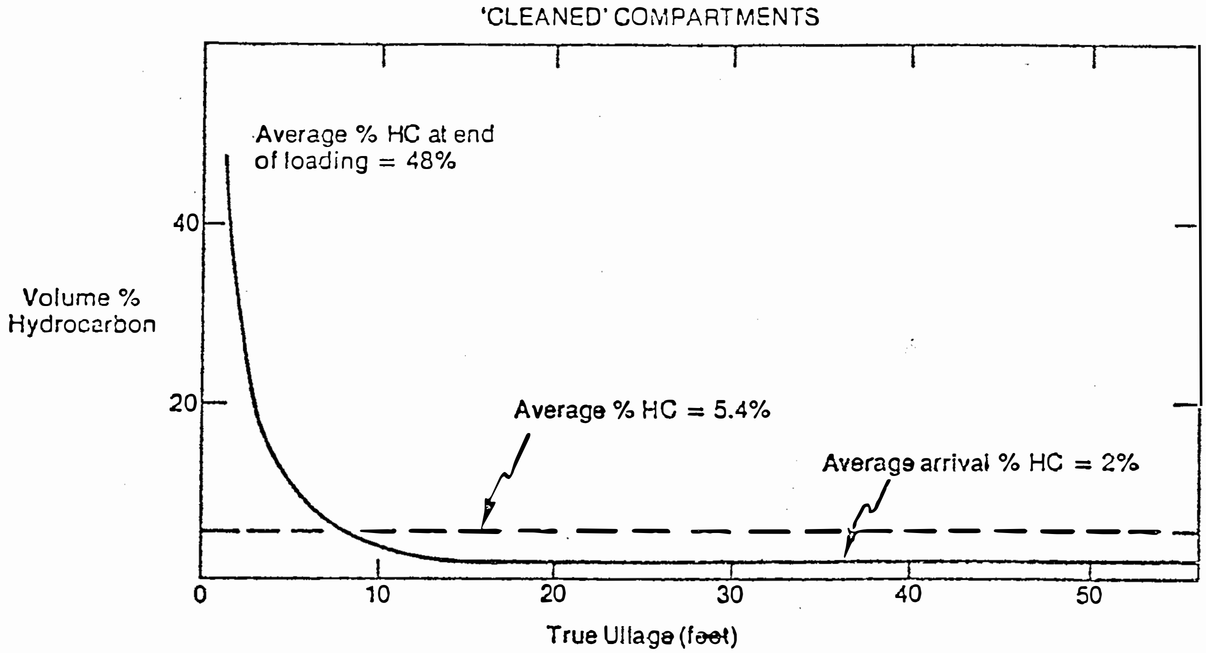
I.2.1 Loading Emissions

Loading emissions are attributable to the displacement to the atmosphere of hydrocarbon vapors residing in empty vessel tanks by volatile hydrocarbon liquids being loaded into the vessel tanks. Loading emissions can be separated into (1) the arrival component and (2) the generated component. The arrival component of loading emissions consists of hydrocarbon vapors left in the empty vessel tanks from previous cargos. The generated component of loading emissions consists of hydrocarbon vapors evaporated in the vessel tanks as hydrocarbon liquids are being loaded.

The arrival component of loading emissions is directly dependent on the true vapor pressure of the previous cargo, the unloading rate of the previous cargo, and the cruise history of the cargo tank on the return voyage. The cruise history of a cargo tank may include heel washing, ballasting, butterworthing, vapor freeing, or no action at all.

The generated component of loading emissions is produced by the evaporation of hydrocarbon liquid being loaded into the vessel tank. The quantity of hydrocarbons evaporated is dependent on both the true vapor pressure of the hydrocarbons and the loading and unloading practices. The loading practice which has the greatest impact on the generated component is the loading and unloading rate.

A typical profile of gasoline concentration in a ship tank during loading is presented in Figure I-1 (American Petroleum Institute, 1976). As indicated in the figure, the hydrocarbons present throughout most of the vessel tank vapor space are contributed to by the arrival vapor component and the concentration is almost uniform. There is a sharp rise in hydrocarbon vapor concentration just above the liquid surface. This is the generated component. The generated component, also called a "vapor blanket," is attributable to evaporation of the hydrocarbon liquid.



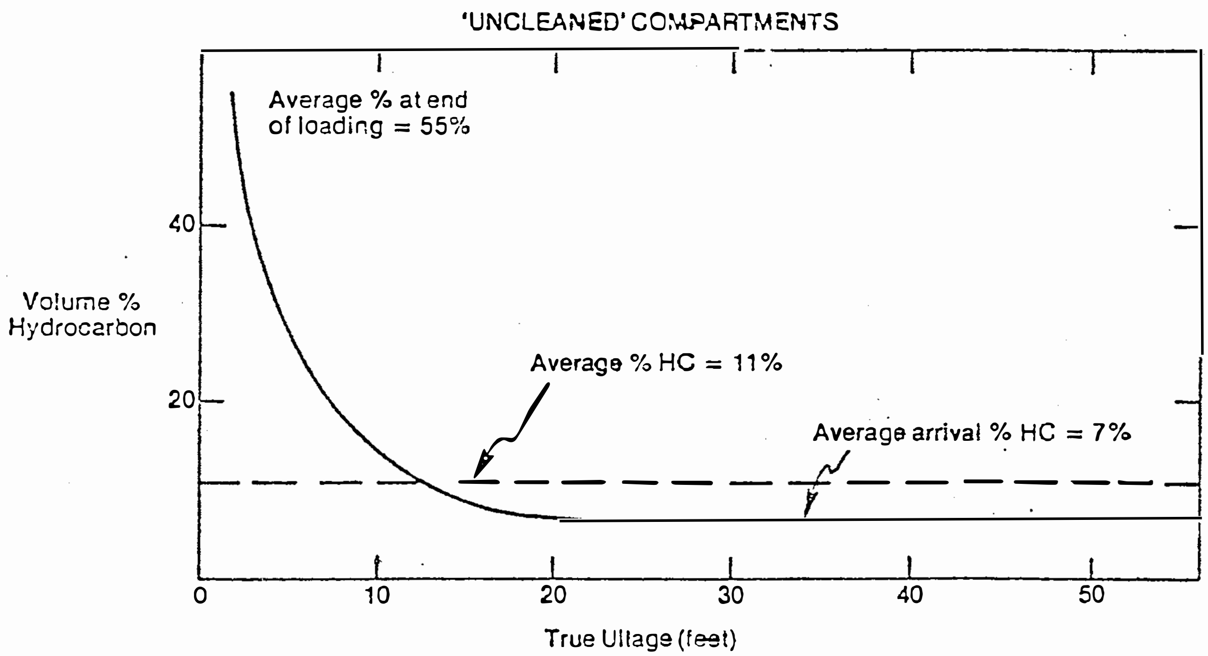


FIGURE I-1 Typical ship emission profiles.

From Figure I-1 it is apparent that for large vessels with 55 foot ullages,[a] the average hydrocarbon concentration of vapors vented during loading operations is primarily dependent on the arrival component. For smaller vessels such as barges with 12 foot ullages, the average hydrocarbon concentration in the vented loading vapors is dependent on both the generated component and the arrival component.

I.2.2 Unloading Emissions

Unloading emissions are hydrocarbon emissions displaced during ballasting operations at the unloading dock subsequent to unloading a volatile hydrocarbon liquid such as gasoline or crude oil. During the unloading of a volatile hydrocarbon liquid, air drawn into the emptying tank absorbs hydrocarbons evaporating from the liquid surface. The greater part of the hydrocarbon vapors normally lies along the liquid surface in a vapor blanket. However, throughout the unloading operation, hydrocarbon liquid clinging to the vessel walls will continue to evaporate and to contribute to the hydrocarbon concentration in the upper levels of the emptying vessel tank.

Before sailing, an empty marine vessel must take on ballast water to maintain trim and stability. Normally, on vessels that are not fitted with segregated ballast tanks, this water is pumped into the empty vessel tanks. As ballast water enters tanks, it displaces the residual hydrocarbon vapors to the atmosphere generating the so termed "unloading emissions."

I.2.3 Parameters Affecting Emissions

Emission testing results indicate that many factors affect the magnitude of crude oil loading and unloading emissions. Due to the interrelated nature of these parameters, it is difficult to quantify the emission impacts. This section qualitatively presents the effects of the following parameters on marine loading and unloading emissions:

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[a]The term "ullage" refers to the distance between the cargo liquid level and the rim of the ullage cap.

- o loading and unloading rate
- o true vapor pressure
- o cruise history
- o previous cargo
- o chemical and physical properties

I.2.3.1 Loading and Unloading Rate

During the loading operation, the initial loading and unloading rate has a significant effect on hydrocarbon emissions due to the splashing and turbulence caused by higher initial loading or withdrawing rates. This splashing and turbulence results in rapid hydrocarbon evaporation and the formation of a vapor blanket. By reducing the initial velocity of entering or withdrawing rates, it is possible to reduce the turbulence and consequently, to reduce the size and concentration of the vapor blanket. Slow final loading rate can also lower the quantity of emissions. This is because when the hydrocarbon level in a marine vessel tank approaches the tank roof, the action of vapors flowing towards the ullage cap vent begins to disrupt the quiescent vapor blanket. Disruption of the vapor blanket results in noticeably higher hydrocarbon concentrations in the vented vapor (Environmental Protection Agency, 1976).

I.2.3.2 True Vapor Pressure

The true vapor pressure (TVP) of a hydrocarbon liquid has a marked impact on the hydrocarbon content of its loading and unloading emissions. TVP is an indicator of a liquid's volatility and is a function of the liquid's Reid Vapor Pressure (RVP) and temperature. Compounds with high TVP exhibit high evaporation rates and consequently, contain high hydrocarbon concentrations in their loading and ballasting vapors. The monographs presented in Figures I-2 and I-3 correlate the TVP for crude oil and gasoline. The RVP of gasoline loaded in the Houston-Galveston area range from 9.5 to 13.6 psia in the winter season, while the RVP of crude oils unloaded normally range from 2 to 7 psia. For the purpose of assessing a SPR facility, the crude oil is assumed to have a maximum RVP of 5 psia and an average RVP of 4 psia at a temperature of 70^{o}F.

I.2.3.3 Cruise History

The cruise history of a marine vessel includes all of the activities which a cargo tank experiences during the voyage prior to a loading or

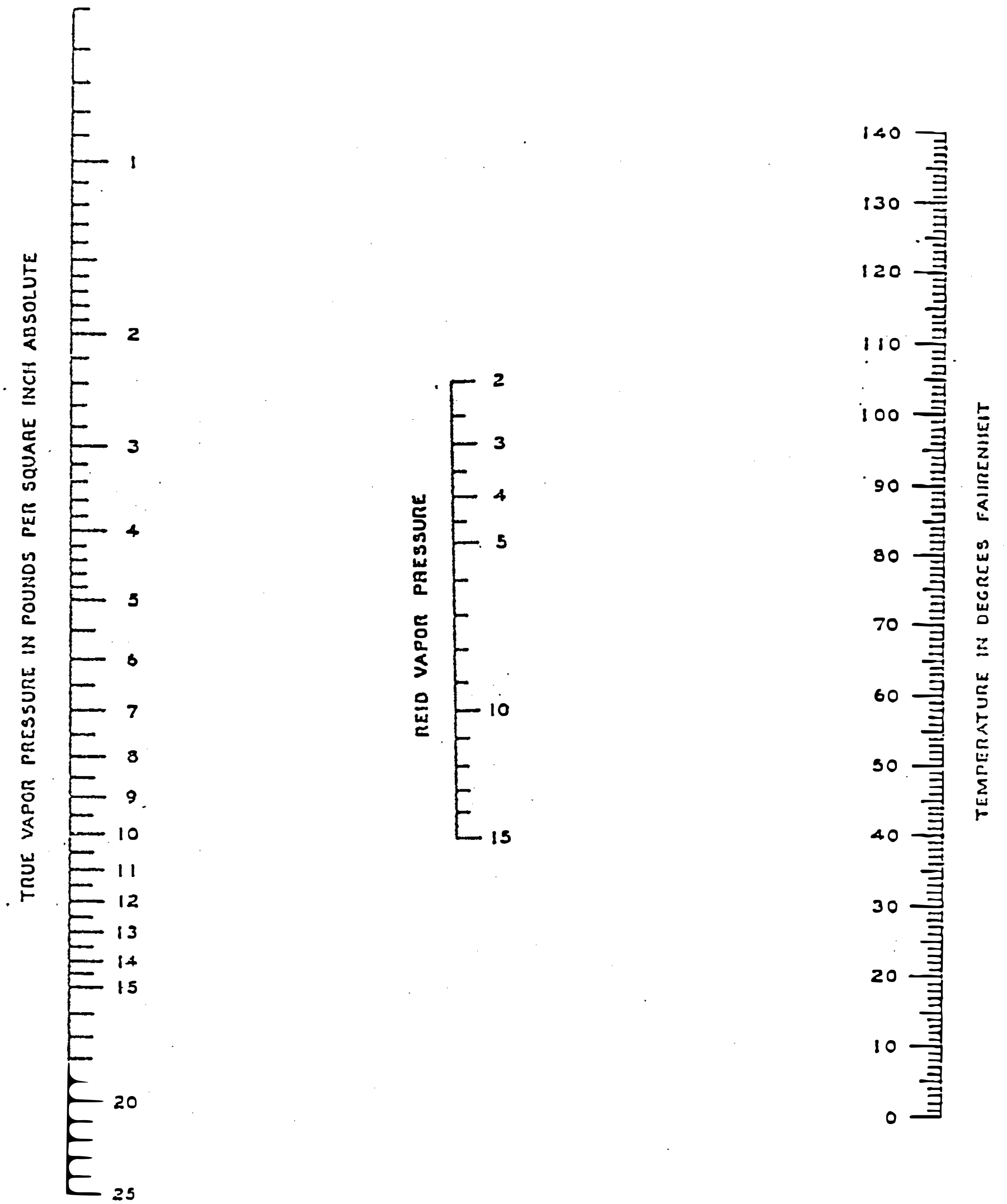

FIGURE I-2 Vapor pressures of crude oil.

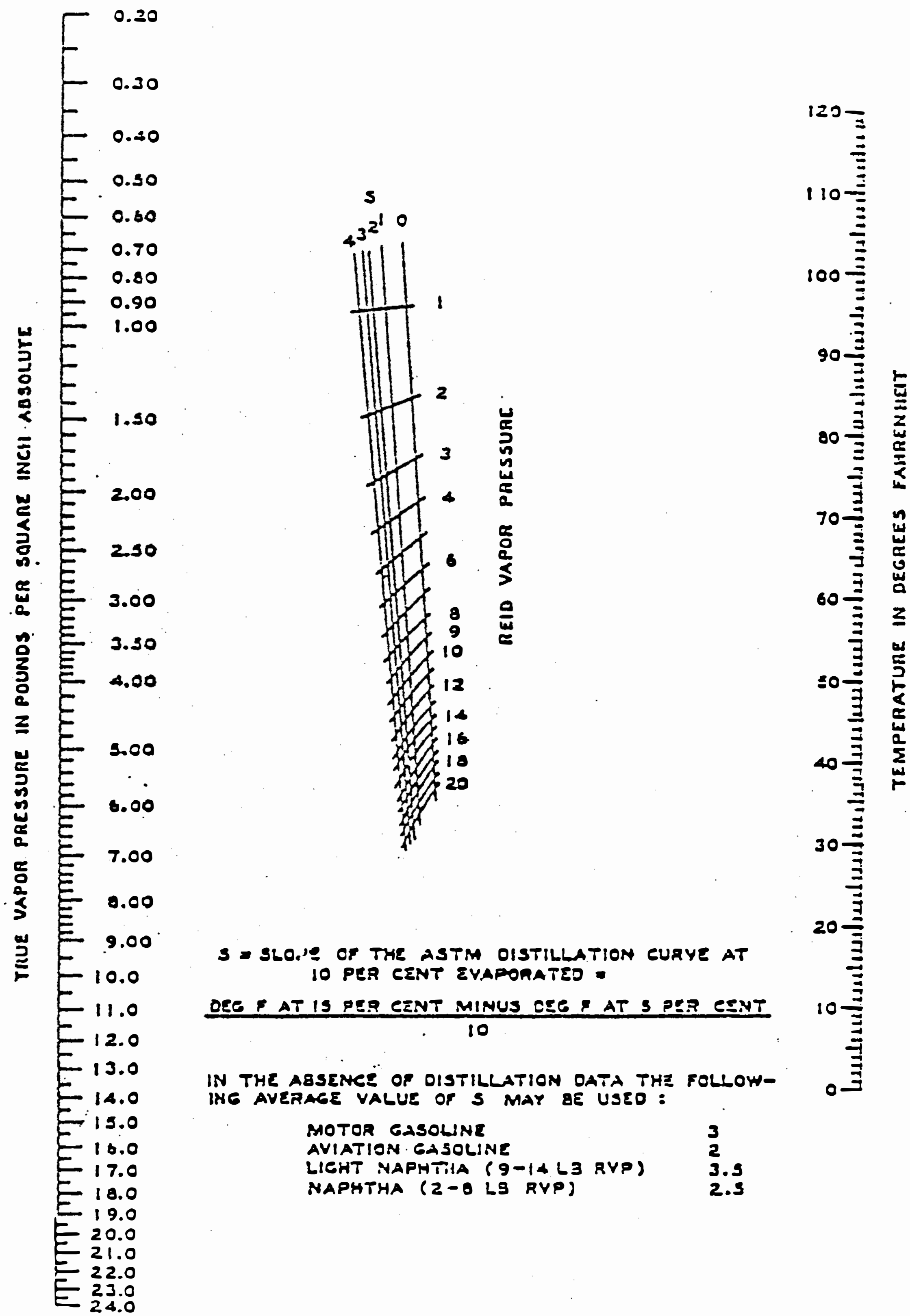

FIGURE I-3 Vapor pressures of gasolines and finished petroleum products.

unloading operation. Examples of significant cruise history activities are ballasting, heel washing, butterworthing, and gas freeing. Cruise Cruise history impacts marine transfer emissions by directly affecting the arrival vapor component. Barges normally do not have significant cruise histories because they rarely take on ballast and do not usually have the manpower to clean cargo tanks.

Ballasting is the act of partially filling empty cargo tanks with water to maintain a ship's stability and trim. Recent testing results indicate that prior to ballasting, empty cargo tanks normally contain an almost homogeneous concentration of residual hydrocarbon vapors. When ballast water is taken into the empty tank, hydrocarbon vapors are vented, but the remaining vapors not displaced retain their original hydrocarbon concentration. Upon arrival at a loading dock, a ship discharges its ballast water and draws fresh air into the tank. The fresh air dilutes the arrival vapor concentration and lowers the effective arrival vapor concentration by an amount proportional to the volume of ballast used. Although ballasting practices vary from vessel to vessel, the average vessel is ballasted approximately 40 percent.

The heel of a tank is the residual puddles of hydrocarbon liquids remaining in tanks after emptying. These residual liquids will eventually evaporate and contribute to the arrival component of subsequent vessel-filling vapors. By washing out this heel with water, AMOCO Oil Company found that they were able to reduce the hydrocarbon emissions from subsequent filling operations from 5.7 volume percent to 2.7 volume percent hydrocarbons (Environmental Protection Agency, 1976). Butterworthing is the washing down of tank walls in addition to washing out tank heels. Butterworthing also reduces loading emissions by reducing the arrival component concentration. The hydrocarbon liquids washed from the tanks are stored in a slops tank for dosposal onshore (Environmentla Protection Agency, 1976).

In addition to heel washing and butterworthing, marine vessels can purge the hydrocarbon vapors from empty and ballasted tanks during the voyage by several gas freeing techniques which include air blowing and emission factor (lb/1000 gal) is derived from the average HC volume concentration. The hydrocarbon volume concentration is then converted into a total hydrocarbon mass by multiplying an average vapor molecular weight and a correction factor accounting for vapor generation factor. These are:

$$H_f = \frac{Xv}{100} \quad \frac{K.W_m}{V_k} \quad \frac{100+F}{100} \qquad (1)$$

and

$$F = \frac{(1-X_T) \quad \frac{U_i}{U_i-U_f} \quad -(1-X_r) \quad \frac{U_i}{U_i-U_f}}{(1 - X_v)} \quad -1 \qquad (2)$$

where:

H_f = hydrocarbon emission factors, lb/1000 gal

X_v = volumetric average of HC concentration of vented vapor, percent

K = constant, 133.7 ft^3/1000 gal

W_m = molecular weight of HC vapor, lb/lb-mole

V_k = molar volume of perfect gas, 379.44 ft^3/lb mole at STP conditions

F = vapor generation factor, see Equation (3)

X_T = volumetric average HC concentration of arrival vapor, percent

X_r = volumetric average HC concentration of remaining vapor, percent

U_i = total tank depth, ft

U_f = final ullage, ft

According to API calculation, a maximum volume increase (vapor generation factor F) of 6 percent for both ships and barge was determined. Thus, if we combine the constants K and V_k with a conservative value of F equivalent to 6 percent, equation (1) can be simplified to:

$$H_f = 0.3735 \; . \; (X_v) \; . \; (W_m) \qquad (3)$$

removal of ullage dome covers. A combination of tank washing and gas freeing will effectively remove the arrival component of loading emissions (Environmental Protection Agency, 1976).

I.2.3.4 Previous Cargo

The previous cargo conveyed by a tanker also has a direct impact on the arrival component of loading emissions. Cargo ships which carried nonvolatile liquids on the previous voyage normally return with low arrival vapor concentration. EXXON Oil Company tests conducted in Baytown, Texas indicated that the arrival component of empty uncleaned cargo tanks which had previously conveyed fuel oil ranged from 0 volume percent to 1 volume percent hydrocarbons. Cargo tanks with the same cruise history which had previously conveyed gasoline, exhibited hydrocarbon concentrations in the arrival vapors which ranged from 4 percent (by volume basis) to 30 percent and averaged 7 percent (Environmental Protection Agency, 1976).

I.2.3.5 Chemical and Physical Properties

The chemical composition and molecular weight of crude oil vapors will vary over a wide range. The typical vapor consists predominantly of C_4 and C_5 compounds. The molecular weight ranges from 45 to 100 pounds per pound mole with an average of approximately 70.

I.3 INDUSTRY EMISSION TESTING RESULTS

The petroleum industry has been involved in test programs to quantify the hydrocarbon emissions from gasoline and crude oil transfer operations at marine terminals. Table I-1 summarizes the test programs which have been conducted by the petroleum industry. The industry programs have included motor gasoline, aviation gasoline, and crude oil loading onto tankers, barges, and ocean barges. Well over 200 vessel tanks were sampled in these programs. The petroleum industry tests were primarily conducted between 1974 and 1975 in the Houston-Galveston area. Tests have also been conducted on the California Coast and in the Great Lakes area (Environmental Protection Agency, 1976).

I.4 PROPOSED EMISSION FACTOR CALCULATING PROCEDURES

The emission factor calculation procedure, suggested in API publication 2514A for loading operations are used. In this method, the total mass

TABLE I-1 Summary of petroleum industry testing programs on marine loading emissions.

Company	Types of Marine Testing	Location	Date	Extent of Testing	Emission Factors
WOGA	tanker loading and ballasting emissions for crude oil and natural gasoline	Ventura County Union Oil Terminal Getty Oil Terminal California	May 1976 (tests are ongoing)	6 tests to date	preliminary data indicates that emissions from loading a nonvolatile crude into ballasted tanks which previously carried more volatile crude and not gasoline are 0.9 to 1.0 lb/1000 gallons
EXXON	primarily gasoline loading, but also averages and crude loading	Exxon Terminal Baytown Texas Karg Island, Iran	winter 1974-1975 summer 1975	100 ship tests 30 barge tests	**Gasoline Loading** tanker - gas free 3.24 vol % tanker - ballasted 6.96 vol % tanker - uncleaned 10.26 vol % average Exxon tanker 6.41 vol % (1.47 lb/mgal) ocean barge -gas free 5.69 vol % ocean barge -ballasted 9.08 vol % ocean barge -uncleaned 14.40 vol % avg. EXXON ocean barge 11.71 vol % (2.66 lb/mgal) barge 18.35 vol % (4.14 lb/mgal) **Aviation Gasoline Loading** tanker - gas free 1.63 vol % tanker - unclean (av. gas prev.) 6. 65 vol % tanker - unclean (no gas prev.) 10.64 vol % average EXXON tanker 5.35 vol % (1.47 lb/mgal) average military tanker 4.13 vol % (1.13 lb/mgal) barge 18.35 vol % (4.25 lb/mgal) **Weighted Average Dock** 1.8 lb/mgal Also have a TVP dependent correlation (see text)
American Petroleum Institute	motor gasoline loading	predominantly in Houston-Galveston area	1974-1976		clean tankers 1.3 lb/mgal clean barges 1.2 lb/mgal uncleaned tankers 2.5 lb/mgal uncleaned barges 3.8 lb/mgal
Arco	motor gasoline loading of tankers	Houston Refinery	Nov. 1974, Feb. and April 1975	11 tests	**Gasoline Loading on Tanker** fast load, low TVP, clean 2.1 vol % (0.4 lb/mgal) fast load, med TVP, clean 2.6 vol % (0.5 lb/mgal) slow load, high TVP, clean 4.2 vol % (0.9 lb/mgal) slow load, high TVP, part clean part lcean 6.9 vol % (1.5 lb/mgal) avg. ARCO tanker 3.9 vol % (0.84 lb/mgal)
AMOCO	primarily motor gasoline loading	Whiting, Ill	2/26/74-7/22/75	40-50 tests	none developed
	crude barge unloading	Texas City, Texas	5/29/74-8/5/75	9 tests	none developed AMOCO did state that average emissions for AMOCO ship less than 10.2 vol %
Shell	gasoline loading on tanker	Deer Park, Texas	Oct. 1974	5-10 tests	none developed
British Petroleum	crude oil loading on tanker	Middle East	1973	Unknown	none developed

The total volume of HC concentration vented at loading conditions (X_v) is equal to the sum of arrival HC concentration (X_a) and the generation HC vapor concentration (X_g). Thus,

$$X_v = X_a + X_g \qquad (4)$$

Based on the above relation, EXXON has further derived the following loading emission correlation:

$$X_v = \frac{E}{V} = \frac{C}{100} + \frac{P \cdot (G - U) \cdot A}{V} \qquad (5)$$

where:

E = total volume of HC emitted at the loading condition, CF

C = arrival HC concentration, percent

V = HC liquid loaded, ft^3

P = true vapor pressure of the HC liquid, psia

A = surface area of the HC liquid, ft^2

G = HC generation coefficient value of 0.36 $ft^3/(ft^2\text{-psia})$

U = final true ullage correction in $ft^3(ft^2\text{-psia})$ from Figure I-4

Assuming $V = A\ (U_i - U_f)$, Equation (5) becomes

$$X_v = \frac{C}{100} + \frac{P \cdot (G - U)}{(U_i - U_f)} \qquad (6)$$

The EXXON correlation of equation (6) is based principally upon gasoline loading data (Environmental Protection Agency, 1976). For the loading of crude oil, SAI has proposed to adjust the first and second terms by multiplying correction factors α_1 and α_2, respectively. Thus, for crude oil ship loading operation:

$$X_v = \alpha_1 \frac{C}{100} + \alpha_2 \frac{P \cdot (G - U)}{(U_i - U_f)} \qquad (7)$$

In the above correlation, α_1 is principally affected by the characteristics of the previous cargo, whereas the value of α_2 is independent to the condition of previous cargo. For barge loading operation, it is further assumed that no

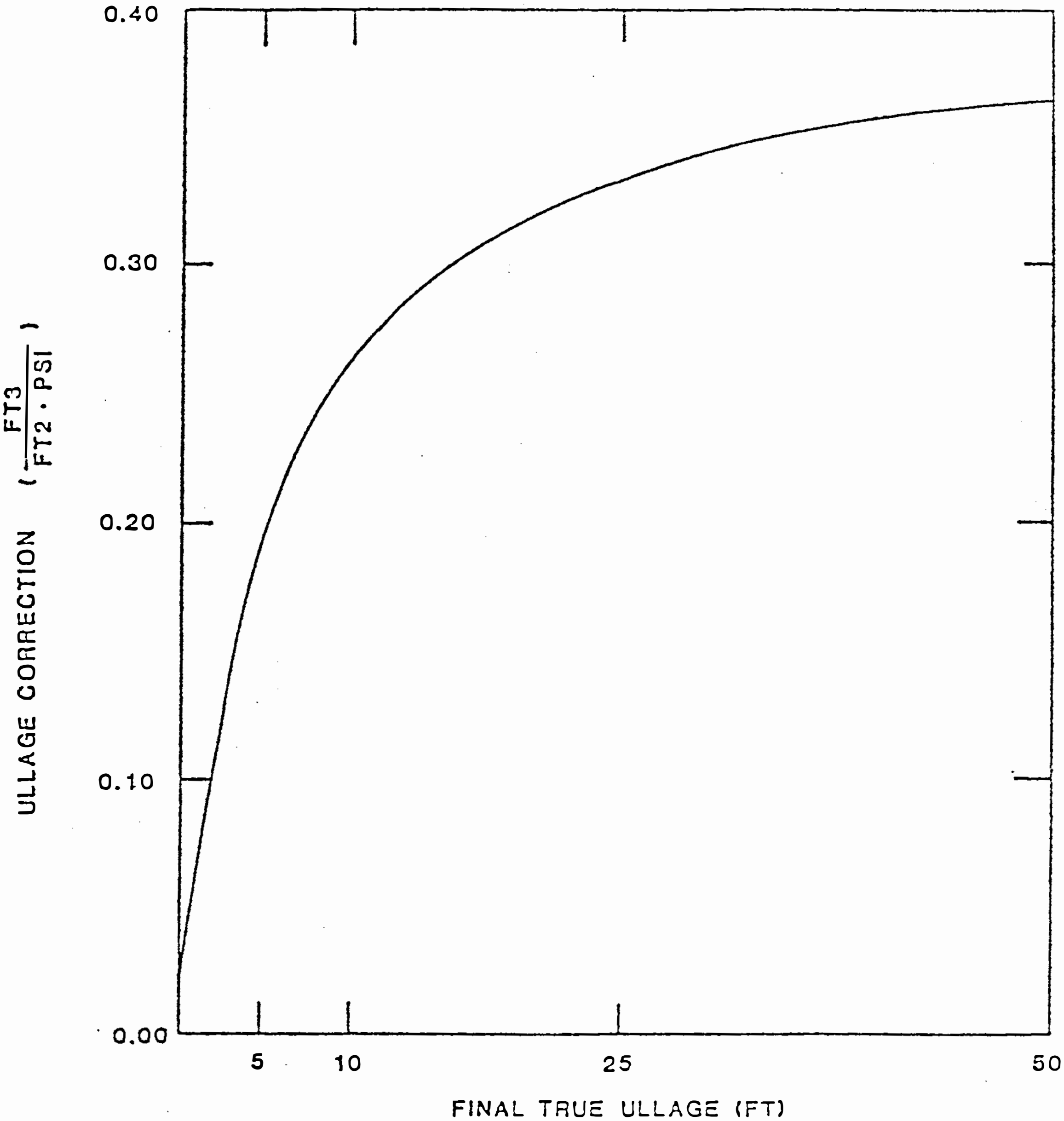

FIGURE I-4 Hydrocarbon generation coefficient, final ullage correction to the EXXON Corporation.

correction factor α_2 for vapor generation terms is necessary. That is because barge loadings are usually operated in short duration and the majority of hydrocarbon vapor generated during this period would be those volatile hydrocarbons with very light molecular weights.

Thus, the basic difference between vapor characteristics for gasoline and crude oil would be slight for a short barge loading duration.

For the purpose of SPR facility analysis, it is further assumed that no correction factor on C is necessary when previous cargo is a volatile hydrocarbon such as gasoline. Thus,

- o $\alpha_1 = 1$, when previous cargo is gasoline
- o $\alpha_1 = \alpha_2$, when previous cargo is crude oil.

The correction factor α_2 can be interpreted as the ratios of evaporation mass transfer coefficients between crude oil and gasoline. Mackay and Matsuger (1973) have correlated the mass transfer coefficient (K) based on wind tunnel studies of evaporative hydrocarbon liquids. They found that the mass transfer coefficient is inversely proportional to the vapor phase Schmidt number (S_c) as follows:

$$K = f(U \cdot A) \cdot (S_c)^{-0.67}$$

where U is wind speed, and A is the oil surface area.

The α_2 thus can be determined by:

$$\alpha_2 = \frac{K_c}{K_g} = \frac{S_c^{-0.67} \text{ crude oil}}{S_c^{-0.67} \text{ gasoline}}$$

Since the Schmidt number (S_c) is defined by the mass transport properties $\mu/\rho\mathcal{D}_{AB}$ (Bird, et al., 1960).

α_2 can then be calculated by the following equations:

$$\alpha_2 = \frac{(\mu/\rho\mathcal{D}_{AB})^{-0.67} \text{ crude oil}}{(\mu/\rho\mathcal{D}_{AB})^{-0.67} \text{ gasoline}} \tag{8}$$

and

$$\mathcal{D}_{AB} = 0.0018583 \frac{T^3 \frac{1}{M_A} + \frac{1}{M_B}}{P\sigma_{AB}^2 \Omega_{\mathcal{D},AB}} \tag{9}$$

$$\mu = 2.6693 \times 10^{-5} \frac{\sqrt{MT}}{\sigma^2 \Omega_{\mu AB}} \quad (10)$$

μ = viscosity of vapor

ρ = density of vapor

$\mathcal{D}_{AB}$ = binary diffusivity for system A (air) and B (hydrocarbon)

M_A, M_B = molecular weight of A, B, respectively

P = fluid pressure, atmosphere

σ_{AB} = collision diameter, A

$\Omega\mathcal{D}$, AB = collision integral for mass diffusivity

$\Omega\mu_{,AB}$ = collision integral for viscosity

The pertinent intermolecular properties and functions for prediction of transport properties of hydrocarbon gases at low densities are presented in Table I-2 and Table I-3, respectively. Table I-4 presents the comparative analysis of hydrocarbon vapor emitted by loading gasoline and crude oil. As can be seen, due to the difference in chemical compositions between gasoline and crude oil, the gasoline generally exhibits higher transport properties and thus results in a higher evaporation mass diffusity coefficient (i.e., 1.345 for gasoline versus 0.513 for crude oil). Based on this analysis, the value of α_2 can be determined as 0.381.

The appropriate arrival HC hydrocarbon concentration, (C), can be calculated based on API gasoline emission factors as follows:

Vessels	Arrival Conditions	Emission Factors (lb/1000 gal)	Generation Vapor $\frac{P \cdot (G - U)}{(U_i - U_f)}$, %	Calculated Arrival Vapor (C), %
Ships	Cleaned	1.3	$\frac{7.5\ (0.36-0.10)}{(55-1.5)} = 3.64$	1.71 (2.50)
	Uncleaned	2.5	3.64	6.65 (8.00)
Barges	Cleaned	1.2	$\frac{7.5\ (0.36-0.27)}{(55-12)} = 1.57$	3.37
	Uncleaned	3.8	1.57	14.10

TABLE I-2 Intermolecular parameters of hydrocarbons.

Substance	Molecular Weight M	Lennard-Jones Parameters[a]	
		σ (Å)	ϵ/κ (° K)
CH_4	16.04	3.822	137.
C_2H_2	26.04	4.221	185.
C_2H_4	28.05	4.232	205.
C_2H_6	30.07	4.418	230.
C_3H_6	42.08	—	—
C_3H_8	44.09	5.061	254.
n-C_4H_{10}	58.12	—	—
i-C_4H_{10}	58.12	5.341	313.
n-C_5H_{12}	72.15	5.769	345.
n-C_6H_{14}	86.17	5.909	413.
n-C_7H_{16}	100.20	—	—
n-C_8H_{18}	114.22	7.451	320.
n-C_9H_{20}	128.25	—	—
Cyclohexane	84.16	6.093	324.
C_6H_6	78.11	5.270	440.
Other organic compounds:			
CH_4	16.04	3.822	137.
CH_3Cl	50.49	3.375	855.
CH_2Cl_2	84.94	4.759	406.
$CHCl_3$	119.39	5.430	327.
CCl_4	153.84	5.881	327.
C_2N_2	52.04	4.38	339.
COS	60.08	4.13	335.
CS_2	76.14	4.438	488.

Source: Bird et al, 1960.

TABLE I-3 Functions for prediction of transport properties of gases at low densities.

$\kappa T/\epsilon$ or $\kappa T/\epsilon_{AB}$	$\Omega_\mu = \Omega_k$ (For viscosity and thermal conductivity)	$\Omega_{\mathscr{D},AB}$ (For mass diffusivity)	$\kappa T/\epsilon$ or $\kappa T/\epsilon_{AB}$	$\Omega_\mu = \Omega_k$ (For viscosity and thermal conductivity)	$\Omega_{\mathscr{D},AB}$ (For mass diffusivity)
			2.50	1.093	0.9996
0.30	2.785	2.662	2.60	1.081	0.9878
0.35	2.628	2.476	2.70	1.069	0.9770
0.40	2.492	2.318	2.80	1.058	0.9672
0.45	2.368	2.184	2.90	1.048	0.9576
0.50	2.257	2.066	3.00	1.039	0.9490
0.55	2.156	1.966	3.10	1.030	0.9406
0.60	2.065	1.877	3.20	1.022	0.9328
0.65	1.982	1.798	3.30	1.014	0.9256
0.70	1.908	1.729	3.40	1.007	0.9186
0.75	1.841	1.667	3.50	0.9999	0.9120
0.80	1.780	1.612	3.60	0.9932	0.9058
0.85	1.725	1.562	3.70	0.9870	0.8998
0.90	1.675	1.517	3.80	0.9811	0.8942
0.95	1.629	1.476	3.90	0.9755	0.8888
1.00	1.587	1.439	4.00	0.9700	0.8836
1.05	1.549	1.406	4.10	0.9649	0.8788
1.10	1.514	1.375	4.20	0.9600	0.8740
1.15	1.482	1.346	4.30	0.9553	0.8694
1.20	1.452	1.320	4.40	0.9507	0.8652
1.25	1.424	1.296	4.50	0.9464	0.8610
1.30	1.399	1.273	4.60	0.9422	0.8568
1.35	1.375	1.253	4.70	0.9382	0.8530
1.40	1.353	1.233	4.80	0.9343	0.8492
1.45	1.333	1.215	4.90	0.9305	0.8456
1.50	1.314	1.198	5.0	0.9269	0.8422
1.55	1.296	1.182	6.0	0.8963	0.8124
1.60	1.279	1.167	7.0	0.8727	0.7896
1.65	1.264	1.153	8.0	0.8538	0.7712
1.70	1.248	1.140	9.0	0.8379	0.7556
1.75	1.234	1.128	10.0	0.8242	0.7424
1.80	1.221	1.116	20.0	0.7432	0.6640
1.85	1.209	1.105	30.0	0.7005	0.6232
1.90	1.197	1.094	40.0	0.6718	0.5960
1.95	1.186	1.084	50.0	0.6504	0.5756
2.00	1.175	1.075	60.0	0.6335	0.5596
2.10	1.156	1.057	70.0	0.6194	0.5464
2.20	1.138	1.041	80.0	0.6076	0.5352
2.30	1.122	1.026	90.0	0.5973	0.5256
2.40	1.107	1.012	100.0	0.5882	0.5170

[a] Taken from J. O. Hirschfelder, R. B. Bird, and E. L. Spotz, *Chem. Revs.*, 44, 205 (1949).

TABLE I-4 Comparison of chemical compositions and mass transport properties between gasoline and crude oil.

Chemical Composition, Volume % of Loading Vapors	Gasoline[a]	Crude Oil[b]
$C_1 + C_2$	0.02	0.12
C_3	0.02	0.15
C_4	2.36	1.33
C_5	1.07	2.05
C_6	0.19	0.63
C_7	0.19	0.32
C_8	0.15	0.03
C_9	---	0.02
C_{10}	---	0.01
C_{11}	---	0.01
Air	96.0	95.35
$\Sigma\, \epsilon/K$	302.1	331.6
$\Sigma\, KT/\epsilon$	1.039	1.055
$\Omega_{D,AB}$	1.42	1.40
$\Omega_{\mu,AB}$	1.56	1.54
σ_A (Air)	3.681	3.681
σ_B	5.28	5.21
σ_{AB}	4.48	4.45
M_B	67	77
μ	6.919×10^{-4}	7.516×10^{-4}
D_{AB}	0.36	0.081
ρ	2.99×10^{-3}	3.43×10^{-3}
$(\mu/\rho D_{AB})^{-0.67}$	1.345	0.513

[a] Shell Oil Company, Ship Valley Forge, test date 10/19/74
[b] Avila Terminal, Lion of California, test data 5/8/76

Source: Environmental Protection Agency, 1976.

The calculated arrival HC vapor concentration for ships using API emission factor seems to be in close agreement with the EXXON reported value (value in parentheses).

By substituting the appropriate values of C, α_2, and P, Equation (7) also compares well with the latest available WOGA test data. The WOGA test on September 5, 1976 estimated the overall crude oil emission factor to be 0.62 lb/1000 gallons which falls in the middle of the calculated emission factors. The calculated emission factors using Equation (7) are 0.35 lb/1000 gallons and 0.85 lb/1000 gallons for cleaned and uncleaned ships, respectively.

Similarly, the emission from ship ballasting operation can be correlated based on arrival vapor concentrations during loading operations. Since the ballasting potentially dilutes tank arrival concentration by approximately the same percentage as that of ballasting volume, for a ship with 40 percent ballasting volume the emission factor can be calculated by dividing the arrival HC concentration (C) by 0.4.

I.5 CONCLUSION

A modified analytical procedure based on API and EXXON gasoline data enables quantitative estimation of hydrocarbon emission factors from crude oil transferring operations under various arrival conditions. The procedure employs correction factors to both arrival and generation components of the hydrocarbon vapors concentration previously derived from gasoline data. An emission reduction factor of 0.38 is derived for crude oil when comparing the evaporation mass diffusivity of crude oil with gasoline. The final hydrocarbon emission factors for crude oil loading operations are summarized in Table I-5. As can be seen, the average emission factors from ship loading operations range from 0.55 to 0.58 lb/1000 gallons. Similar hydrocarbon emission factors range from 1.01 to 1.06 lb/1000 gallons for barge crude oil loading operations. The ballasting emission factors are calculated to range from 0.17 to 0.66 lb/1000 gallons.

TABLE I-5 Summary of maximum and average hydrocarbon emission factors (lb/1000 gallon) for crude oil transport operation.

essels	Arrival[a] Conditions	Maximum Emission Factor[b]		Average Emission Factor[c]	
		Previous Cargo		Previous Cargo	
		Gasoline	Crude Oil	Gasoline	Crude Oil
Ship Loading					
	Cleaned	--	0.33	--	0.30
	Uncleaned	1.90	0.83	1.86	0.79
	Average	--	0.58	--	0.55
Barge Loading					
	Cleaned	--	0.52	--	0.48
	Uncleaned	3.87	1.59	3.83	1.54
	Average	--	1.06	--	1.01
Ship Ballasting					
	Cleaned	--	0.17	--	0.17
	Uncleaned	--	0.66	--	0.66
	Average	--	0.42	--	0.42

---

[a] Average condition lies between cleaned and uncleaned conditions. The cleaned is defined as the arrival conditions where vessels had been subjected to any cleaning process prior to loading, as well as compartments which had previously contained a nonvolatile hydrocarbon.

[b] Based on RVP = 5.0 and temperature of 70^{o} F.

[c] Based on RVP = 4.0 and temperature of 70^{o} F.

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APPENDIX J

OIL TEMPERATURES DURING WITHDRAWAL

APPENDIX J

OIL TEMPERATURES DURING WITHDRAWAL

J.1 INTRODUCTION

The temperature of the oil being handled is an important factor in determining the emission of hydrocarbon vapors from storage tanks, tankers and barges in transit, and during transfers to and from carrier vessels. The oil temperature during oil fill operations will tend to average about 70^{o}F, the average ambient temperature. During storage, however, heat transfer from the salt dome structure to the oil in the cavities could heat the oil to temperatures approaching that of the rock salt. Therefore, the hydrocarbon emissions from this higher temperature oil will be greater during withdrawal than during fill.

To determine the hydrocarbon emission factors during oil withdrawal, estimates must be made of the heat transfer rates during oil movement. The temperature of the storage cavity walls is a critical parameter; temperatures may range from 90^{o} to 100^{o}F at 500 foot depths to 150^{o}F at 4000 to 5000 foot depths. The oil in storage, which is able to circulate in free convection, will tend to reach the temperature of the warmest portion of the cavity. Heat transfer analyses to estimate the temperature of the oil withdrawn must consider the following: (1) heat exchange from the warm oil to the incoming raw water flowing through the fill pipe; (2) heat loss from buried pipelines during transport to the distribution terminal; and (3) frictional heating of the oil during pipeline transport. Oil temperatures calculated at terminal delivery can then be used to determine oil properties for calculation of hydrocarbon vapor losses during tank storage, tanker transfer, and tanker transit.

The following subsections develop the method used for estimating the heat transfer rates which are applied to withdrawals from the Seaway Group candidate storage sites. Controlling equations, oil properties, and physical configurations are developed and applied to the conditions of withdrawal at these sites.

J.2 PROPERTIES OF THE OIL AND BRINE

The oil is assumed to be characterized by an average U.S. crude, API 26^{o} (Perry, 1963).

Density - 316 lbm/barrel, (56.03 lbm/cu.ft.)
Specific heat - 0.45 BTU/lbm^{o}F
Thermal conductivity - 0.08 BTU/hr-ft-^{o}F.

Variation of properties with temperture and pressure can be neglected, except for viscosity. Viscosity values (Brown, 1967; Firch, 1962) are:

6 centipoise = 14.5 lbm/ft.hr. at 140^{o}F
13 centipoise = 31.5 lbm/ft.hr. at 120^{o}F
19 centipoise = 46.0 lbm/ft.hr. at 100^{o}F
30 centipoise = 72.6 lbm/ft.hr. at 80^{o}F

The brine solution is characterized as 5.1 molal, or 300 ppt salt. The heat capacity and thermal conductivity of the salt in solution may be neglected, so that the thermal properties per unit volume are equivalent to those for water.

Density - 75 lbm/cu.ft.
Thermal conductivity - 0.38 BTU/hr-ft-^{o}F
Specific heat - 0.77 BTU/lbm^{o}F = 62.4 BTU/cu.ft.^{o}F
Viscosity - 0.3 centipoise = 0.73 lbm/ft.hr.

J.3 HEAT EXCHANGE DURING OIL DISPLACEMENT

The heat exchange between the oil and displacement water can be described by standard heat transfer equations for heating or cooling of fluids flowing in tubes.

The heating of a fluid during flow between points 1 and 2 along a tube is defined by

$$WC(T_2-T_1) = h\pi DL(\Delta t) \qquad (1)$$
$$= h_L L(\Delta t)$$

where h is the heat transfer coeffiecient per unit area

h_L is the heat transfer coefficient per unit length

W is the mass flow rate

C is the specific heat

T_2, T_1 are the fluid temperatures at points 1, 2

(Δt) is the average temperature difference between the fluid and tube wall

L is the tube length

D is tube diameter or hydraulic diameter.

To simplify the problem it is noted that the potential rate of heat release or uptake into the water is much more rapid than that for oil; consequently it is assumed that the wall temperature is identical to the temperature of the water in the inner pipe. The heat exchange between oil and water is balanced:

$$W_o C_o (T_{01} - T_{02}) = W_w C_w (T_{w2} - T_{w1}) \qquad (2)$$

The average temperature differential between points 1 and 2 is:

$$(\Delta t) = 1/2\ (T_{w2} - T_{02}) + (T_{w1} - T_{01}) \qquad (3)$$

The heat transfer coefficient of the oil in turbulent flow is given by a well-known Nusselt correlation (Perry, 1963):

$$(Nu) = \frac{hD}{K} = 0.023\ (Re)^{0.8} (Pr)^{1/3} \qquad (4)$$

and for flow regimes transitional between turbulent and laminar, (Sieder & Tate, 1936)

$$(Nu) = \frac{hD}{K} = 0.027\ (Re)^{0.8} (Pr)^{1/3} (\mu/\mu_w)^{.14} \qquad (5)$$

where (Nu) is Nusselt number

(Re) is the Reynold's number $4W/\pi D\mu$

(Pr) is Prandtl number $\mu C/K$

μ_w is fluid viscosity at the wall temperature

μ,C,K are, respectively, the fluid viscosity, specific heat, and thermal conductivity.

The system of four equations with four unknowns (T_{oil}, $T_{water\ at\ exit}$, (Δt), h) is solved iteratively because the viscosity varies enough with temperature to prevent treatment as a constant.

J.4 OIL COOLING IN PIPELINE FLOW

Warm oil flowing in a pipeline in cooler soil will release heat to the soil. Davenport and Conti (1971) give an approximate formula for the heat transfer coefficient per unit length of pipeline, based upon the method of images:

$$h_p = 2\pi K_s / \ln (4H/D)$$

where K_s is the thermal conductivity of soil

H is the burial depth to pipeline centerline

D is the pipe diameter

ln refers to the natural logarithm.

The formula assumes a homogeneous soil. About 10% more heat may be dissipated to the air for shallow-buried lines, and with air and soil near temperature equilibrium. The thermal conductivity of a typyical soil (90% sand, with 10% clay) ranges from 0.7 to 1.5 BTU/hr-ft^{o}F (from dry soil at 0.7 to wet soil at 1.5) (Makowshi & Mochlinski, 1956). Thermal conductivity decreases with further water percentage increases until the mixture is sufficiently fluid to permit convective movement of the water around the pipe.

In contrast to the oil-water heat exchange in the fill pipe, where the heat transfer in the pipe wall can be neglected, the pipeline may be coated with insulating materials or concrete. Such coatings will have a thermal resistance per unit length of

$$h_i = \frac{\Pi \, DK_i}{X_i} \qquad (7)$$

where X is the coating thickness and K is the conductivity of the covering material. Typical values for coatings are:

corrosion coating X_i = 1/2 inch = .042 ft; K_i = 0.09

concrete X_i = 3 inches = 0.25 ft; K_i 0.7

Further, the oil heat transfer to the pipe wall, as given in Section J.3, must be included. An approximate value of the heat transfer coefficient, conveniently expressed per unit length of pipeline instead of per unit area, is derived from Perry (1963).

$$h_L = S\Pi \, (VD')^{0.8} / \mu^{0.467} \qquad (8)$$

where the units are selected to have the following dimensions:

V in ft/sec, D´ in inches, and μ is the viscosity in centipoise.

The reciprocals of the heat transfer coefficients, $R = \frac{1}{h}$, define thermal resistances which are additive. The cooling of the line is then given by (see equation (1)):

$$\frac{T_2 - T_1}{L} = \frac{\Delta t}{WC} \quad \Sigma R^{-1} = \frac{\Delta t}{WC} \quad \left(\frac{1}{h_L} + \frac{1}{h_i} + \frac{1}{h_p} \right)^{-1}$$

J.5 OIL FRICTIONAL HEATING IN PIPELINE FLOW

The frictional heating of the oil is a strong function of fluid velocity; it is general negligible below 5 ft/sec but significant at 10 feet/sec. The heating may be expressed by (Szilas, 1975):

$$\frac{\Delta T}{L} = \frac{\pi}{8} e \, f \, r \frac{V^3 D}{WC} \tag{9}$$

where r is the fluid density,

v is the fluid velocity,

e is a roughness factor (adding 2% to 10% to the friction)

f is the friction factor in the Blasius or Nikuradse form:

$$f = \frac{.316}{(Re)^{.25}}, \text{ for } (Re) < 10^5$$

$$\text{and } f = .0032 + \frac{.221}{(Re)^{.237}}, \text{ for } (Re) > 10^5$$

In calculating the heating in ^{o}F/mile, conversion factors of 777.6 ft-lbf per BTU and 32.2 lbm ft/sec^2 per lbf are used. The roughness factor varies from 1.02 at (Re) of 50,000, to 1.10 at (Re) of 250,000, and can be obtained from standard piping handbooks. (There is no functional expression for e).

J.6 ESTIMATION OF OIL TEMPERATURE

The following section illustrates calculations required to estimate temperatures for oil received at the terminals. The Bryan Mound storage site, and the pipeline to dock facilities at Freeport are used in the calculations detailed in this section. Section J.7 and Table J.1 summarize analogous oil temperature estimates for all Seaway Group SPR sites for oil transfer to the Seaway tank farm and the dock facilities at Freeport.

TABLE J-1. Oil Temperatures During Withdrawal

Storage Site	Oil Temperature at Depth (^{o}F)	Temperature Change During Displacement (^{o}F)	Net Temperature Change (^{o}F) During Pipeline Transfer to:		Oil Temperature (^{o}F) as Received at:	
			Seaway Tank Farm	Freeport Docks	Seaway Tank Farm	Freeport Docks
1) Bryan Mound	150	-26	-1	-1	123	123
2) Allen	150	-26	0	0	124	124
3) West Columbia	150	-26	-5	-6	119	118
4) Damon Mound	150	-26	-6	-7	118	117
5) Nash	150	-26	-6	-7	118	117

J.6.1 <u>Water-Oil Heat Exchange</u>

The fill pipe for each cavern is annular with oil in the outer annulus. The flow rate is about 5600 barrels per hour through an annulus of 143 square inches. Dimensions are ID of 19" and OD of 13-3/8" (hydraulic diameter 0.47 ft.), with a nominal length of 2500 feet. The water flows in a tubing of area 123 square inches and 12-1/2" ID.

Water flow is 2.1×10^6 lbm/hr, at 10.3 ft/sec. (Re) is 3.5×10^6. Oil flow is 1.8×10^6 lbm/hr at 8.9 ft/sec. Reynolds numbers are 11,800; 18,600; 27,200; and 59,000 at 80^0F, 100^0F, and 140^0F, respectively.

The worst case assumption of cavern temperatures is 150^0F; water intake can be expected to average 70^0F. Thus $\Delta t = 40 + 1/2\ (T_{02} - T_{W1})$, where T_{02} and T_{W1} are unknown.

The Nusselt correlation, expressed as a function of average cooling temperature differential gives:

T_2-T_1	Δt	(Nu)	(Pr)	(Re)
5.1^0F	10^0F	654	82	59,000
9.5^0F	20^0F	612	100	50,000
12.9^0F	30^0F	555	120	41,000
16.3^0F	40^0F	526	160	34,000
17.7^0F	50^0F	455	177	27,200
20.5^0F	60^0F	441	180	26,000

The solution of the problem, obtained by matching the oil exit temperature and the wall/oil differential temperature in the equation for (Δt) and the above table, gives

oil - cooled from 150^0 to 124^0 at the surface
water - heated from 70^0 to 80^0 at the salt dome cavity.

Other solutions, assuming alternate cavern temperatures, are:

- o oil cooled from 140^0 to 120^0; water heated from 70^0 to 77.5^0
- o oil cooled from 130^0 to 114^0; water heated 70^0 to 76^0
- o oil cooled from 120^0 to 107^0; water heated form 70^0 to 75^0

J.6.2 Pipeline Cooling

The pipeline conditions assumed are cover of 3 feet, moist sandy soil, and 1/2 inch of corrosion wrapping. Concrete sections are ignored over the pipeline length, although there may be substantial length of weighted sections. Maximum flow is 400 MBD in the 30" line from Bryan Mound to the dock facilities of Freeport. The resistances are:

soil: H/D = 1.4; K_s = 1.5: therefore, R = .203

wrapping: $R = \frac{x}{\pi D K_i}$ K_i = 0.09; x = 0.042; D = 2.5

therefore, R = .61

Oil internal thermal resistance at 400,000 barrels per day in the 30" line, with V = 5.7 ft/sec, is:

R = .003 at 120^{0}F

R = .004 at 100^{0}F

The total pipeline thermal resistance is thus about .268 in wet soil and 40 percent greater in dry soil. The cooling per mile for 120^{0}F oil would be 0.36^{0}F to an ambient of 70^{0}F and 0.21^{0}F for 100^{0}F oil. Cooling in dry soil would be about 40 percent less.

J.6.3 Heating in the Pipeline

With a flow of 400 MBD, velocity is 5.7 feet per second, mass flow is 5.3 x 10^6 lbm/hr,

	(Re)	(f)	(e)
80^{0}F	38,400	.0226	1.01
100^{0}F	60,700	.0201	1.02
120^{0}F	88,700	.0183	1.05

Heating is 0.07^{0}F per mile at 80^{0}F; 0.06^{0}F per mile at 100^{0}F and 120^{0}F.

J.6.4 Summary of Thermal Effects

If oil at 150^{0}F is released from Bryan Mound, predominantly from reservoirs of 10 MMB capacity, it will reach the surface at 124^{0}F (Section J.6.1). In flowing to the docks at 400,000 B/D, it will cool in wet soils at a net rate of .32^{O}F per mile (.38 (Section J.6.2) - .06 (Section J.6.3)), reaching the docks at about 123^{O}F. The oil flowing to the Seaway tank farm at 667,000 B/D in wet soils will cool at a net rate of .18^{O}F per mile (.24^{O}F - .06^{O}F/mile), also arriving at about 123^{O}F.

For oil in storage at 120^{O}F, the temperature at the surface will be 107^{O}F, and approximately that same temperature will be maintained at the delivery points four miles away.

J.7 SUMMARY OF OIL TEMPERATURE ESTIMATES FOR SEAWAY GROUP STORAGE SITES

Controlling equations, oil properties, and physical configurations applicable to oil withdrawal at the Seaway Group storage sites were developed in Sections J.1 through J.5. Their application to a particular site (Bryan Mound) was illustrated in Section J.6.

This section summarizes the results of the application of the methodology developed in Sections J.1 through J.5 to each of the five SPR storage sites. Table J.1 presents the temperatures estimated for oil received at the Seaway tank farm and at the Freeport docks from each of the storage sites. Oil temperatures for the Bryan Mound storage site are summarized in Section J.6.4.

At the Allen dome storage site, cooling during displacement to the surface will fall in the same range as for Bryan Mound. However, the frictional heating rate in the oil line is barely less than the cooling rate in wet soil, the net heating rate would be about .07^{O}F/mile (.21-.14) at 120^{O}F, but would be negligible at 140^{O}F. The oil temperature could rise 1/2^{O}F in transit for flow at 107^{O}F. At both Damon Mound and Nash, oil cooling in the pipeline will range from about .18 to .28^{O}F/mile in wet soils, .1 to .15^{O}F/mile in dry soils. This will reduce the arrival temperature by 3 to 6^{O}F below the surface exit temperatures, and by 4 to 7^{O}F at the docks.

Oil cooling rates for West Columbia dome would be approximately the same as for Nash and Damon Mound. The shorter pipeline distances would reduce the temperature drop by 1^{O} to 2^{O} for oil and by 3^{O} to 4^{O} for brine.

J.8 REFERENCE

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APPENDIX K

COMMENTS RECEIVED

APPENDIX K

COMMENTS RECEIVED

K.1 DRAFT ENVIRONMENTAL IMPACT STATEMENT FOR SEAWAY GROUP SALT DOMES (DES 77-10, September 1977)

K.2 DRAFT SUPPLEMENT FINAL ENVIRONMENTAL STATEMENT, BRYAN MOUND SALT DOME (FES 76/77-6, July 1977) *

* All comments received on this document during the comment period are included in this section. Substative comments concerning brine diffusion in the Gulf of Mexico are addressed in Section 9.5. All other substantive comments were addressed in the Final Environmental Impact Statement (Final Supplement to FEA FES 76/77-6) Strategic Petroleum Reserve, Bryan Mound Salt Dome (DOE/EIS-0001).

UNITED STATES ENVIRONMENTAL PROTECTION AGENCY

FIRST INTERNATIONAL BUILDING
1201 ELM STREET
DALLAS, TEXAS 75270

November 30, 1977

Mr. Thomas A. Noel
Acting Assistant Secretary
Resource Application
Department of Energy
1725 M Street NW
Washington, D.C. 20461

Dear Mr. Noel:

We have reviewed the Draft Environmental Impact Statement (EIS) for the proposed Seaway Group Salt Domes of the Strategic Petroleum Reserve (SPR) program. The Seaway Group consists of five salt domes located in the southeast Texas counties of Brazoria and Fort Bend. The primary site for SPR development in this group is the Bryan Mound Early Storage Reserve (ESR) facility located in Brazoria County. At Bryan Mound, 63 million barrels (MMB) of storage capacity is presently being modified for ESR storage. The proposed development is to expand Bryan Mound by an additional 100 MMB for a total storage capacity of 163 MMB. Development of 100 MMB of storage capacity at either Allen dome, West Columbia dome, Damon Mound, or Nash dome are alternatives to the 100 MMB expansion at Bryan Mound.

The following comments are provided for your consideration in preparation of the Final EIS:

1. The statement would be strengthened if it included dimensional drawings of the proposed intake structures for raw water withdrawal. In addition, the statement should address intake flow velocity and screen designs that will be used. This information would allow for an effective evaluation of these structures to determine whether best technology in their design has been used to minimize environmental impacts.

2. Proposed expansion activities for the SPR for the Seaway Group involves hydrocarbon storage by emplacement of crude oil into salt domes, solution mining of the salt to create or enlarge existing storage capacity, and alternate brine disposal by deep-well injection. All these types of operations will be regulated under the Underground Injection Control (UIC) program of the Safe Drinking Water Act (Public Law 93-523, as per Draft regulations, August 31, 1976).

Under these regulations, the data presented in the draft statement needs to be strengthened to support an effective evaluation of the environmental impact of these operations. Therefore, sufficient data should be presented to EPA when it becomes available from the on-going testing and analysis program before initiation of the emplacement, mining, or disposal operations. Since the State of Texas is expected to assume enforcement authority of the UIC Program, the data and analysis provided shall be consistent both with those requirements proposed in EPA Administrator's Decision Statement #5 (39 CFR:69), or those required under the superseding UIC regulations, when they become applicable, and those required for permit application under regulations promulgated by the Texas Railroad Commission, Oil and Gas Division. In addition, close coordination should be afforded both EPA and the Texas Railroad Commission by DOE in all phases of data requirements, collection, and presentation. Also, selected technical data should be provided to the public in the form of a "by request" appendix to the Final EIS. We are requesting that the intentions of the applicant to comply with the above recommendations be adequately addressed in the Final EIS.

3. The method of brine disposal strongly recommended involves using the displaced brine as a chemical feed stock wherever practicable. The applicant's intention on this recommendation should be addressed in the Final.

4. In assessing environmental impacts of the Seaway Group proposed and alternative SPR salt dome expansion sites, it appears that impacts regarding utilization and loss of wetlands could be minimized if appropriate measures were taken. In reviewing wetland impacts associated with each of the four alternative expansion sites, use of the Allen and West Columbia sites would involve the greatest amount of wetland loss, sixteen and thirty acres respectively. Use of the Damon Mound and Nash alternative expansion sites would involve losses of less than four acres each. The wetland policy as expressed and emphasized by the Environmental Protection Agency, published in the Federal Register (40 CFR 230, September 5, 1975), and presented by The President in Executive Order 11990 (Protection of Wetlands), requires cognizance and consideration be given any proposal that has potential to damage or destroy wetlands by dredge and fill activities. Therefore, the applicant should substantively evaluate all proposed and alternate actions regarding their potential to adversely impact the wetlands. The selected project actions should be shown to be the most practicable of all alternative actions and will provide possible mitigative measures to minimize harm to the wetlands. In the selection of any right-of-ways, efforts should be made to avoid wetland utilization. Mitigative measures are available to minimize the environmental impacts and we will be happy to work with you to define these areas. As possible alternate salt dome crude oil storage sites for future storage and expansion, the Final should consider using off-shore domes and other sites inland away from Gulf Coast wetland areas.

We recognize that The President's Executive Order 11990 (Protection of Wetlands) does not apply directly to this project because of the exemptions allowed in Section 8 of this Order. However, for future projects of this nature, the applicant is advised that EPA will implement this Order to its fullest degree to preserve and protect the wetlands and will take appropriate actions to carry out its mandates. The applicant's consideration and response on this matter should be provided in the Final EIS.

5. The statement should address if there will be any discharges as a result of domestic wastewater treatment at the selected SPR expansion sites. The statement should address the location of the discharge point, the type of treatment, and the possible impacts this discharge could have on the receiving stream. In addition, the statement should address whether application for a National Pollutant Discharge and Elimination System (NPDES) permit has been made.

6. On page B-82, in the discussion of the interpretative ruling of December 21, 1976, regarding the Federal Clean Air Act, the name "Emission Trade-Offs" is incorrectly used since it is more commonly referred to as "Emission Offset." This discrepancy in terminology should be corrected in the final statement. Furthermore, based on the extrapolation from regional air quality data, the statement indicates that levels of non-methane hydrocarbons and photochemical oxidants are predicted to be high and are expected to continue to exceed standards occasionally in the Freeport, Texas area. Therefore, the emission offset policy may apply for the proposed project. In addition, the final statement should note that the exclusion of new sources, which emit less than 100 tons per year, as required under the emission offset policy, is based on "potential" instead of "actual" emissions. These matters and their effect upon this project should be adequately considered and addressed in the final statement.

7. In addressing the ambient air quality standards, the final statement should recognize that the Clean Air Act, amended on August 7, 1977, has changed past Prevention of Significant Deterioration (PSD) Regulations. Those changes that are significant to this project are that PSD designated source categories have been expanded from 19 to 28 sources, one of which is petroleum storage and transfer facilities. Also, PSD regulations no longer apply only to particulate and sulphur dioxide emissions but to all criteria pollutants, (i.e., Sulfur Dioxide (SO_2), Total Suspended Particulate (TSP), Non-Methane Hydrocarbon (NMHC), Nitrous Oxides (NO_x), Carbon Monoxide (CO), and Photochemical Oxidants (O_3)). These changes and their effect upon this project should be considered and adequately addressed in the final statement.

8. The levels of environmental noise tabulated on page B.2-88 of the Draft EIS have been labeled as "established guidelines," from EPA. This phrase, "established guidelines," is incorrect. Rather, this table reflects "identified levels" which are requisites to protect public health and welfare with an adequate margin of safety for both activity interference and hearing loss. Furthermore, the noise levels cited in this table do not constitute a regulation, specification, or standard. This discrepancy should be corrected in the final statement.

9. The Draft EIS needs to be strengthened in the section addressing the Spill Prevention Control and Countermeasure (SPCC) Plan. The Final EIS should contain a statement that a SPCC Plan, which will meet the requirements of Coded Federal Regulations 40 CFR 112, will be prepared within six months after the facilities begin operation and shall be fully implemented no later than one year after operations begin.

These comments classify your Draft Environmental Impact Statement as ER-2. Specifically, based upon the information contained in the statement, we have established environmental reservations concerning the destruction and loss of wetlands and the possible adverse impacts that alternate brine disposal by deep-well injection could have on ground water aquifers. We are requesting additional information and response on air, underground injection, wastewater treatment, and other areas as specifically addressed in the above comments. Furthermore, we do want to reemphasize that EPA in the future will review projects of this nature with the fullest intent to protect and preserve the wetlands as mandated by Executive Order 11990, and in doing so, would consider an environmental unsatisfactory determination for projects of this nature. The classification and the date of our comments will be published in the Federal Register in accordance with our responsibility to inform the public of our views on proposed Federal actions, under Section 309 of the Clean Air Act.

Definitions of the categories are provided on the enclosure. Our procedure is to categorize our comments on both the environmental consequences of the proposed action and on the adequacy of the impact statement at the draft stage, whenever possible.

We appreciate the opportunity to review the Draft Environmental Impact Statement, and we would be happy to discuss our comments with you. Please send us two copies of the Final Environmental Impact Statement at the same time it is sent to the Council on Environmental Quality.

Sincerely,

Adlene Harrison

Adlene Harrison
Regional Administrator

Enclosures

UNITED STATES DEPARTMENT OF COMMERCE
The Assistant Secretary for Science and Technology
Washington, D.C. 20230
(202) 377-3111

November 16, 1977

Executive Communications
Room 3309
Federal Energy Administration
Washington, D.C. 20461

Gentlemen:

This is in reference to your draft environmental impact statement entitled, "Seaway Group (Bryan Mound Expansion; Allen Damon Mound; Nash (West Columbia) Salt Domes Crude Oil Storage Sites." The enclosed comments from the National Oceanic and Atmospheric Administration are forwarded for your consideration.

Thank you for giving us an opportunity to provide these comments, which we hope will be of assistance to you. We would appreciate receiving ten (10) copies of the final statement.

Sincerely,

Sidney R. Galler
Deputy Assistant Secretary
for Environmental Affairs

Enclosures--Memo from: National Oceanic and Atmospheric Administration (10/21/77 & 11/2/77)

U.S. DEPARTMENT OF COMMERCE
National Oceanic and Atmospheric Administration
NATIONAL OCEAN SURVEY
Rockville, Md. 20852

[illegible] 3 1977 C52/JLR

NOV 2 1977

TO: William Aron
Director
Office of Ecology and Environmental Conservation

FROM: Gordon Lill
Deputy Director
National Ocean Survey

SUBJECT: DEIS #7710.05 - Bryan Mound Expansion

The subject statement has been reviewed within the areas of NOS responsibility and expertise, and in terms of the impact of the proposed action on NOS activities and projects.

The following comments are offered for your consideration.

Appendix B - Description of the Environment -
Historical mean surface current data are for a position 30 miles SW of diffuser location. Topographic, wind shear, and other effects may cause significant differences. Site specific data are missing.

Appendix E - Oil and Brine Spill Risk Analysis -
The present state-of-the-art for oil spill analysis includes models which provide contours of probabilistic impact and probabilistic time to impact. This information, missing in the subject DEIS, would improve the plan for containment and removal of spilled oil.

Appendix G - Brine Dispersion Modeling -
The two modeling approaches used to characterize the dispersion of brine into surrounding waters may suffer from assumptive mathematical simplifications. The limitation of steady state and constant current field of the Radian Corporation model has been recognized in the DEIS. The assumptions of constant depth and vertically constant current are weaknesses in the MIT model.

UNITED STATES DEPARTMENT OF COMMERCE
National Oceanic and Atmospheric Administration
NATIONAL MARINE FISHERIES SERVICE
Duval Building
9450 Gandy Boulevard
St. Petersburg, FL 33702

NOV 2 1977

October 21, 1977 FSE61/GB

TO: Director, Ofc. of Ecology and Environmental Conservation, EE

NOV 01 1977

THRU: Assistant Director for Scientific and Technical Services, F5

FROM: William H. Stevenson
Regional Director

SUBJECT: Comments on Draft Environmental Impact Statement - Seaway Group Salt Domes (FEA 77-10) (DEIS #7710.05)

The draft environmental impact statement for Seaway Group Salt Domes that accompanied your memorandum of October 7, 1977, has been received by the National Marine Fisheries Service for review and comment.

The statement has been reviewed and the following comments are offered for your consideration.

General Comments:

In the numerous sections of this DEIS dealing with the primary brine disposal location for all sites being considered, it appears that the locations in the Gulf of Mexico five nautical miles southeast of Bryan Mound were selected solely to obtain a 50-ft. depth for disposal of the brine. Apparently, no considerations are given to alternative sites in the Gulf which would be less damaging to marine fishery resources.

The portion of the Gulf of Mexico where the proposed diffuser would terminate is located within the limits of Grid No. 19 identified by the NMFS for the purpose of computing Gulf of Mexico shrimp fishery statistics. During 1975, 13.3 million pounds of shrimp worth more than $18 million dockside, were harvested within Grid No. 19[1/]. From information previously

1/ Anon. 1976. Gulf coast shrimp data annual summary 1975. Current Fisheries Statistics No. 6925. NOAA/NMFS. 26pp.

provided by the NOAA Environmental Data Service (EDS), 2/ Texas A&M University, 3/ and others, the FEA, SPRO has already noted that at or near the site of the proposed diffuser there is a rich diversity of zooplankton, phytoplankton, and benthic fauna.

We have recently obtained additional information on the productivity of living marine resources at and near the proposed diffuser site, through correspondence with Mr. Gary Graham, Associate Marine Fisheries Specialist of the Texas Agricultural Extension Service at Angleton, Texas. By letter of August 9, 1977, (copy attached) he informed us of documented catches of spawning white shrimp about 0.8 to 1.0 nautical mile inshore, 2.5 nautical miles offshore, and 1.6 to 3 nautical miles toward Freeport from the proposed diffuser site. He further noted that during these three collecting trips in 1977, they investigated an area extending east of the Freeport jetties to west of the San Bernard River and out to 10 fathoms in search of mated shrimp. In summarizing, he said that "the three sites are the only locations in which we have documented female white shrimp with spermatophores, thus far. The presence of these spermatophores indicates a definite spawning site."

In a subsequent letter dated August 12, 1977, (copy attached) Mr. Graham informed us that there are intense commercial and concentrated sport fishing activities in the vicinity of the proposed diffuser site and much less in waters 10 nautical miles and 12.5 nautical miles from shore. We note that the area in the vicinity of the proposed diffuser site is one of the most productive white shrimp grounds along the Texas coast whereas the two areas further offshore support a shrimp fishery only when brown shrimp are migrating offshore. The area of concentrated sport fishing is shown to be about 1 to 2 nautical miles south of the proposed diffuser site. The only other good sport fishing site between the proposed and alternate sites in the east end of Middle Bank is a shell bank located about 8 to 9 nautical miles offshore.

Much of the information contained in the August 12 letter from Mr. Graham was incorporated into the Analysis of Brine Disposal in the Gulf of Mexico, Bryan Mound Addendum dated September 1977 which the NOAA/EDS submitted to FEA. That report also contains a discussion of the performance of four types of discharge alternatives for the Bryan Mound site, namely bottom diffusion and surface discharge in both 50 to 70 ft. of water.

2/ Anon. 1977. Analysis of brine disposal in the Gulf of Mexico (1) Bryan Mound. Report to FEA, Strategic Petroleum Reserve Program Salt Dome Storage. U.S. DOC, NOAA, EDS Ctr for Experiment Design and Data Analysis, Mar. Assess. Div., Feb. 1977, 165pp.

All of the above information should be incorporated and discussed in the appropriate sections of the FEIS, which should also contain discussions of additional alternative disposal sites in other nearby parts of the Gulf of Mexico that are not known to be sensitive habitats for marine species that are major components of the recreational and commercial fisheries.

In the presentation of deep well injection of brine into deep saline aquifers as an alternative to discharge of brine into the Gulf of Mexico, for each of the five Seaway candidate sites, the alternative of directional drilling from non-wetland locations should also be discussed for those candidate sites wherein wetlands are presently being considered as possible injection wellpad locations.

It is requested that one copy of the FEIS be sent our Area Supervisor, Environmental Assessment Branch, 4700 Avenue U, Galveston Texas 77550.

Attachments (2)

cc:
F53 (3)
FSE612

3/ James, W. P. ed. 1977. Environmental considerations of brine disposal near Freeport, Texas. Proc. Strategic Petroleum Reserve Workshop, Houston, Tx, Feb. 17-18, 1977, Tex. A&M Univ. Ctr for Mar Res College Station, Tx, Apr. 1977, 75pp.

TEXAS AGRICULTURAL EXTENSION SERVICE

THE TEXAS A&M UNIVERSITY SYSTEM
County Extension Office
Route 2, Armory
Angleton, Texas 77515
August 9, 1977

ir. Don Moore
Area Supervisor
:nvironmental Assessment Branch
Vational Marine Fisheries Service
4700 Avenue U
Galveston, Texas 77550

Dear Mr. Moore,

Efforts have been conducted to collect and document gravid white shrimp, Peneaus setiferus. Although the majority of this work has focused out of Port Aransas, we have begun investigating and collecting gravid shrimp south of Freeport. I have worked closely with our Mariculture Staff on this project out of Freeport and have served as Party Chief aboard leased shrimp vessels identified with this activity.

This year, three collecting trips have been conducted out of Freeport. Mated white shrimp were found and collected from a different site on each trip. These sites are labled A, B, and C on the enclosed chart. As you expressed interest of the location of the proposed brine diffuser as related to these spawning sites, the approximate position of the diffuser is also plotted on the chart. Loran A l.o.p.'s are estimated at 3H3 3373, 3H2 4031 as plotted from latitude and longitude readings obtained from the U. S. Corps of Engineers. It is not known with certainty if this reading was given as the central position of the diffuser array or the offshore point.

Loran A l.o.p.'s of Site A are 3H3 3351 and 3H2 4020. On May 2, 1977, 33 white shrimp with spermatophores were collected. Numerous other shrimp with ovarian development were monitored at this location.

Site B produced 6 mated females on June 1, 1977. Several hundred other females containing roe were also collected near dusk at this location. Loran A readings were approximately 3H3 3370 to 3H3 3378, 3H2 4035.

Loran A l.o.p.'s of Site C were 3H3 3390 to 3H3 3403 and 3H2 4037 to 4042. Only 250 white shrimp were produced of which 200 were females. Twenty-two of these shrimp were mated.

·. Don Moore
ıgust 9, 1977
ıge 2

Don, it should be noted that during these trips we have investigated an area ‹tending east of the Freeport jetties to west of the San Bernard River in search f mated shrimp. Depths have ranged from the immediate beach front to ten fathoms. ıe three sites are the only locations in which we have documented female white ırimp with spermatophores, thusfar. The presence of these spermatophores indicate definite spawning site. Females containing these spermatophores generally spawn ı the laboratory within twelve hours after we collect them.

If we can provide any further information, please do not hesitate to contact his office.

Sincerely,

Gary Graham

Gary Graham
Associate Marine Fisheries Specialist

G:cb
nclosure

c: Dr. Wallace G. Klussmann

TEXAS AGRICULTURAL EXTENSION SERVICE
THE TEXAS A&M UNIVERSITY SYSTEM
County Extension Office
Route 2, Armory
Angleton, Texas 77515
August 12, 1977

Mr. Don Moore
Area Supervisor
Environmental Assessment Branch
National Marine Fisheries Service
4700 Avenue U
Galveston, Texas 77550

Dear Mr. Moore,

I have been studying your question regarding the importance of fisheries in the proposed 5 N mile brine diffuser site and the alternative 12.5 N mile location. The differences in these two areas are significant as they impact on commercial and recreational fisheries.

Commercial fishing activities in the 5 N mile site is quite intense. This area is one of the most productive white shrimp grounds along the Texas coast. I have personally experienced daily catches of up to 1,230 pounds of large, white shrimp, Peneaus setiferus, in the immediate vicinity of this proposed diffuser site. On numerous occasions shrimp fleets numbering more than 50 large vessels have been observed fishing this area. In addition to locally based vessels, it is common to see vessels from Florida, Louisiana, and South Texas directing shrimping efforts in this location off the Brazos River.

The productivity of this area is further enhanced by bottom characteristics with a large shell ridge located immediately offshore of the 5 N mile diffuser site. Adjacent to the inshore portion of the ridge is a type of trough which has historically provided habitat for white shrimp during winter, spring, and early summer. During certain periods, white shrimp can be found in this trough when, in fact, they cannot be located in an offshore area extending from San Luis Pass to the San Bernard River. This area is one of our documented white shrimp spawning sites.

Sportfishing activity near the proposed diffuser site is often concentrated during the summer months. Large schools of Spanish mackerel Scomberomorus maculatus occurring near the site attract numerous sportfishermen. Of extreme importance to sportfishing is the East Bank Area. This area is adjacent to the 5 N mile diffuser site. Loran A l.o.p.'s of this rock formation are 3H3-3355 to 3360, 3H2-4022 to 4028. It should be noted that this area is fished by offshore recreational fishermen more than any area off Freeport. A combination of productiveness and the proximity of these rocks to Freeport is especially meaningful to medium-sized outboard sport vessels. Charter boats and yachts also fish this area intensely. Pelagic fish such as king mackerel Scomberomorus cavalla, bonito Euthynnus alletteratus, jack crevalle Caranx hippos, cobia Rachycentron canadum, and various species of sharks are abundant in the East Bank area during summer months. Throughout the year, demersal fish such as red snapper Lutjanus campechanus, silver seatrout Cynoscion nothus, and small grouper Epinephelus sp. are caught in this area by little boats unable to travel large distances offshore. Recently, it was discovered that large red drum, Sciaenops ocellata, congregate near the rocks of East Bank during the fall and winter months. This phenomenon has added a new dimension to the recreational fishing activity near the proposed diffuser site.

The adjacent shell ridge to East Bank is also productive for the various pelagic fish that were previously discussed. The recently placed artificial reef south of the proposed diffuser site will provide additional sportfishing for the area.

It should be noted that the adjacent shell ridge to the 5 N mile diffuser site, is of little commercial importance in terms of shrimp landings. Pink shrimp, Penaeus duorarum, are harvested on the ridge in small quantities, but concentrations of these shrimp could be considered of only marginal economic importance.

In contrast to the proposed 5 N mile diffuser site, the 12.5 N mile alternative site is of less importance to our fisheries. The primary consideration of this area relative to the commercial fishery is that of emigrating brown shrimp, Penaeus aztecus. The area of the alternative diffuser site received shrimping activity during a period when brown shrimp are migrating from the estuaries to offshore waters of the Gulf. It should be noted that shrimping activity in this area is limited to a very short period of time and is virtually non-existent after this migration terminates. Another important consideration is a comparison of other areas with the same depth. Any losses resulting from selection of the alternative diffuser site would be minimal as other shrimping grounds, (San Bernard River, Freeport Jetties or San Luis Pass), offer sufficient production to accomodate the fleet at this time of year. During periods of brown shrimp emigration, an area of similiar water depth may be just as productive. Shrimp during this period of time are often uniformally scattered along the coast.

The importance of sportfishing within the 12.5 N mile site, is also less than that of the 5 N mile site. Sportfishing vessels generally tend to move further offshore to fish near shrimp boats, platforms, and underwater obstructions or they will concentrate their activity nearshore on the shell ridge or rock banks. The 12.5 N mile site is between the productive nearshore sportfishing areas and those offshore.

A personal observation may be of interest to you. On August 10, 1977, the number of shrimp vessels fishing the 5 N mile site and the 12.5 N mile site were counted. Twenty-four vessels were in the immediate vicinity of the 5 N mile site. Two vessels were in the area of the 12.5 N mile site.

Your question concerning commercial and sportfishing activities in an area 10 N miles from shore can be related to that of the 12.5 N mile site. The 10 N mile area is extremely similiar to that of the 12.5 N mile location. A slight amount of white shrimp production is obtained from the trough adjacent to the offshore side of the shell ridge. White shrimp harvested from this area are considerably less than that of the previously discussed inshore side. Emigrating brown shrimp comprise the major commercial fishery in this area. The same phenomenon relative to concentrations of migrating shrimp apply to that of the proposed alternative brine disposal site. Sport-fishing activity in this area is minimal as identified with the 12.5 N mile site.

I hope that this letter has provided you with useable information. If we can be of any further assistance to you from this office, please do not hesitate to contact us.

Sincerely,

Gary Graham

Gary Graham
Associate Marine Fisheries Specialist

GG:cb

cc: Dr. Wallace Klussmann
Allan J. Mueller
Carlos H. Mendoza

DEPARTMENT OF THE ARMY
GALVESTON DISTRICT, CORPS OF ENGINEERS
P.O. BOX 1229
GALVESTON, TEXAS 77553

REPLY TO
ATTENTION OF:

SWGED-E

17 NOV 1977

Executive Communications
Room 3309
Federal Energy Administration
Washington, D.C. 20461

Gentlemen:

The draft Environmental Statement, "Seaway Group of Salt Dome Crude Oil Storage Sites, Texas," furnished to the Executive Director of Civil Works, Office of the Chief of Engineers with your letter dated 23 September 1977, has been referred to us for review and comments.

We have coordinated review of the draft statement with the staff of the Southwestern Division, Corps of Engineers, and our consolidated comments are as follows:

a. The dredging work and most of the facilities to be constructed in connection with the proposed Strategic Petroleum Reserve storage site will require Section 10 and 404 permits under the regulatory program of the Corps of Engineers. In view of this requirement as part of the overall Federal action and the apparent concerns of environmental groups and organizations with the impact of certain aspects of the project on shrimp and other marine life, we believe the Federal Energy Administration environmental statement should be expanded sufficiently so as to adequately cover the effects of these permit activities as well as the primary activity of petroleum storage. This might obviate the necessity for preparation of a separate Environmental Impact Statement when the Corps of Engineers takes action on the Section 10 and 404 permit application.

b. The discussion under paragraph 4.3.1, Volume I on the impacts of brine disposal, dock construction and dredging shows little quantification of the total impact of these activities on the ecosystems and the biota of the area, both marine and terrestrial. We believe these discussions should be expanded to more adequately quantify these impacts.

c. The referenced Corps of Engineers Regulations as listed in Table 9.2-1 in Volume I are not current. The regulations on "Permits for Activities in Navigable Waters or Ocean Waters," 33 CFR 209.120 and "Permits for Discharges of Deposits into Navigable Waters," 33 CFR 209.131 were rescinded by regulations entitled "Regulatory Program of the Corps of Engineers" published in the Federal Register, Part II, Tuesday, 19 July 1977. Applicable regulations for activities addressed in paragraph B in Table 9.2-1 ("Piers, Dredging, etc. in Waterways") are now covered by 33 CFR Part 322 of the above referenced 19 July 1977 regulations.

d. Discussions of brine disposal in the Gulf of Mexico occur in several parts of Section 4 of the Environmental Impact Statement and in Appendix C. The discussions center around the findings of two models showing the extent and magnitude of salinity increase above ambient around the diffuser. However, no information on the salinity tolerance of various biological elements found in the area is presented to aid in assessing the significance of the described changes. Also, some life history information, on at least commercial species, should be presented along with describing critical growth stages, spawning habits, migrations, etc. which may be affected by the brine discharge. The results of the predisposal studies briefly described on page 4.3-18 along with a review of existing literature, much of which is available through Federal agencies and State universities associated with mariculture, should be presented in the final Environmental Statement.

Sincerely yours,

JON C. VANDEN BOSCH
Colonel, Corps of Engineers
District Engineer

UNITED STATES DEPARTMENT OF AGRICULTURE
SOIL CONSERVATION SERVICE
P. O. Box 648
Temple, TX 76501

November 18

Mr. Michael E. Carosella
Associate Assistant Administrator
Special Programs
Strategic Petroleum Reserve
Federal Energy Administration
Washington, DC 20461

Dear Mr. Carosella:

We have reviewed the draft environmental impact statement for the proposed Seaway Group Salt Domes, Texas and feel that the impact statement, as written, adequately reflects the impacts this project will have on soil, plant, and water resources.

We appreciate the opportunity of reviewing this environmental impact statement.

Sincerely,

For C. Bud Stanton

George C. Marks
State Conservationist

Advisory Council on
Historic Preservation
1522 K Street N.W.
Washington, D.C. 20005

October 26, 1977

Mr. Michael E. Carosella
Associate Assistant Administrator
Special Programs
Strategic Petroleum Reserve
Federal Energy Administration
Washington, D. C. 20461

Dear Mr. Carosella:

This is in response to your request of September 23, 1977, for comments on the draft environmental statement (DES) for the Seaway Group salt dome crude oil storage sites located in the Gulf Coast region of southeastern Texas.

The Council notes from its review that while cultural resource studies to date indicate no properties included in or known to be eligible for inclusion in the National Register of Historic Places will be affected additional studies are necessary before final determinations can be made. Accordingly, the Federal Energy Administration is reminded that should those additional studies identify cultural resources eligible for inclusion in the National Register which will be affected by the undertaking, it should delay further processing of the undertaking and afford the Council an opportunity to comment pursuant to the "Procedures for the Protection of Historic and Cultural Properties" (36 C.F.R. Part 800).

Should you have any questions or require additional assistance in this matter, please contact Michael H. Bureman of the Council's staff at P. O. Box 25085, Denver, Colorado 80225, or at (303) 234-4946, an FTS number.

Sincerely yours,

Louis S. Wall
Assistant Director, Office
of Review and Compliance, Denver

The Council is an independent unit of the Executive Branch of the Federal Government charged by the Act of October 15, 1966 to advise the President and Congress in the field of Historic Preservation.

DEPARTMENT OF THE ARMY
GALVESTON DISTRICT, CORPS OF ENGINEERS
P.O. BOX 1229
GALVESTON, TEXAS 77553

REPLY TO
ATTENTION OF:
SWGED-E

2 SEP 1977

Executive Communications
Room 3309
Federal Energy Administration
Washington, D.C. 20461

Dear Sir:

This is in response to your letter dated 15 July 1977, which provided a copy of the "Draft Supplement Final Environmental Statement, Strategic Petroleum Reserve, Bryan Mound Salt Dome," for our review and comments.

Our comments are as follows:

a. The authorized 45-foot Federal Navigation Channel Enlargement for Freeport Harbor would have a proposed dredged material disposal area near the injection well pipelines. A copy of Figure 1, page 4, showing the proposed dredged material disposal site is inclosed.

b. Request that the second sentence of the third paragraph of Section 1.2.1 be changed to read "Detailed plans and construction procedures for pipeline crossings and proposed structures at the flood protection levee system will be coordinated with the Velasco Drainage District to insure the integrity of the levee system is maintained," in lieu of "All construction work would be coordinated with the Velasco Drainage District to avoid creating a flood hazard to the property behind the levee."

c. The proposed water intake in the Brazos River Diversion Channel, the Seven Mile Pipeline, and the offshore brine diffuser structure will require Department of the Army permits under Section 10 of the River and Harbor Act of 1899 prior to construction. Facilities constructed in wetlands will require Department of the Army permits under Section 404 of the Federal Water Pollution Control Act Amendments of 1972.

d. Page 1-3, Paragraph 1.2.1. - Consideration should be given to the alternative of locating the pump station on the interior side of the hurricane protection levee.

e. Page 1-7, Section A-A. - There may be erosion at the base of the walkway supports and at the sides of the pump station during high discharges, and riprap protection should be considered.

f. Page 2-24, Paragraph 2.7.1. -

Identify the source of the statement "combined storage capacity of approximately 6,900 acre-foot."

The maximum Brazos River discharges at Rosharon are calculated to exceed 100,000 cfs, since the one precent discharge at River Mile 52 is approximately 103,000 cfs.

g. Pumps and mechanical gear susceptible to flood damage should be raised to an elevation at or above the one percent flood elevation in consonance with Executive Order 11988. "Normal flooding elevations" is an ambiguous term which does not specifically indicate compliance with the flood damage prevention requirements contained in the Executive Order. Figure 2 implies that susceptible gear is located above 18 feet elevation, but such items are not specifically labelled on the elevation view.

h. It is suggested that construction of the injection well pipeline be coordinated with the Brazos River Harbor Navigation District so as to avoid reductions in capacity of the disposal area. Also, construction of the pipeline crossing the small drainage ditch between the injection wells and the proposed disposal area should be coordinated with the U.S. Fish and Wildlife Service.

Sincerely yours,

JON C. VANDEN BOSCH
Colonel, Corps of Engineers
District Engineer

1 Incl
As stated

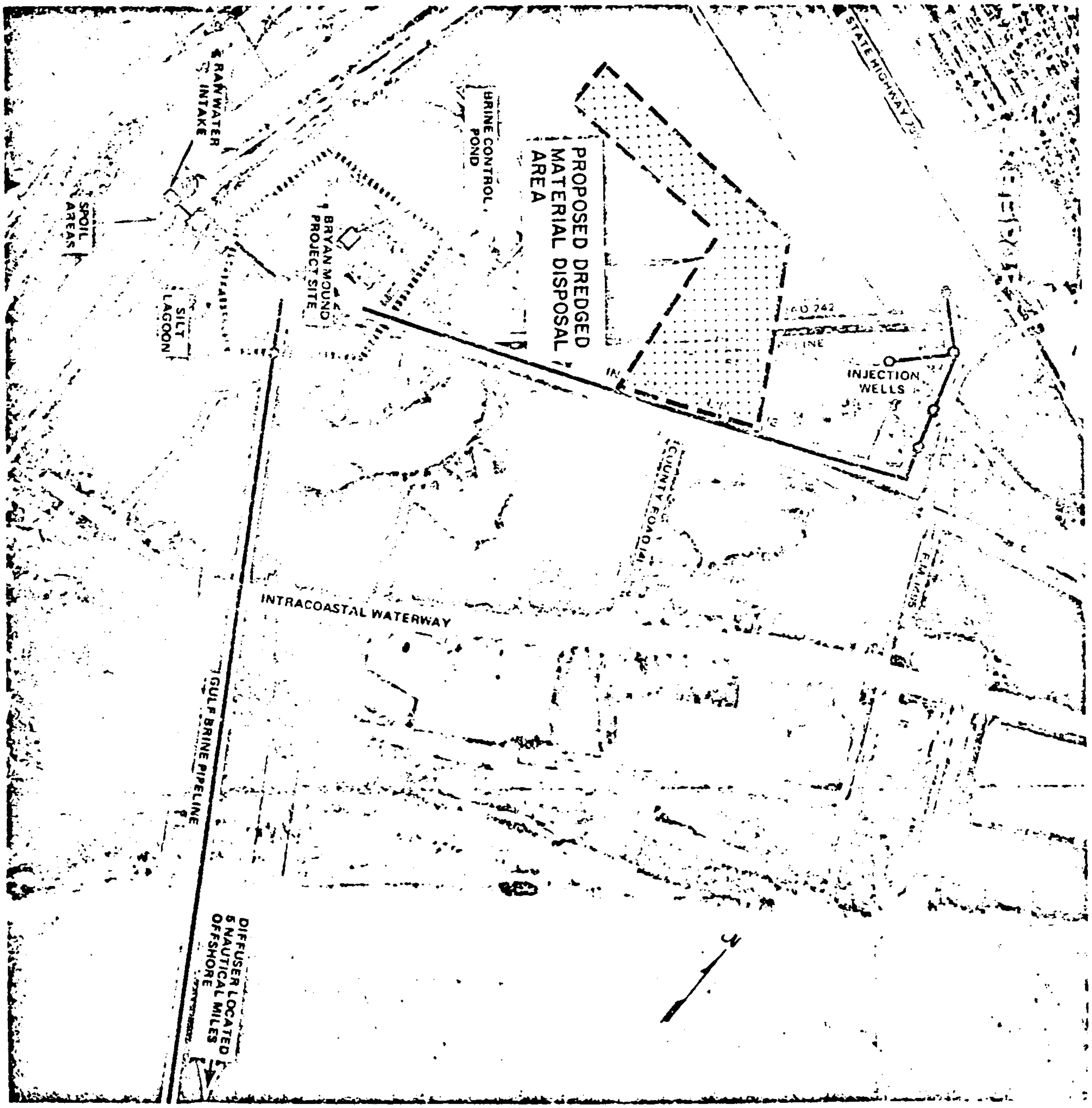

Figure 1 BRYAN MOUND REVISED FRESHWATER INTAKE AND BRINE DISPOSAL SYSTEMS LOCATIONS

378002

DOW CHEMICAL U.S.A.

BARSTOW BUILDING
2020 DOW CENTER
MIDLAND, MICHIGAN 48640

September 1, 1977

Executive Communications
Room 3309
Federal Energy Administration
Washington, D.C. 20461

Gentlemen:

Thank you for the opportunity to comment on the Draft Supplement to the Final Environmental Impact Statement, Bryan Mound Salt Dome. We have no comment on the technical portion of the statement. However, on pages 1-9 and 1-10, it is stated that there is an agreement with the FEA whereby Dow would dispose of 56,500 BPD of brine from the site. Dow and the FEA have been discussing this possibility for sometime, but there was no firm agreement at the time of the statement and there is still no agreement now. So the impact statement is in error and misleading on this point.

Sincerely yours,

Roger Gohrband
Director of Planning

hc

AN OPERATING UNIT OF THE DOW CHEMICAL COMPANY

UNITED STATES
ENERGY RESEARCH AND DEVELOPMENT ADMINISTRATION
WASHINGTON, D.C. 20545

078003

SEP 1 1977

Executive Communications
Federal Energy Administration
Room 3309
Washington, D.C. 20461

Dear Sir:

This is in response to Mr. Michael E. Carosella's transmittal dated July 15, 1977, in which he invited the Energy Research and Development Administration (ERDA) to review and comment on the Federal Energy Administration's draft supplement to the final environmental impact statement for the Bryan Mound salt dome (FES 76/77-6).

We have reviewed the supplement and have determined that we have no objection to the change in the design of the Bryan Mound brine disposal and water supply systems. We have no comments to offer on the supplement itself.

Thank you for the opportunity to review and comment on the draft supplement.

Sincerely,

W. H. Pennington, Director
Office of NEPA Coordination

cc: Council on Environmental
Quality (5)
Mr. Michael E. Carosella, FEA

TEXAS
PARKS AND WILDLIFE DEPARTMENT

IISSIONERS

CE JOHNSON
irman, Austin

FULTON
:—Chairman, Lubbock

R. STONE
ls

CLAYTON T. GARRISON
EXECUTIVE DIRECTOR

COMMISSIONERS

BOB BURLESON
Temple

JOHN M. GREEN
Beaumont

LOUIS H. STUMBERG
San Antonio

4200 Smith School Road
Austin, Texas 78744

37001

August 8, 1977

Federal Energy Administration
Executive Communications, Room 3309
Washington, D. C. 20461

Re: Draft Supplement - Final Environmental Impact Statement,
Bryan Mound Salt Dome

Dear Sirs:

Reference is made to the document which was submitted to this agency for review and comment on July 15, 1977. We have reviewed the draft and offer the following comments for your consideration.

The plans for operation of the Bryan Mound Salt Dome Strategic Petroleum Reserve include three methods of disposing of brine from the facility - use as feedstock by Dow Chemical Company, use of injection wells, and disposal by diffuser in the Gulf of Mexico. It is recommended that disposal in the Gulf of Mexico be kept as low as possible in order to avoid adverse impacts to the offshore fisheries, particularly with respect to the white shrimp fishery.

Section 3.1.8 of the draft should be expanded to discuss possible interference with navigation and trawling operations which may result from the installation of a Gulf brine diffuser system. Section 4.6 should also be expanded to discuss this subject.

The opportunity to review and comment upon this document is appreciated.

Sincerely,

CLAYTON T. GARRISON
Executive Director

CTG:BDK:gs3/1

cc: Mr. Ward C. Goessling, Jr., Coordinator
Natural Resources Section
Governor's Budget and Planning Office
Executive Office Building
411 West 13th Street
Austin, Texas 78701

RALPH M. PARSONS LABORATORY
FOR WATER RESOURCES AND HYDRODYNAMICS
DEPARTMENT OF CIVIL ENGINEERING, BLDG. 48—321
MASSACHUSETTS INSTITUTE OF TECHNOLOGY
CAMBRIDGE, MASSACHUSETTS 02139

3?8005

PHONE: (617) 253- 6761

August 22, 1977

Executive Communications
Room 3309, Federal Energy Administration
Washington, D.C. 20461

Dear Sirs,

The purpose of this letter is to address two small issues concerning the design and operation of the offshore brine diffuser and to make several small corrections to those parts of the document for which we at MIT were responsible.

The first point concerns the orientation of the diffuser ports. The angle of 90° was selected for preliminary analysis based on prior experimental data obtained with that orientation. We are presently conducting some experiments in which the question of nozzle orientation will be explored in detail. We expect to have some results available by mid-fall, and hope that these could be factored into the final design.

The second point concerns the operation of the diffuser at flow rates less than the maximum discharge. The table on page 1-15 suggests that the recommended range in Froude number of 16-20 will be maintained. This could be accomplished by incorporating raw water from the Brazos as mentioned on page 1-12 or by capping a number of nozzles. If the risers were threaded so that caps could be easily fitted or removed, then it would also be possible to fit nozzles which might discharge at angles of other than 90°.

The following errata are noted:

1. The discussion of the MIT model appears to be extracted directly from section 7.3 of NOAA's Bryan Mound report. Thus the two figures on pages D-4 and D-5 actually refer to the previous section of the NOAA report and their inclusion is somewhat out of context.

2. On page D-58 the dimension of 16d on part a) of the figure (upper part) should read 8d.

3. On page D-77, the first sentence of the 2nd paragraph should read, "The properties of a round buoyant submerged jet (or a negatively buoyant surface jet) can be determined using an integral jet analysis."

4. On page D-78, several of the table entries are in error. A revised table is enclosed.

Sincerely,

E. Eric Adams

E. Eric Adams
Research Engineer

enclosure

cc. Dr. Dail Brown

Table 18 Comparison of Parameters for Typical Ocean Discharges of Thermal, Sewage and Saturated Brine Effluents

	Thermal	Sewage	Saturated Brine
Nature of Discharge	Condenser cooling water for 2000 MWe Nuclear Power Station	200 MGD Sewage Treatment Plant	Proposed Bryan Mound Brine Discharge
Flow Rate, $Q_o (m^3/s)$	100	10	1.2
Initial Density Difference, $\rho_o - \rho_a / \rho_a$	.003 (12°C temperature rise)	.025 (fresh-salt water)	-.25 (saturated brine)
Buoyancy Flux, $(\rho_o - \rho_a) g Q_o / \rho_a$ (m^4/s^3)	2.9	2.5	-2.9
Typical Dilution Required	10	100	50-100

FEDERAL POWER COMMISSION
WASHINGTON, D.C. 20426

IN REPLY REFER TO:

August 2, 1977

Executive Communications
Room 3309
Federal Energy Administration
Washington, D.C. 20461

Dear Sir:

I am replying to your request of 15 July 1977 to the Federal Power Commission for comments on the Draft Environmental Impact Statement for the Bryan Mound, Strategic Petroleum Reserve. This Draft EIS has been reviewed by appropriate FPC staff components upon whose evaluation this response is based.

The staff concentrates its review of other agencies' environmental impact statements basically on those areas of the electric power and natural gas industries for which the Federal Power Commission has jurisdiction by law, or where staff has special expertise in evaluating environmental impacts involved with the proposed action. It does not appear that there would be any significificant impacts in these areas of concern nor serious conflicts with this agency's responsibilities should this action be undertaken.

Our review, however, noted the following items for your evaluation:

1) The solution mining of additional salt dome caverns or enlargement will impact areas much larger than stated.

2) Super saline conditions will probably persist for a longer period, depending upon the frequency of storage operation.

3) Initial filling of storage should be at a lesser rate to reduce emulsification.

4) Consideration should be given to filtration of the brine discharge.

Thank you for the opportunity to review this statement.

Sincerely,

Jack M. Heinemann
Advisor on Environmental Quality

BROWNSVILLE-PORT ISABEL
SHRIMP PRODUCERS ASSOCIATION

P. O. BOX 953
BROWNSVILLE. TEXAS

373007

August 24, 1977

Executive Communications
Room 3309
Federal Energy Administration
Washington, D.C. 20461

Dear Sirs:

Concerning brine disposal from the Bryan Mound salt dome, the Brownsville -Port Isabel Shrimp Producers Assoc. would like to go on record as opposing the proposed location of brine diffuser pipes just 5 nautical miles offshore from Freeport, Texas.

Fleets from our area depend on the entire Texas Coast for shrimp production and over the years the fishing grounds just offshore from Freeport have become recognized as prime white shrimp areas.

The proposed location of the brine diffuser system would directly conflict with major white shrimping efforts and would definitely hamper production. There is a distinct possibility that high salinity waters found in the area could affect reproduction of gravid white shrimp, which congregate near shore for mating and spawning.

We are also concerned about the effect of brines on the migration patterns of larval and juvenile shrimp, respectively, immigrating and emigrating to and from bays.

An alternative diffuser site at 12.5 N. miles offshore, would not significantly conflict with the interest of most shrimpers, in which case, our Association strongly supports a diffuser site further from land than the proposed 5 nautical mile site. We further recommend that whichever site chosen be properly marked for night and day observation.

Sincerely,

Julius Collins
PRESIDENT

PORT ISABEL SHRIMP ASSOCIATION
P. O. BOX 1046
PORT ISABEL, TEXAS 78578

August 24, 1977

Executive Communications
Room 3309
Federal Energy Administration
Washington D.C. 20461

Dear Sirs:

In reference to the environmental impact statement (EIS), for the Bryan Mound salt dome, the Pt. Isabel Shrimpers Assoc. would like to submit the following comments.

Our local Shrimpers Assoc. fully recognizes our Nation's need for energy at a reasonable cost, but at the same time we, as representatives of the Texas Shrimp Industry, also realize that a healthy marine enviroment must not be sacrificed toward those goals.

The Port Isabel Shrimpers Assoc. has a great deal of interest in fishing zones other than those just off our coast. By nature of our far ranging shrimp fleets, which harvest shrimp over the entire northern Gulf, we cannot ignore events which might be of detriment to common shrimp grounds, whether they are 50 or even 600 or more miles from port.

Shrimp and many other commercially important marine species use near shore areas as well as bays and estuaries, during all or a part of their life cycle. We feel that these areas must be protected to allow our renewable fishery resources to retain a high level of productivity. we therefore express our concern that the proposed location of a Bryan Mound diffuser system - only 5N. miles from shore, would definitely conflict with production, and possibly reproduction of white shrimp in that area. White shrimp production decreases would certainly result from the direct trawl hindrance of diffuser pipes in the area. It is not inconceivable that high saline (314 parts per thousand) brines, could affect mating behavior of white shrimp, which occurs in the diffuser site area.

Survival of newly fertilized eggs and developing larvae exposed to abnormally high salinities, must also be considered. High saline brines might also disrupt normal emigration patterns of juvenile white and brown shrimp, as they leave bays and estuaries, and possible interfere with longshore migrations of adult shrimp.

A diffusion site located 11.5 to 12.5 miles offshore, would be less harmful to both shrimp biology and commercial shrimping activity, and as such, our Association highly recommends that such a site be selected instead of the 5 N mile diffusion area.

Sincerely

Sammy Snodgrass
President

c.c. Freeport Shrimp Assoc.
P. O. Box 1123
Freeport, Texas 77541

c.c. Col. Jon C. Vanden Bosch
District Engineer
Galveston District
P. O. Box 1229
Galvaston, Texas 77553

UNITED STATES DEPARTMENT OF COMMERCE
The Assistant Secretary for Science and Technology
Washington, D.C. 20230
(202) 377-3111

September 2, 1977

Executive Communications
Federal Energy Administration
Room 3309
Washington, D. C. 20461

Gentlemen:

This is in reference to your draft supplement final environmental impact statement entitled "Strategic Petroleum Reserve, Bryan Mound Salt Dome." The enclosed comments from the National Oceanic and Atmospheric Administration (NOAA) are forwarded for your consideration.

Thank you for giving us an opportunity to provide these comments, which we hope will be of assistance to you. We would appreciate receiving fifteen (15) copies of the final statement.

Sincerely,

Sidney R. Galler
Deputy Assistant Secretary
for Environmental Affairs

Enclosure: Memo from NOAA, National Marine Fisheries Service

U.S. DEPARTMENT OF COMMERCE
National Oceanic and Atmospheric Administration
NATIONAL MARINE FISHERIES SERVICE
Duval Building
9450 Gandy Boulevard
St. Petersburg, FL 33702

AUG 22 1977

August 12, 1977

FSE61/DM

TO: Director, Office of Ecology & Environmental Conservation, EE

AUG 22 1977

THRU: Assistant Director for Scientific and Technical Services, F5

FROM: William H. Stevenson
Regional Director

SUBJECT: Comments on Draft Supplement Final Environmental Impact Statement - Bryan Mound Salt Dome (FEA 76/77-6)

The draft supplement final environmental impact statement for Bryan Mound Salt Dome, has been received by the National Marine Fisheries Service for review and comment.

The statement has been reviewed and the following comments are offered for your consideration.

Specific Comments:

1. DESCRIPTION OF PROJECT
1.2 PROPOSED ACTION
1.2.2 Brine Disposal
1.2.2.3 Marine Disposal in the Gulf of Mexico

Page 1-10, paragraph 5. The rationale for the necessity of this brine disposal method, which would adversely impact some marine life, should be discussed since it is stated on the same page, second paragraph, that the projected fill rate would be 150,000 BPD and in the 4th paragraph, that the proposed five injection wells would be designed to accommodate disposal of 150,000 BPD.

2. DESCRIPTION OF THE EXISTING ENVIRONMENT
2.9 GULF OF MEXICO MARINE ENVIRONMENT
2.9.3 Marine Ecology

Page 2-68. The various descriptions of salinity tolerances found in subsections under Marine Ecology should, where appropriate, include a discussion of the work done by Copeland and Bechtel (1974) and Gunter, Ballard and Venkataramiah (1974).

2.9.3.5 Shrimp

Page 2-86, Figure 22. This figure was apparently developed primarily from information contained in Figure 2.7, Migration of Gulf of Mexico Penaeid Shrimp in the Atlas of the Living Resources of the Seas published by FAO, Department of Fisheries, Rome, in 1972. However, the boundaries of the major white and brown shrimp fishing grounds shown in Figure 22 are considerably different than those in Figure 2.7 of the FAO publication. Also, the migration routes were illustrated as examples only by FAO.

Realizing some errors even in their publication, FAO is in the process of revising it. We, therefore, recommend that the figures on pages 7 and 11 of the Bureau of Commercial Fisheries Circular 312 (Osborn, Magham and Drummond, 1969) be used to portray the brown and white shrimp fisheries.

In addition, we believe that Figure 23 (page 2-87) sufficiently portrays the migration of larval and juvenile penaeid shrimps, so that the incomplete and inaccurate portrayal can be deleted from Figure 22.

Page 2-88, paragraph 1. Since the peak migration of brown shrimp to the Gulf occurs during May and June (Trent, 1966), it appears that brown shrimp migration from the estuaries is unrelated to temperature reduction.

Page 2-88, paragraph 2. The statement that white shrimp post-larvae, which come into the estuary later in the year, "overwinter in the estuaries," should be modified to state that they may overwinter in the estuaries.

It is also stated in this paragraph that "some recent information indicates that a white shrimp spawning stock occurs 5-7 miles off Bryan Beach." It should also be noted that the Associate Marine Fisheries Specialist of the Texas Agricultural Extension Service at Angleton recently informed the NMFS by letter of August 9, 1977, of documented spawning populations of white shrimp inside of the proposed diffuser site, in waters about 4 miles offshore, as well as beyond. He denoted three sites ranging about 0.8 to 3 nautical miles from the proposed diffuser site where he collected white shrimp with spermatophores, ready to spawn. He noted that during three collecting trips in 1977 they have investigated an area extending east of the Freeport jetties to west of the San Bernard River and out to 10 fathoms in search of mated shrimp. He stated that "the three sites are the only locations in which we have documented female white shrimp with spermatophores, thus far. The presence of these spermatophores indicates a definite spawning site." (A copy of the letter discussed above is being forwarded to the FEA contact designated for this EIS.) Since an alternative of placing the diffuser 12.5 N miles offshore is presented, the comparison of the shrimp resources and fishery at that location, in to 10 N miles, should be compared to these in the vicinity of the proposed site, in view of this additional information. The Associate Marine Fisheries Specialist is preparing a letter reviewing the fisheries in both the proposed location and alternate sites out to 12.5 N miles offshore. That will also be forwarded to the FEA contact when available. The final supplement EIS should also discuss all the additional information on the fisheries at each possible diffuser site. Copies of both letters should be included in the FEIS.

3. ENVIRONMENTAL IMPACTS

3.1 CONSTRUCTION

3.1.3 Terrestrial Environment
Injection Well Pipeline and Well Sites

Page 3-7, paragraph 2. This section states that "Long term loss of about 3 acres of marsh habitat...would be unavoidable...". The alternative of directionally drilling the disposal wells from nearby upland terrain should be thoroughly discussed since that would make the marsh habitat loss avoidable.

3.2 OPERATION

3.2.4 Brazos River Diversion Channel

Page 3-21, paragraph 4. The statement "Even if a worst case were assumed and all organisms within the intake waters were lost, only a negligible fraction of the biota would be lost," should be documented.

3.2.5 Gulf of Mexico Brine Diffuser

3.2.5.3 Biological Impacts of the Gulf Diffuser Operation

Page 3-37. The supplemental final environmental impact statement should include and discuss the results of bioassays recommended in the Summary and Conclusions section of the Proceedings of the Strategic Petroleum Reserve Workshop - Environmental Considerations of Brine Disposal Near Freeport, Texas, held in Houston, Texas, on February 17 and 18, 1977. It was concluded that at least three candidate organisms be selected for tolerance studies under laboratory conditions. These include: white shrimp (all life stages), red drum (adult and juvenile), and polychaete worms. It was further recommended that brine from the Bryan Mound Dome be used for these tolerance studies and that the water used to form the brine for the bioassays be from the same source as the water that will be used during the drawdown phase and when enlarging the dome by leaching. This is extremely important since, as the EIS notes, the Brazos River Diversion Channel (from which the water will be drawn) is often extremely polluted. The results of the bioassays should also be included and discussed in the final supplement.

7. ALTERNATIVES TO PROPOSED ACTIONS

7.2 BRINE DISPOSAL ALTERNATIVES

7.2.2 Gulf Diffuser System Alternatives

7.2.2.2 Alternate Diffuser Site

Page 7-7. Since locating the diffuser 10 N miles offshore would apparently locate it beyond the white shrimp spawning grounds and the sportfishing bank, this location should also be discussed as an alternative because it should involve less construction costs and less disruption of Gulf bottom than the 12.5 N mile alternative. Any additional information available concerning the fisheries in the vicinity of these sites should be discussed.

Literature Cited

Copeland, B.J. and T.J. Bechtel, 1974. Some environmental limits of six Gulf coast estuarine organisms. Contributions in Maine Science (Univ. TX) Vol. 18, p. 169-204.

Gunter, G., D.S. Ballard, and A. Venkataramiah, 1974. A review of salinity problems of organisms in United States coastal areas subject to the effects of engineering works. Gulf Research Reports (Gulf Coast Research Lab., Ocean Springs, MS) Vol. 4, No. 3, p. 380-475.

Osborn, K.W., B.W. Maghan, and S.B. Drummond, 1969. Gulf of Mexico shrimp atlas, U.S. Dept. of Int., Bur. of Comm. Fish., Circular, 312, 20p.

Trent, L., 1966. Size of brown shrimp and time of emigration from the Galveston Bay system, Texas. Proc. Gulf Carib. Fish. Inst., 19th Annual Session, p. 7-16.

COASTAL BEND CONSERVATION ASSOCIATION INC. ~~Box [illegible] Corpus Christi Texas [illegible]~~

P.O. Box 1116, Port Aransas,
Texas 78373

August 27, 1977

Executive Communications
Room 3309
Federal Energy Administration
Washington, D.C. 20461

RE: Draft Supplement, Final Environmental Impact Statement, Bryan Mound Salt Dome. FEA 76/77-6, July 1977.

Dear Sirs:

My comments here are being submitted as those of the Texas Environmental Coalition.

Following our meeting with Mr. Thomas E. Noel, Assistant Administrator, Strategic Petroleum Reserve, on July 11, 1977, at Freeport, Texas, we have had an opportunity to examine the supplemental document of which he spoke and to which we have reference in this communication. At the time of our meeting, Mr. Noel indicated that the draft supplement would answer a number of the questions raised at our meeting. On examination, we find that, though a number of the questions raised were addressed in the document, definitive answers are lacking.

Our concerns here are mainly with the impacts of placing a brine diffuser in the Gulf of Mexico, at the proposed location beginning 30,380 feet from shore and extending seaward an additional 2,000 feet. We also have some concerns regarding the construction of the brine transmission line from Bryanmound to the diffuser site.

We are in agreement with the following paragraph from Sec. 3.2.5. (page 3-21) of the draft supplement that states:

> The magnitude of the impacts of the brine discharge are an interaction of the quality of the displacement water, oil-brine reactions within the cavern, oil-brine reactions in the brine surface control facility, respective water quality parameters at the diffuser site, existing current conditions, diffuser response and salinity tolerences of the indigenous marine species, timing sequence and discharge rates.

And, we further agree that a monitering system, as described to be in the planning (in the next paragraph, page 3-22) is an absolute necessity, should the project be undertaken. The predisposal laboratory and field studies (mentioned in the same paragraph) are also a necessity, and should have been completed before this draft supplement

RECYCLED PAPER -

was prepared for distribution and comment. The subjects of the pre-disposal studies are primarily those which raised the greatest concern in our meeting with Mr. Noel, and which are most inadequately discussed in the draft supplement.

The brine tolerence of various indigenous species, and their life-cycle forms is not now known, relative to the brines under consideration, and this is made quite clear in the draft supplement, though a great deal of information of questionable applicability is presented, in an effort to demonstrate that these species may not be harmed. The assumption is made in the draft that those species that are mobile enough will move away from the highly impacted brine diffusion area, thus the conclusion (Page 5-1) "The single long-term environmental impact [of the entire project] would be the removal of 15 acres of land from present use." This conclusion discounts the real possibility of damage, especially to a known white shrimp spawning area. If the brine disposal results in mortality associated with the spawning, then a long-term impact has been created. The draft tends to play down the significance of this spawning area, as well as the shrimp fishery in this area. It further suggests that the white shrimp is not of great importance to the Texas shrimp fishery. The draft is in error on all three stands. The area under discussion is one of the few where egg-bearing white shrimp have been collected for research purposes, consistently. As recently as early August, 1977, one Gulf shrimp boat, in a six-day period landed 2,600 pounds of marketable shrimp from the immediate vicinity of the proposed diffuser site (Brazosport Facts, August 10, 1977). Also, the white shrimp is important to the fishery in terms of poundage landed as well as its seasonal catch aspect, that allows for more productive working days for the Texas fleet, that otherwise would be responding only to the seasonal catch of brown shrimp. It is also recognized (page 4-6) that the project may have an adverse impact on redfish spawning, yet this potential consequence is also glossed over by the suggestion that these fish will probably spawn elsewhere, thus, having no real effect. What data indicates that this would be the case, to the extent that there would be no adverse effect on spawning success? Data are not presented in the draft regarding the recreational fishery of the area, and the potential loss, should the project be constructed.

Water quality data, both in the diffuser area, and in relation to displacement water is scanty in the draft supplement. In fact, most conclusions of the draft are based on one set of samples, taken in April, 1977. Considerably more background data on water quality is necessary before any validity can be expected from the monitering program, and, certainly before any valid predictions can be made about how the brine may effect ambient water quality.

Biologic populations in the immediate area of impact are not described. Of special importance are the benthos, which will surely sustain some level of loss. It may be that the benthos, in combination with the yet to be examined bottom sediments of the area are in some way responsible for this being a successful spawning area for shrimp and redfish.

The coastal dynamics of the immediate vicinity of the proposed diffuser site are also not reported in the draft supplement. Data used in preparing the diffusion models were not taken from the immediate area, and do not reflect the magnitude of day-to-day and hour-to-hour changes that could take place in the local current regime. In addition, local experience indicates that the 16-day stagnation period, chosen as an extreme in the model projections, may, in fact, fall short of the extreme condition.

As we told Mr. Noel at our July meeting, the needed data for making a valid assessment of the environmental impacts of the brine diffuser in the proposed application are not in hand. Minimal sampling, by any scientific standard, has taken place in advance of preparation of the draft supplement, and crucial laboratory data is only now being collected. Any final environmental statement on this project should contain sufficient biological, chemical and physical data to approach the real questions, discussed here, concerning the impacts of the proposed brine and displacement water disposal in the Gulf of Mexico.

Regarding construction of the brine transmission line, we urge that all possible restoration techinque be employed after trench backfill on land and in the wetlands. The draft supplement indicates a recognition of this necessity, and a practical understanding of the factors and lengths of time involved. Monitering and necessary additional work should be undertaken during the restoration period to assure total restoration in the delicate areas of wetlands and dunes. Removal of excess dredge material after backfill of the pipeline trench in the Gulf is apparently not contemplated, therefore the work should be undertaken at a time when the increased turbidity and bottom sedimentation will have the least adverse environmental impact, in regard to migratory and spawning species in the vicinity. (Note: see attached letter to Col. Jon C. Vanden Bosch, District Engineer, Galveston District, Corps of Engineers, regarding permitting for this pipeline construction.)

We appreciate this opportunity to comment on the draft supplement in hand, and look forward to further consideration of this matter. If you have any questions, please do not hesitate to contact us at any time.

Very truly yours,

Steve Frishman

Steve Frishman
for the Texas Environmental Coalition

COASTAL BEND CONSERVATION ASSOCIATION, INC

Box 1118, Port Aransas, Texas
78373

August 27, 1977

Col. Jon C. Vanden Bosch
District Engineer
Galveston District
U.S. Army Corps of Engineers
P.O. Box 1229
Galveston, Texas 77553

Dear Col. Vanden Bosch:

RE: SWGCO-RP, Permit Application -12062; and the Reglatory Program of the Corps of Engineers, published in the Federal Register, July 19, 1977.

In the past we have discussed the Bryanmound Strategic Oil Reserve project in relation to the need, or lack of need, for a Sec. 404 permit in regard to construction of a 30 inch brine outlet pipeline and brine outlet diffuser in the Gulf of Mexico.

As I understand your note of 22 July 1977, it appears that you are interpreting this line and diffuser as a utility. While I may not agree that a diffuser is a utility, and may further, at some point, argue the entire concept of all pipelines being utilities, I see that you are reading the definition of"utility" in §323.4-3 (a)(1) of the 1977 regs. Therefore, we have no resolvable disagreement regarding this point.

The point I wish to press is that, in this case, according to the same citation, "excess material must be removed to an upland disposal area." I find from FEA's draft supplement to the Final Environmental Impact Statement for the project that (Sec. 3.1.6) the assumption is that the excess material will be washed away by the prevailing current, and I really can't imagine that any excess material would even be considered for removal to shore.

In addition, under §323.4-3 (b)(2) of Corps regs, "The discharge will not occur in areas of concentrated shellfish production." The FEA draft supplement (Sec. 3.1.6) states,"Dredging operations are expected to be conducted over a period of four months and would commence in November to avoid interference with the white shrimp spawning season which begins in April."

As I see it, the conditions under which a 404 permit application is not necessary have not been met on at least two fronts.

YCLED PAPER -

Further, under the new regs, it would seem that the associated oil pipeline (Public Notice SWGCO-RP, Permit Application -12112) would not require a 404 permit, though your office's notice says it does.

As you know, my concern is for process in this case, and I am seeking to retain every level possible at which public input remains at a premium. Sec. 404 gives the public a better handle than Sec. 10, and I am interested that this handle be retained to its fullest extent within existing law.

I look forward to your consideration of the points I have raised regarding this issue, and am ready to discuss the matter at your convenience.

Thank your for your interest in this matter.

Very truly yours,

Steve Frishman

Steve Frishman

p.s. I am still most easily reached by phone at 512/743-6377, or by writing the letterhead address.

cc Executive Communications
Room 3309
Federal Energy Administration
Washington, D.C. 20461

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