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HABITAT DEVELOPMENT FIELD INVESTIGATIONS, BOLIVAR PENINSULA MARSH AND UPLAND HABITAT DEVELOPMENT SITE, GALVESTON BAY, TEXAS

APPENDIX A: BASELINE INVENTORY OF WATER QUALITY, SEDIMENT QUALITY, AND HYDRODYNAMICS

by

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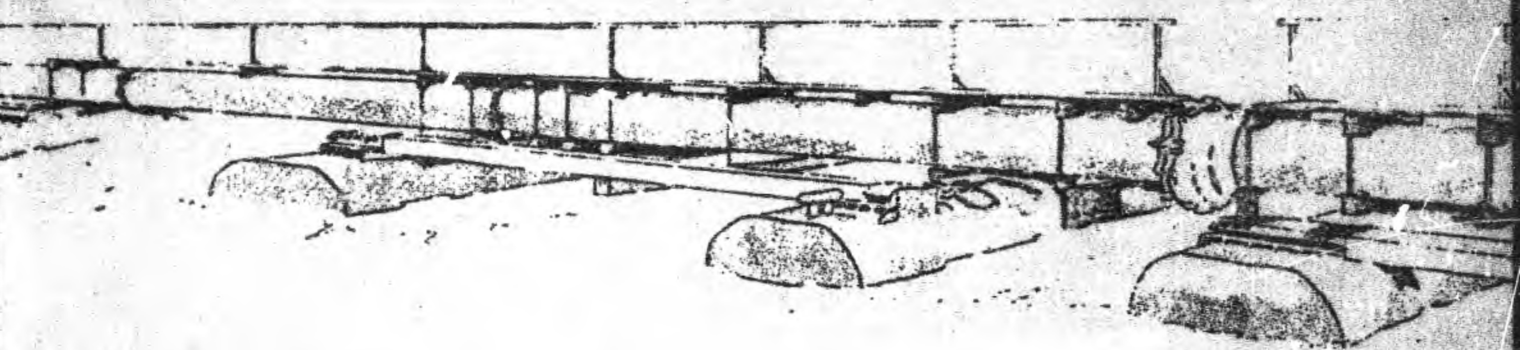

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HABITAT DEVELOPMENT FIELD INVESTIGATIONS, BOLIVAR PENINSULA
MARSH AND UPLAND HABITAT DEVELOPMENT SITE
GALVESTON BAY, TEXAS

Appendix A: Baseline Inventory of Water Quality, Sediment Quality, and Hydrodynamics

Appendix B: Baseline Inventory of Terrestrial Flora, Fauna, and Sediment Chemistry

Appendix C: Baseline Inventory of Aquatic Biota

Appendix D: Propagation of Vascular Plants and Postpropagation Monitoring of Botanical, Soil, Aquatic Biota, and Wildlife Resources

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Water and sediment quality and hydrodynamics in Galveston Bay at Bolivar Peninsula, Texas, were inventoried in connection with a proposed experimental marsh and upland habitat development project using dredged material.

Results of field studies at the site and a review of historical data considering various field parameters and nutrient, metal, insecticide, and herbicide concentrations in the water and sediments are presented; studies of tide and current conditions related to prevailing winds are described.

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20. ABSTRACT (Continued).

The water and sediments were found to be free of levels of metals or organic pollutants likely to adversely influence the experimental habitat development. Nutrient concentrations were low and dissolved oxygen values high. The site was influenced by small short-period waves that scour the sediments on the site. Water stages were between 0.85 and -0.37 m (National Geodetic Vertical Datum) 98 percent of the time and were strongly influenced by seasonal wind conditions. Winds from the northwest at 16 to 23 km/hr may lower the water stage as much as 0.30 m. Currents flowed in southwesterly and northeasterly directions with an average velocity of 21 cm/sec during usual tide and wind conditions.

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Summary

This report presents water quality, sediment quality, and hydrodynamic information collected by the U. S. Geological Survey during April, May, June, and August 1975, along with a review of selected historical data. The information was collected for use by the U. S. Army Corps of Engineers in evaluating environmental conditions at a proposed marsh and upland habitat development site on Bolivar Peninsula in Galveston Bay, Texas. The low concentrations of nitrogen and phosphorus species, the low biochemical oxygen demand (BOD), the low concentrations of heavy metals, the near absence of insecticide and herbicide residues, and the high dissolved oxygen saturation indicated that conditions at the test site were favorable for salt-marsh plant and animal growth.

Water velocities at the test site exceeded 30 cm/sec during one storm period but were less than 21 cm/sec during usual wind and tidal conditions. Water stages for 13 years of record were between 0.85 and -0.37 m (National Geodetic Vertical Datum) during 98 percent of the time. The mean water stage from October 1973 to September 1975 was 0.32 m.

The climate at the test site was described by data collected at the Galveston airport. The mean monthly air temperatures for 1940-60 were 12.3° to 28.8°C, and the mean annual temperature was 21.2°C. The mean monthly rainfall was 72.1 to 151.9 mm. The mean annual rainfall was 1160.8 mm.

Wind speeds greater than 21 km/hr, which occurred 45 percent of the days each year, caused changes in the water stages. West and northwest winds caused the greatest stage change for the least wind. Winds of 24 to 32 km/hr from any direction caused stage changes between 0.15 and 0.30 m, but southeast winds greater than 32 km/hr were required to cause more than an 0.30-m stage change.

Preface

Data presented in this report were collected under Interagency Agreement Nos. WESRF 75-95 and 76-59 dated 25 March 1975 and 18 November 1975, between the U. S. Army Engineer Waterways Experiment Station (WES), Vicksburg, Mississippi, and the U. S. Geological Survey (USGS), Austin, Texas. The agreements were sponsored by the Office, Chief of Engineers, U. S. Army, under the Dredged Material Research Program (DMRP) which was managed by the Environmental Laboratory (EL), formerly the Environmental Effects Laboratory, WES.

Field collections and observations, sample analyses, and initial data reduction were conducted under the supervision of Mr. D. C. Hahl, Chief, Texas Bays and Estuaries Project, USGS, and transmitted to the Environmental Laboratory as an open-file report, "Data on Water Quality and Hydrodynamics at the Bolivar Wetland - Habitat Development Site, Galveston, Texas." Hydrologic aspects of the open-file report are contained herein as amplified and revised by Mr. Ellis J. Clairain, Jr., Fisheries Biologist, EL. Technical reviews and revisions of text and tabular materials for publication were made by Mr. John D. Lunz, Marine Biologist, EL, and Dr. John W. Simmers, Biologist, EL. The editorial supervisor was Ms. Dorothy P. Booth.

The agreement was monitored by Mr. Lunz and coordinated by Dr. John Byrne, Site Coordinator, EL.

The project was under the general supervision of Dr. H. K. Smith, Project Manager, Habitat Development Project; Dr. C. J. Kirby, Chief, Environmental Resources Division; and Dr. John Harrison, Chief, EL.

Commanders and Directors of WES during the preparation and publication of this report were COL G. H. Hilt, CE, and COL J. L. Cannon, CE. Technical Director was Mr. F. R. Brown.

<u>Contents</u>

HABITAT DEVELOPMENT FIELD INVESTIGATIONS
BOLIVAR PENINSULA MARSH AND UPLAND
HABITAT DEVELOPMENT SITE
GALVESTON BAY, TEXAS

APPENDIX A: BASELINE INVENTORY OF WATER QUALITY, SEDIMENT QUALITY, AND HYDRODYNAMICS

Introduction

1. This report presents water quality, sediment quality, water stage, and water velocity and direction data collected by the U. S. Geological Survey (USGS) in response to a 30 January 1975 request from the U. S. Army Engineer Waterways Experiment Station (WES) to participate in a study of environmental conditions at the Bolivar Peninsula habitat development site (Figure 1).

2. The Bolivar Peninsula test site is located near lat. 29°25'N and long. 94°44'W about 20.1 km northeast of the Galveston, Texas, airport. The test site is in the Galveston Bay reach of the Trinity-San Jacinto Estuary about 6.4 km from the western end of Bolivar Peninsula.

3. The objective of the program is to develop a marsh and upland habitat complex using dredged material from the Intracoastal Waterway as a substrate. The dredged material will be protected by a dike. The objective of the work by the USGS was to document the water and sediment quality and hydrodynamic conditions at the proposed project location.

4. To achieve the objectives, the USGS scheduled hydrologic studies prior to and during development of the site. In the conduct of these studies, the USGS arranged:

- a. To review and summarize climatic data for the nearest weather station.
- b. To collect water quality and sediment quality data at the test site and to perform a literature search to ascertain the applicability of historical data.
- c. To establish a water stage recorder at the test site or determine historical water stages by correlation of

the test site data with data from a nearby long-term water stage recorder and evaluate changes in water stage due to wind velocities.

d. To measure water velocities and directions at the test site during extreme conditions.

5. The work proposal and sampling sites (Figure 2) were agreed upon by USGS and WES representatives, and work began in April 1975. By June 1975, a water stage recorder was installed; three water quality surveys were completed; water velocities were measured; and historical water quality, climatological, and water stage data were obtained. In September 1975, a change in dredging plans by the Corps of Engineers caused discontinuance of all work by the USGS except operation of the water stage recorder.

Climate

6. The test site is on the bayward side of a 3.2-km-wide barrier peninsula along the Gulf of Mexico. The following data, taken from "Climatography of the United States" (U. S. Weather Bureau 1965), indicate the mild climate of the area.

7. Mean monthly air temperatures at the Galveston airport for 21 years of record (1940-60) ranged from a high of 28.8°C to a low of 12.3°C. The mean annual temperature was 21.2°C. Air temperature for 10 years of record (1951-60) was 32.2°C or more on an average of 35 times a year and was 0°C or less on an average of only 2 times a year. The extreme temperatures recorded in Galveston during 1951-60 were 36.7° and -7.8°C.

8. Mean monthly rainfall at Galveston airport for 21 years of record (1940-60) ranged from a high of 151.9 mm to a low of 72.1 mm. The mean annual rainfall was 1160.8 mm. Rainfall for 10 years of record (1951-60) was 12.7 mm or more on an average of 23 days a year and for 7 years of record (1954-60) was 2.5 mm or less on an average of 52 days a year.

9. Frequency of wind occurrence and mean wind velocity data based on 87,690 hourly observations during the 10-year period 1951-60 (U. S. Weather Bureau 1962) for the Galveston airport are summarized in Table 1. These data show that winds occur on an average of 99 percent of the days each year and that the mean daily wind speed exceeds 21 km/hr 45 percent of the days each year.

10. The selection of the two periods shown in Table 1 is based on predominant wind directions. From March through August, wind is from the south quadrant 69 percent of the days; from September through February, wind is from the northeast quadrant 46 percent of the days.

Water and Sediment Quality

11. Water and sediment quality at the proposed site were determined by considering both historical data from the area and an analysis of water and sediment samples collected by the USGS during this project.

Historical data

12. As part of its Galveston Bay project, the Texas Water Quality Board (TWQB) conducted an extensive sampling program in the bay from July 1968 to September 1971. Samples were collected monthly from 15 to 39 stations, at 2- or 3-hour intervals during five 24-hour periods. The data collected during this period and related material are presented in a publication by Huston (1971). The TWQB site 29, located at the Hanna Reef tide gage shown in Figure 1, was sampled 27 times during the TWQB study. Review of the data from site 29 and TWQB data from other sites in Galveston Bay indicates that water quality was nearly uniform in the area of the bay between Bolivar Peninsula and Hanna Reef; therefore, data from site 29 can be considered representative of conditions at the test site from July 1968 to September 1971.

Data collection and analysis during this project

13. During April, May, June, and August 1975, in situ measurements of dissolved oxygen (DO), pH, specific conductance, and temperature were made, and laboratory analyses for nutrients, major constituents, metals,

insecticides, herbicides, and radiochemicals were performed. Specific parameters and procedures for both field collection/analysis and laboratory analysis are presented in Table 2.

14. Table 3 is a comparison of water quality data for samples collected at a depth of 0.3 m from July 1968 to September 1971 by the TWQB at site 29 and of similar data for samples collected at depths of 0.3 up to 4.9 m from April to August 1975 by the USGS at the Bolivar Peninsula test site. All of the water and sediment data collected for this project by the USGS are presented in Tables 4-10.

15. Data collected by the USGS show that the differences in chemical and physical characteristics between water in the bay and water in the Intracoastal Waterway are minor except for the dissolved oxygen concentration, which averaged about 0.5 mg/ℓ less in the Intracoastal Waterway.

16. Turbidity at the test site is a direct function of wave energy. On 14 May 1975, after 2000 hours, northerly winds increased to about 32 km/hr. The turbidity increased through the night until a predawn lessening of the wind reduced the wave heights. Through 16 May 1975, winds continued at speeds greater than 24 km/hr and the turbidity remained high. Southerly winds during the April, June, and August 1975 sampling periods were less than 24 km/hr, and the resultant turbidities were much less than in May.

17. The concentrations of nitrogen species were low, but phosphorus concentrations ranged from 0.06 to 0.35 mg/ℓ. Biochemical oxygen demand (BOD) did not exceed 2.7 mg/ℓ, indicating that a deficiency of dissolved oxygen would not occur.

18. Analyses for minor elements and pesticides showed that the concentrations of these constituents were low; most of them were too low for the analytical methods to detect. Results of an analysis for lead, mercury, and zinc based on samples collected in 1972 about 91 m from line 61C, site 40 (Galveston District 1975), showed concentrations

of the same order of magnitude as those collected by the USGS in 1975 (USGS 1976).

19. The low concentrations of nitrogen and phosphorus species, the low BOD, the low concentrations of heavy metals, the absence of insecticide and herbicide residues, and the high dissolved oxygen saturation indicate that the Bolivar Peninsula test site is nearly free of pollutants; therefore, marsh development at the site should not be adversely affected by water quality.

Water Velocities and Directions

20. Water velocities and directions were measured hourly at line 640, site 40, from 1425 hours on 14 May until 0100 hours on 16 May 1975. Surface winds during this sampling period were from the north at 24 to 32 km/hr. Measurements were repeated at this site during the period from 1300 hours on 25 June until 1200 hours on 26 June 1975. During the June sampling period, winds were from the southeast and moderate. Observations were also made on line 620, site 40, during the same periods in May and June. However, these measurements were obtained only when the water depth allowed boat access to the site. The data for both sampling periods are presented in Tables 11 and 12.

21. Water velocities and directions at line 640, site 40, differed significantly between May and June (Figure 3). In May, with the strong northerly wind predominant, water movement was to the southwest 80 percent of the time, and water velocity averaged 24.4 cm/sec. Northeasterly water movement only occurred 20 percent of the time, and water velocity averaged 21.0 cm/sec.

22. During the June sampling period, when moderate winds were from the southeast, flow at line 640, site 40, was to the southwest 38 percent of the time, and velocity averaged only about half (13.6 cm/sec) of that observed in May. Flow to the northeast, however, occurred 62 percent of the time with an average velocity of 12.5 cm/sec.

23. At line 620, site 40, close to the proposed habitat development project dike, only 7 observations were made in May and 19 in June 1975. May current measurements, made during the strong northerly wind, are presented in Figure 4. The average current velocity during the sampling period was 14.8 cm/sec, and all flow was in a southwesterly direction.

24. In June, with the moderate southeasterly winds, current velocity averaged 7.7 cm/sec for the 39 percent of the time that flow was to the southwest. During the remaining 61 percent of the time, average current velocity was 10.0 cm/sec, and flow was to the northeast (Figure 4).

25. In summary, observations made during this study show that currents flow parallel to the proposed site in Galveston Bay regardless of the tide or wind condition. Water velocities and directions are influenced by both wind and tide. Effects of northeast winds blowing water out of the bay are negated by incoming tides during short periods of large stage differences between the gulf and the bay. Velocity difference during a tide cycle or between different tide cycles is a function of head differences if wind can be ignored. Antecedent wind and water stages have a marked effect on velocities. Nearshore current speeds were lower than offshore current speeds during both sampling periods.

Water Stages

26. A water stage recorder was installed at the test site on 16 May 1975. Datum of the gage was set to that of the U. S. Army Corps of Engineers benchmark (BM) 2960 + 43.9 at 1.786 m National Geodetic Vertical Datum (NGVD) as determined in 1975. By using a water level datum transfer based on 39 days of nonstorm record, it was determined that the datum of the gage at Hanna Reef must be raised by 0.378 m to agree with the NGVD elevation for BM 2960 + 43.9.

The following discussion of water stages is based on the datum of BM 2960 + 43.9.

27. The range in water stage for the period January 1963 through September 1975 at Hanna Reef was 1.28 to -1.07 m. However, during about 98 percent of that period, water stages were between 0.85 and -0.37 m; during more than 50 percent of the period, water stages were between 0.70 and -0.21 m.

28. A few storms occurred during the period of common record between the gages at Hanna Reef and the test site. This common record indicates that water stages are the same at both places when water is being blown into the bay, but that water stages are different when water is being blown out of the bay. Tides driven by northerly winds overrun the land, and during moderate storms, the overrun persists for most of the storm period and appears to cause stages as much as 0.06 m higher at the test site than those at Hanna Reef.

29. The wake from oceangoing vessels causes significant wave action at the site. These waves are 0.3 m or more in height; they occur in groups; and they roll onto the shore with surflike action. These groups of waves, even though they occur at irregular intervals, probably will have an undetermined effect on the test site.

30. Review of the data suggests that historical records for the gage at Hanna Reef represent water stages at the test site most of the time. The mean water stage at Hanna Reef, adjusted to the datum of BM 2960 + 43.9, for the 24 months from October 1973 through September 1975 is 0.317 m. An illustration of application of the historical water stage data to the elevation specifications of the proposed habitat development project is presented by Figure 5.

Deviations of Water Stages

31. Deviations in water stage from symmetrical tidal fluctuations are usually caused by wind. Daily wind data for 1974 (National Oceanic and Atmospheric Administration 1974) were obtained from the

Galveston office of the National Weather Service, tabulated, and reduced, and tide charts for Galveston Bay at the Hanna Reef tide gage were obtained from the Galveston District. For periods of wind greater than 23 km/hr during 1974, the daily mean wind velocities and directions were selected from the National Weather Service data; corresponding deviations in tide stage as recorded on the tide charts were noted. These paired events were grouped first by wind direction and second by wind velocity. The data were then sorted by the magnitude of the change in stage. The results are given in Table 13.

32. The greatest deviations from mean water stage occur with winds from the west and northwest. It appears that westerly winds may either decrease the water stage when combined with an ebbing tide or increase the water stage by action with the flooding tide. Northwesterly winds tend to push water out of the bay or retard water entering the bay. Winds off the Gulf of Mexico from the south, southeast, and southwest all tend to increase the mean water stage by moving water into or holding water in the bay. For the period of record in 1974, wind conditions from the southeast were most common, and velocities often exceeded 32 km/hr raising water stages by 0.3 m. Less common winds from the southwest had similar effects at more moderate velocities of 24 to 32 km/hr.

33. Different antecedent wind velocities and the coincidence of peak winds with high or low tides alter the magnitude of the recorded changes in stage. Although antecedent conditions were not examined, the data in Table 13 show that different wind velocities have unique effects on water stages. The magnitude and frequency of deviation from usual tidal stages and the time of year that the deviations should occur can be inferred by a combination of the information contained in Tables 1 and 13.

34. Winter wind conditions favor a lower mean water stage than spring and summer conditions. September to February wind conditions during the 10-year period of record (1951-60) were characterized by dominant winds (condition based on percent frequency of occurrence)

varying between those that tend to increase water stages and those that decrease water stages. Strongest average wind velocities occur in winter from the north, northeast, and northwest, conditions that favor greatest downward deviations in water stage. By comparison with winter wind conditions, spring and summer winds predominantly come from southerly directions and tend to increase the mean water stage.

Conclusions and Recommendations

35. Water quality and sediment quality parameters are favorable for the establishment and growth of salt-marsh plants and animals. Phosphorus and nitrogen species were present in low concentrations as were heavy metals. Additionally, herbicide and insecticide residues were absent, BOD was low, and dissolved oxygen saturation was high.

36. Current velocities exceeded 30 cm/sec only during one storm period and were less than 21 cm/sec during usual wind and tide conditions. Water stages for 98 percent of the period January 1963-September 1975 were 0.85 to -0.37 m, and the mean water stage for the period October 1973-September 1975 was 0.317 m.

37. The historical climate information for 1940-60 indicated mean monthly temperatures of 12.3° to 28.8°C and a mean annual temperature of 21.2°C. The mean monthly rainfall was 72.1 to 151.9 mm, and the mean annual rainfall was 1160.8 mm.

38. Wind velocities greater than 21 km/hr occurred 45 percent of the days each year and caused changes in the water stage. West and northwesterly winds caused the greatest stage change for the least wind. Winds of 24 to 32 km/hr from any direction caused stage changes of 0.15 to 0.30 m, but southeasterly winds had to be greater than 32 km/hr to cause more than a 0.30-m stage change.

39. The test site is an environment characterized by high wave energy. Development of a gulf coast salt marsh would be facilitated by the absence of water and sediment pollutants but would require protection from the wave actions and water stage fluctuations, as well as selection of species adaptable to this energy regime.

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Table 1

Frequency and Mean Velocity of Surface W[illegible], Galveston Airport, 1951-1960*

	September-February				March-August			
			Percent of Days with Wind				Percent of Days with Wind	
Wind Direction	Mean Daily Wind Speed km/hr	Percent of Days with Wind	20.9-38.6 km/hr	>38.6 km/hr	Mean Daily Wind Speed km/hr	Percent of Days with Wind	20.9-38.6 km/hr	>38.6 km/hr
North	24.5	15.6	8.2	1.5	20.9	6.4	3.0	0.6
Northeast	22.0	15.0	7.0	0.8	19.5	6.4	2.7	0.1
East	20.1	15.2	6.3	0.4	19.3	9.5	4.5	0.0
Southeast	18.0	21.1	6.8	0.1	19.5	26.0	12.0	0.2
South	18.5	15.2	5.3	0.1	20.3	32.2	15.3	0.1
Southwest	18.3	5.6	2.0	0.2	18.2	10.7	4.5	0.1
West	16.7	3.9	1.1	0.1	17.1	3.6	0.8	0.1
Northwest	22.0	7.2	3.4	0.7	20.1	4.3	1.5	0.4
--	Calm	1.2	--	--	Calm	0.9	--	--
Total	--	100.0	40.1	3.9	--	100.0	44.3	1.6
Average	20.0	--	--	--	19.4	--	--	--

* Adapted from U. S. Geological Survey open-file report.

Table 2

Water and Sediment Quality Parameters and Procedures

Parameter	Sample Type	Collection/In Situ Analysis	Method of Analysis	Reference	Table
SiO_2	Water	Drawn from submerged in situ analysis probe holding manifold	Atomic absorption	Brown et al. (1974)	5
NO_3	Water (total)	"	Brucine (spectrophotometric, manual)	"	5
NH_3	Water (total)	"	Diazotization (spectrophotometric, manual)	"	5
NO_2	Water (total)	"	Distillation (spectrophotometric, manual)	"	5
Total P	Water (total)	"	Phosphomolybdate (spectrophotometric, manual)	"	5
BOD	Water (total)	"	Manometric	"	5
Ca	Water	"	Atomic absorption	"	6
Mg	Water	"	Atomic absorption	"	6
Na	Water	"	Atomic absorption	"	6
K	Water	"	Atomic absorption	"	6
HCO_3	Water	"	Manual calculation	"	6
SO_4	Water	"	Thorin (spectrophotometric, manual)	"	6

(Continued)

Table 2 (Continued)

Parameter	Sample Type	Collection/In Situ Analysis	Method of Analysis	Reference	Table
Cl (Chloride)	Water	Drawn from submerged in situ analysis probe holding manifold	Mohr (Titrimetric, manual)	Brown et al. (1974)	6
Total dissolved solids	Water	"	Manual calculation	"	6
Al (aluminum)	Water	"	Ferron-orthophenanthroline (spectrophotometric, manual)	"	7
As	Water	"	Silver-diethyldithiocarbamate (spectrophotometric, manual)	"	7
	Sediment	Ponar grab	Silver-diethyldithiocarbamate (spectrophotometric, manual)	"	7
Cd	Water	Drawn from manifold	Atomic absorption	"	7
	Sediment	Ponar grab	Atomic absorption	"	7
Cr	Water	Drawn from manifold	Atomic absorption	"	7
Co	Water	Drawn from manifold	Atomic absorption	"	7
	Sediment	Ponar grab	Atomic absorption	"	7
Cu	Water	Drawn from manifold	Atomic absorption	"	7
	Sediment	Ponar grab	Atomic absorption	"	7

(Continued)

Table 2 (Continued)

Parameter	Sample Type	Collection/In Situ Analysis	Method of Analysis	Reference	Table
CN	Sediment	Ponar grab	Pyridine-pyrazolone (spectrophotometric, manual)	Brown et al. (1974)	7
Fe	Water	Drawn from manifold	Atomic absorption	"	7
Pb	Water	Drawn from manifold	Atomic absorption	"	7
	Sediment	Ponar grab	Atomic absorption	"	7
Li	Water	Drawn from manifold	Atomic absorption	"	7
Mn	Water	Drawn from manifold	Atomic absorption	"	7
	Sediment	Ponar grab	Atomic absorption	"	7
Hg	Water	Drawn from manifold	Atomic absorption	USGS (1976)	7
	Sediment	Ponar grab	Atomic absorption	USGS (1976)	7
Ni	Water	Drawn from manifold	Atomic absorption	Brown et al. (1974)	7
Sr	Water	Drawn from manifold	Atomic absorption	"	7
Zn	Water	Drawn from manifold	Atomic absorption	"	7
	Sediment	Ponar grab	Atomic absorption	"	7
Aldrin	Water (total)	Drawn from manifold	Gas chromatography	Goerlitz and Brown (1972)	8
	Sediment	Ponar grab	Gas chromatography	"	8
Chlordane	Water (total)	Drawn from manifold	Gas chromatography	"	8
	Sediment	Ponar grab	Gas chromatography	"	8

(Continued)

(Sheet 3 of 6)

Table 2 (Continued)

Parameter	Sample Type	Collection/In Situ Analysis	Method of Analysis	Reference	Table
DDD	Water (total)	Drawn from manifold	Gas chromatography	Goerlitz and Brown (1972)	8
	Sediment	Ponar grab	"	"	8
DDE	Water (total)	Drawn from manifold	"	"	8
	Sediment	Ponar grab	"	"	8
DDT	Water (total)	Drawn from manifold	"	"	8
	Sediment	Ponar grab	"	"	8
Dieldrin	Water (total)	Drawn from manifold	"	"	8
	Sediment	Ponar grab	"	"	8
Endrin	Water (total)	Drawn from manifold	"	"	8
	Sediment	Ponar grab	"	"	8
Heptachlor	Water (total)	Drawn from manifold	"	"	8
	Sediment	Ponar grab	"	"	8
Heptachlor-epoxide	Water (total)	Drawn from manifold	"	"	8
	Sediment	Ponar grab	"	"	8
Lindane	Water (total)	Drawn from manifold	"	"	8
	Sediment	Ponar grab	"	"	8
Parathion	Water (total)	Drawn from manifold	"	"	8
Methyl parathion	Water (total)	Drawn from manifold	"	"	8

(Continued)

Table 2 (Continued)

Parameter	Sample Type	Collection/In Situ Analysis	Method of Analysis	Reference	Table
Malathion	Water (total)	Drawn from manifold	Gas chromatography	Goerlitz and Brown (1972)	8
Diazinon	Water (total)	Drawn from manifold	"	"	8
PCB	Water (total)	Drawn from manifold	"	"	8
	Sediment	Ponar grab	"	"	8
2,4-D	Water (total)	Drawn from manifold	"	"	8
	Sediment	Ponar grab	"	"	8
2,4,5-T	Water (total)	Drawn from manifold	"	"	8
	Sediment	Ponar grab	"	"	8
Silvex	Water (total)	Drawn from manifold	"	"	8
	Sediment	Ponar grab	"	"	8
Toxaphene	Water (total)	Drawn from manifold	"	"	8
	Sediment	Ponar grab	"	"	8
Ethion	Water (total)	Drawn from manifold	"	"	8
	Sediment	Ponar grab	"	"	8
Methyl-trithion	Water (total)	Drawn from manifold	"	"	8
	Sediment	Ponar grab	"	"	8
Trithion	Water (total)	Drawn from manifold	"	"	8
	Sediment	Ponar grab	"	"	8

(Continued)

Table 2 (Concluded)

Parameter	Sample Type	Collection/In Situ Analysis	Method of Analysis	Reference	Table
Organic Carbon	Water	Drawn from manifold	Infrared analysis	Goerlitz and Brown (1972)	9
	Suspended	Drawn from manifold	"	"	9
	Total	Drawn from manifold	"	"	9
RA-226	Water	Drawn from manifold	"	"	10
U	Water	Drawn from manifold	"	"	10
Gross α (U-NAT)	Water	Drawn from manifold	"	"	10
	Suspended	Drawn from manifold	"	"	10
Gross β (SR 90/Y 90)	Water	Drawn from manifold	"	"	10
	Suspended	Drawn from manifold	"	"	10
Gross β (CS-137)	Water	Drawn from manifold	"	"	10
	Suspended	Drawn from manifold	"	"	10
Filterable residue	Water (total)	Drawn from manifold	"	"	10
Nonfilterable residue	Water (total	Drawn from manifold	"	"	10

(Sheet 6 of 6)

Table 3

Comparison of Water Quality Data Collected Near Hanna Reef With That Collected Near Bolivar Peninsula Test Site

Parameter	Hanna Reef Site 29 Data*	Bolivar Peninsula Test Site Data**	Mean Value at Surface+ For All Sampling Sites
Organic nitrogen, mg/ℓ			--
Maximum	1.3	--	
Minimum	0.4	--	
Mean ($\bar{x}$)	0.7	--	
Total nitrate, mg/ℓ			0
Maximum	0.2	0.0	
Minimum	<0.05	0.0	0
Mean ($\bar{x}$)	0.1	--	0
Ammonia nitrogen, mg/ℓ			
Maximum	1.3	0.13	
Minimum	0.0	0.00	0.01
Mean ($\bar{x}$)	0.06	--	0.02
Total nitrite, mg/ℓ			
Maximum	0.05	0.01	
Minimum	<0.005	0.00	0.005
Mean ($\bar{x}$)	0.01	--	0.003
Total phosphorus, mg/ℓ			
Maximum	0.63	0.35	
Minimum	0.06	0.06	0.18
Mean ($\bar{x}$)	0.28	--	0.19

(Continued)

Table 3 (Continued)

Parameter	Hanna Reef Site 29 Data*	Bolivar Peninsula Test Site Data**	Mean Value at Surface+ For All Sampling Sites
Dissolved organic carbon, mg/ℓ			
Maximum	--	15	
Minimum	--	5.0	6.5
Mean ($\bar{x}$)	--	--	7.5
Suspended organic carbon, mg/ℓ			
Maximum	--	1.4	
Minimum	--	0.6	0.9
Mean ($\bar{x}$)	--	--	1.0
Dissolved oxygen, mg/ℓ			
Maximum	11.1	10.1	
Minimum	5.4	5.6	8.6
Mean ($\bar{x}$)	8.0	--	8.2
BOD, mg/ℓ			
Maximum	4	2.7	
Minimum	0	0.5	1.4
Mean ($\bar{x}$)	2	--	1.7
Total coliform, MPN/100 ml			
Maximum	200	--	
Minimum	<2	--	
Mean ($\bar{x}$)	15	--	
Fecal coliform, MPN/100 ml			
Maximum	23	--	
Minimum	<2	--	
Mean ($\bar{x}$)	<2	--	

(Continued)

Table 3 (Concluded)

Parameter	Hanna Reef Site 29 Data*	Bolivar Peninsula Test Site Data**	Mean Value at Surface+ For All Sampling Sites
Specific conductance, µmhos			
Maximum	37,600	30,000	
Minimum	7,400	11,000	14,655.2
Mean ($\bar{x}$)	22,300	--	14,755.6
Turbidity, JTU			
Maximum	--	275	
Minimum	--	5	69.1
Mean ($\bar{x}$)	--	--	97.9
Temperature, $^{\circ}C$			
Maximum	30.2	29.0	
Minimum	7.6	23.3	26.4
Mean ($\bar{x}$)	20.3	--	26.1

(Sheet 3 of 3)

Note: It should be remembered that the Hanna Reef Site 29 data were collected monthly over a period exceeding 3 years (Huston 1971), and that the Bolivar Peninsula test site data were collected by the USGS during 4 months of a single year (1975).

*Based on samples collected from a depth of 0.3 m.

**Based on samples collected from a depth of 0.3 m and other depths up to 4.9 m.

+Surface samples are those collected from a depth of 0.3 m.

Table 4

Bolivar Peninsula Test Site Data; Field Determinations*

Date of Collection	Time	Site	Depth (m)	Specific Conductance (μmhos) (Field)	Temperature (°C)	pH	Dissolved Oxygen (mg/ℓ)	Percent Saturation	Turbidity (JTU)	Transparency Secchi Disk (cm)
				Line 610						
Apr 25, 75	1500	40	0.3	18000	24.7	8.2	8.8	111	10	--
			1.5	18000	24.6	8.2	8.7	110	5	--
			3.0	19000	23.9	8.2	8.2	102	10	--
			4.9	19000	23.9	8.1	8.1	101	10	--
Jun 24, 75	1245	40	0.3	16000	27.2	8.3	7.9	103	25	62
			1.5	16000	27.2	8.2	7.5	97	25	--
			3.0	18000	27.2	8.2	6.9	91	25	--
			4.9	18000	27.2	8.2	7.0	92	50	--
Aug 06, 75	1040	40	0.3	23000	28.8	--	7.2	100	10	81
			1.5	23000	28.0	--	5.6	77	20	--
			3.0	30000	28.2	--	6.0	86	15	--
			4.6	30000	28.0	--	5.9	84	15	--
				Line 620						
Apr 25, 75	1430	40	0.3	19000	26.7	8.4	9.3	122	15	--
			0.6	19000	26.6	8.4	9.3	122	30	--
Jun 24, 75	1400	40	0.3	17000	26.6	8.3	9.2	121	50	45
			0.6	17000	26.6	8.3	8.8	116	50	--

(Continued)

* Taken from U. S. Geological Survey open-file report.

Table 4 (Continued)

Date of Collection	Time	Site	Depth (m)	Specific Conductance (μmhos) (Field)	Temperature (°C)	pH	Dissolved Oxygen (mg/ℓ)	Percent Saturation	Turbidity (JTU)	Transparency Secchi Disk (cm)
				Line 620 Continued						
Aug 06, 75	1245	40	0.5	17000	29.0	--	8.7	119	--	--
				Line 630						
Apr 25, 75	1415	40	0.3	19000	25.3	8.4	9.5	122	10	--
			1.1	19000	25.2	8.4	9.5	120	10	--
Jun 24, 75	1345	40	0.3	16000	26.9	8.3	8.7	114	25	55
			1.2	17000	26.7	8.3	8.1	107	40	--
Aug 06, 75	1230	40	0.3	18000	28.5	--	8.0	108	15	--
			1.1	25000	28.0	--	7.0	97	20	--
				Line 640						
Apr 25, 75	1330	40	0.3	18000	24.9	8.4	9.3	118	10	--
			0.9	18000	24.7	8.4	9.3	118	10	--
			1.4	18000	24.6	8.4	9.1	115	10	--
May 14, 75	1425	40	0.3	13000	27.7	--	9.1	118	55	--
			1.2	13000	27.0	--	9.3	119	70	--
May 14, 75	1500	40	0.3	14000	27.9	--	9.1	120	40	--
			1.2	14000	26.8	--	8.8	113	85	--
May 14, 75	1600	40	0.3	13000	28.2	--	9.6	126	35	--
			1.4	15000	26.5	--	8.9	114	80	--

(Continued)

Table 4 (Continued)

Date of Collection	Time	Site	Depth (m)	Specific Conductance (μmhos) (Field)	Temperature (°C)	pH	Dissolved Oxygen (mg/ℓ)	Percent Saturation	Turbidity (JTU)	Transparency Secchi Disk (cm)
				Line 640 Continued						
May 14, 75	1700	40	0.3	13000	28.3	--	10.1	133	30	--
			1.4	15000	26.6	--	7.2	94	60	--
May 14, 75	1805	40	0.3	14000	27.8	--	10.0	132	30	--
			1.4	15000	26.5	--	7.4	95	50	--
May 14, 75	1900	40	0.3	14000	27.6	--	9.8	127	30	--
			1.4	17000	26.4	--	7.2	94	60	--
May 14, 75	2000	40	0.3	14000	27.3	--	9.3	121	30	--
			1.4	15000	26.5	--	7.6	97	50	--
May 14, 75	2230	40	0.6	12000	26.8	8.2	8.9	114	--	--
			1.4	12000	26.8	8.1	8.7	112	120	--
May 14, 75	2400	40	0.6	12000	26.3	8.3	8.3	105	--	--
			1.2	12000	26.3	8.2	8.2	104	170	--
May 15, 75	0105	40	1.1	11000	25.5	8.1	8.2	101	190	--
May 15, 75	0205	40	1.1	12000	25.0	8.3	7.9	98	230	--
May 15, 75	0305	40	1.1	12000	24.7	8.2	7.9	98	180	--
May 15, 75	0410	40	1.0	12000	24.4	8.2	7.9	96	170	--
May 15, 75	0505	40	1.0	12000	24.0	7.9	7.9	96	180	--
May 15, 75	0610	40	1.1	12000	23.8	8.2	7.9	96	170	--
May 15, 75	0710	40	1.2	11000	23.4	8.2	7.8	93	180	--

(Continued)

Table 4 (Continued)

Date of Collection	Time	Site	Depth (m)	Specific Conductance (μmhos) (Field)	Temperature (°C)	pH	Dissolved Oxygen (mg/ℓ)	Percent Saturation	Turbidity (JTU)	Transparency Secchi Disk (cm)
				Line 640 Continued						
May 15, 75	0810	40	1.1	11000	23.7	8.3	7.6	90	130	--
May 15, 75	0930	40	0.3	12000	24.3	8.4	7.7	94	140	--
			1.2	12000	23.9	8.0	7.9	96	240	--
May 15, 75	1000	40	0.3	12000	24.5	8.4	7.6	93	130	--
			1.2	12000	24.4	8.2	7.7	94	260	--
May 15, 75	1100	40	0.3	12000	24.4	--	7.8	95	120	--
			1.2	12000	24.5	--	7.9	96	200	--
May 15, 75	1200	40	0.3	12000	24.8	--	7.9	98	105	--
			1.2	12000	24.9	--	8.0	99	200	--
May 15, 75	1300	40	0.3	12000	25.2	--	8.1	100	80	--
			1.2	12000	25.4	--	8.2	102	100	--
May 15, 75	1400	40	0.3	12000	25.4	--	8.5	106	100	--
			1.2	12000	25.7	--	8.5	106	95	--
May 15, 75	1500	40	0.3	12000	25.1	--	8.4	104	115	--
			1.4	12000	25.1	--	8.6	106	150	--
May 15, 75	1600	40	0.3	12000	25.3	--	8.4	105	150	--
			1.2	12000	25.2	--	8.8	109	225	--
May 15, 75	1700	40	0.3	11000	25.7	--	8.0	99	210	--
			1.2	11000	25.7	--	8.3	102	275	--

(Continued)

Table 4 (Concluded)

Date of Collection	Time	Site	Depth (m)	Specific Conductance (μmhos) (Field)	Temperature (^{o}C)	pH	Dissolved Oxygen (mg/ℓ)	Percent Saturation	Turbidity (JTU)	Transparency Secchi Disk (cm)
				Line 640 Continued						
May 15, 75	1800	40	0.3	11000	25.4	--	8.2	101	190	--
			1.2	11000	25.5	--	8.3	102	270	--
May 15, 75	1900	40	0.3	11000	25.2	--	8.1	99	200	--
			1.2	11000	25.3	--	8.5	105	200	--
May 15, 75	2010	40	0.6	11000	24.9	--	8.1	99	--	--
			1.3	11000	24.8	--	8.2	100	200	--
May 15, 75	2110	40	0.6	11000	24.6	--	8.0	98	--	--
			1.3	11000	24.5	--	8.1	98	240	--
May 15, 75	2210	40	0.6	11000	24.4	--	7.9	96	--	--
			1.2	12000	24.2	--	7.9	96	180	--
May 15, 75	2300	40	0.6	12000	24.0	--	7.9	96	--	--
			1.2	12000	23.8	--	7.9	96	200	--
May 15, 75	2400	40	0.6	13000	23.6	--	7.9	95	--	--
			1.1	13000	23.5	--	7.9	95	150	--
May 16, 75	0100	40	0.6	12000	23.4	--	7.8	94	--	--
			1.1	12000	23.3	--	7.9	95	130	--
Jun 24, 75	1320	40	0.3	16000	26.9	8.3	8.5	112	25	53
			1.4	19000	27.3	8.2	6.8	91	60	--
Aug 06, 75	1215	40	0.3	21000	28.4	--	7.4	101	20	--
			1.2	28000	28.4	--	6.3	89	20	--

(Sheet 5 of 5)

Table 5

Bolivar Peninsula Test Site Data: Nutrients and Other Environmental Characteristics*

Date of Collection	Time	Site	Depth (m)	Dissolved Silica (SiO_2) (mg/ℓ)	Total Nitrate (N) (mg/ℓ)	Ammonia Nitrogen (N) (mg/ℓ)	Total Nitrite (N) (mg/ℓ)	Dissolved Phosphorus Ortho (P) (mg/ℓ)	Total Phosphorus (P) (mg/ℓ)	Biochemical Oxygen Demand (BOD) (mg/ℓ)	Chemical Oxygen Demand (COD) (mg/ℓ)
					Line 610						
Apr 25, 75	1500	40	0.3	2.2	0.0	0.00	0.00	--	0.06	2.3	--
			4.9	2.1	0.0	0.02	0.00	--	0.08	2.3	--
Jun 24, 75	1245	40	0.3	2.5	0.0	0.04	0.00	--	0.19	1.2	--
			4.9	2.4	0.0	0.07	0.01	--	0.15	1.0	--
Aug 06, 75	1040	40	0.3	--	0.0	0.01	0.01	--	0.27	--	--
			4.6	4.4	0.0	0.01	0.01	--	0.27	1.4	--
					Line 620						
Apr 25, 75	1430	40	0.6	1.9	0.0	0.01	0.00		0.08	2.5	--
Jun 24, 75	1400	40	0.3	2.5	0.0	0.01	0.01	--	0.18	1.1	--
Aug 06, 75	1245	40	0.5	6.4	0.0	0.01	0.00	--	0.28	2.1	--
					Line 630						
Apr 25, 75	1415	40	1.1	2.2	0.0	0.00	0.00	--	0.07	2.1	--
Jun 24, 75	1345	40	0.3	2.5	0.0	0.01	0.01	--	0.17	0.6	--
Aug 06, 75	1230	40	1.1	--	0.0	0.03	0.00	--	0.35	--	--
					Line 640						
Apr 25, 75	1330	40	0.3	2.1	0.0	0.01	0.00	--	0.09	2.4	--
			1.4	2.1	0.0	0.01	0.00	--	0.10	2.3	--
Jun 24, 75	1320	40	0.3	2.6	0.0	0.01	0.01	--	0.17	0.9	--
			1.4	2.5	0.0	0.13	0.00	--	0.22	0.5	--
Aug 06, 75	1215	40	0.3	--	0.0	0.01	0.00	--	0.27	--	--
			1.2	4.6	0.0	0.01	0.00	--	0.31	2.7	--

* Taken from U. S. Geological Survey open-file report.

Table 6

Bolivar Peninsula Test Site Data; Major Constituents*

Date of Collection	Time	Site	Depth (m)	Dissolved Calcium (Ca) (mg/ℓ)	Dissolved Magnesium (Mg) (mg/ℓ)	Dissolved Sodium (Na) (mg/ℓ)	Dissolved Potassium (K) (mg/ℓ)	Bicarbonate (HCO_3) (mg/ℓ)	Dissolved Sulfate (SO_4) (mg/ℓ)	Dissolved Chloride (Cl) (mg/ℓ)	Dissolved Solids (Sum of Constituents) (mg/ℓ)
						Line 610					
Apr 25, 75	1500	40	0.3	150.0	390.0	3400	130	117	850	6000	11000
			4.9	150.0	400.0	3400	140	116	870	6100	11100
Jun 24, 75	1245	40	0.3	140.0	350.0	3100	120	115	760	5400	9930
			4.9	160.0	410.0	3600	180	115	880	6200	11500
Aug 06, 75	1040	40	0.3	—	—	—	—	—	—	—	—
			4.6	290.0	750.0	6600	260	138	1300	11000	20400
						Line 620					
Apr 25, 75	1430	40	0.6	160.0	410.0	3600	140	119	940	6400	11700
Jun 24, 75	1400	40	0.3	150.0	380.0	3300	140	108	950	5800	10800
Aug 06, 75	1245	40	0.3	150.0	360.0	3200	130	128	740	5600	10300
						Line 630					
Apr 25, 75	1415	40	1.1	160.0	410.0	3500	140	117	970	6200	11400
Jun 24, 75	1345	40	0.3	140.0	350.0	3100	130	111	790	5500	10100
Aug 06, 75	1230	40	1.1	—	—	—	—	—	—	—	—
						Line 640					
Apr 25, 75	1330	40	0.3	150.0	400.0	3400	140	119	870	6200	11200
			1.4	150.0	400.0	3400	140	119	770	6000	10900
May 15, 75	0710	40	1.2	—	—	—	—	—	—	—	—
May 15, 75	2010	40	0.6	—	—	—	—	—	—	—	—
Jun 24, 75	1320	40	0.3	140.0	420.0	3100	130	111	780	5500	10100
			1.4	160.0	360.0	3600	150	117	930	6400	11700
Aug 06, 75	1215	40	0.3	—	—	—	—	—	—	—	—
			1.2	250.0	740.0	5900	250	135	1600	11000	19800

* Taken from U. S. Geological Survey open-file report.

Table 7

Bolivar Peninsula Test Site Data; Selected Ions Analyses*

Date of Collection	Time	Site	Depth (m)	Dissolved Aluminum (Al) (µg/ℓ)	Dissolved Arsenic (As) (µg/ℓ)	Total Arsenic (As) (µg/ℓ)	Bottom Deposit Arsenic (As) (µg/g)	Dissolved Cadmium (Cd) (µg/ℓ)	Total Cadmium (Cd) (µg/ℓ)	Bottom Deposit Cadmium (Cd) (µg/g)
				Line 610						
Apr 25, 75	1500	40	0.3	10	0	--	--	0	--	--
			4.9	10	0	--	2	0	--	<10.0
Jun 24, 75	1245	40	0.3	20	1	--	--	0	--	--
			4.9	20	1	--	--	0	--	--
				Line 620						
Apr 25, 75	1430	40	0.6	10	1	--	1	0	--	<10.0
Jun 24, 75	1400	40	0.3	20	1	--	--	0	--	--
				Line 630						
Apr 25, 75	1415	40	1.1	10	1	--	1	0	--	<10.0
Jun 24, 75	1345	40	0.3	9	2	--	--	0	--	--
				Line 640						
Apr 25, 75	1330	40	0.3	0	1	--	--	0	--	--
			1.4	10	1	--	1	0	--	<10.0
Jun 24, 75	1320	40	0.3	6	1	--	--	0	--	--
			1.4	20	1	--	--	0	--	--

(Continued)

* Taken from U. S. Geological Survey open-file report.

(Sheet 1 of 5)

Table 7 (Continued)

Date of Collection	Time	Site	Depth (m)	Dissolved Chromium (Cr) (µg/ℓ)	Total Chromium (Cr) (µg/ℓ)	Dissolved Cobalt (Co) (µg/ℓ)	Total Cobalt (Co) (µg/ℓ)	Bottom Deposit Cobalt (Co) (µg/g)	Dissolved Copper (Cu) (µg/ℓ)	Total Copper (Cu) (µg/ℓ)	Bottom Deposit Copper (Cu) (µg/g)
				Line 610							
Apr 25, 75	1500	40	0.3	0	--	0	--	--	4.0	--	--
			4.9	0	--	0	--	<10.0	2.0	--	<10.0
Jun 24, 75	1245	40	0.3	0	--	0	--	--	4.0	--	--
			4.9	0	--	0	--	--	5.0	--	--
				Line 620							
Apr 25, 75	1430	40	0.6	0	--	0	--	<10.0	12.0	--	<10.0
Jun 24, 75	1400	40	0.3	0	--	0	--	--	1.0	--	--
				Line 630							
Apr 25, 75	1415	40	1.1	0	--	0	--	<10.0	2.0	--	<10.0
Jun 24, 75	1345	40	0.3	0	--	0	--	--	4.0	--	--
				Line 640							
Apr 25, 75	1330	40	0.3	0	--	0	--	--	2.0	--	--
			1.4	0	--	0	--	<10.0	6.0	--	<10.0
Jun 24, 75	1320	40	0.3	0	--	0	--	--	1.0	--	--
			1.4	0	--	0	--	--	2.0	--	--

(Continued)

Table 7 (Continued)

Date of Collection	Time	Site	Depth (m)	Dissolved Cyanide (Cn) (mg/ℓ)	Bottom Deposit Cyanide (Cn) (µg/g)	Dissolved Iron (Fe) (µg/ℓ)	Total Iron (Fe) (µg/ℓ)	Bottom Deposit Iron (Fe) (µg/g)	Dissolved Lead (Pb) (µg/ℓ)	Total Lead (Pb) (µg/ℓ)	Bottom Deposit Lead (Pb) (µg/g)
					Line 610						
Apr 25, 75	1500	40	0.3	—	—	40	—	—	0	—	—
			4.9	—	0.0	40	—	—	0	—	<10.0
Jun 24, 75	1245	40	0.3	—	—	40	—	—	0	—	—
			4.9	—	—	40	—	—	0	—	—
					Line 620						
Apr 25, 75	1430	40	0.6	—	0.0	50	—	—	1	—	<10.0
Jun 24, 75	1400	40	0.3	—	—	40	—	—	0	—	—
					Line 630						
Apr 25, 75	1415	40	1.1	—	0.0	50	—	—	1	—	<10.0
Jun 24, 75	1345	40	0.3	—	—	40	—	—	0	—	—
					Line 640						
Apr 25, 75	1330	40	0.3	—	—	40	—	—	0	—	—
			1.4	—	0.0	40	—	—	0	—	<10.0
Jun 24, 75	1320	40	0.3	—	—	40	—	—	0	—	—
			1.4	—	—	40	—	—	0	—	—

(Continued)

Table 7 (Continued)

Date of Collection	Time	Site	Depth (m)	Dissolved Lithium (Li) (μg/ℓ)	Dissolved Manganese (Mn) (μg/ℓ)	Total Manganese (Mn) (μg/ℓ)	Bottom Deposit Manganese (Mn) (μg/g)	Dissolved Mercury (Hg) (μg/ℓ)	Total Mercury (Hg) (μg/ℓ)	Bottom Deposit Mercury (Hg) (μg/g)	Dissolved Nickle (Ni) (μg/ℓ)	Dissolved Strontium (Sr) (μg/ℓ)
Line 610												
Apr 25, 75	1500	40	0.3	60	10	--	--	0.3	--	--	0	2400
			4.9	50	10	--	140	0.1	--	0.9	1	2300
Jun 24, 75	1245	40	0.3	50	10	--	--	0.0	--	--	0	2100
			4.9	60	10	--	--	0.0	--	--	0	2400
Line 620												
Apr 25, 75	1430	40	0.6	50	10	--	50	0.1	--	0.7	4	2500
Jun 24, 75	1400	40	0.3	60	10	--	--	0.0	--	--	0	2200
Line 630												
Apr 25, 75	1415	40	1.1	50	10	--	70	0.1	--	1.3	1	2400
Jun 24, 75	1345	40	0.3	50	10	--	--	0.0	--	--	1	--
Line 640												
Apr 25, 75	1330	40	0.3	50	10	--	--	0.2	--	--	0	2300
			1.4	50	10	--	80	0.1	--	1.3	1	2300
Jun 24, 75	1320	40	0.3	50	10	--	--	0.0	--	--	0	2100
			1.4	60	10	--	--	0.0	--	--	1	2300

(Continued)

Table 7 (Concluded)

Date of Collection	Time	Site	Depth (m)	Dissolved Zinc (Zn) (µg/ℓ)	Total Zinc (Zn) (µg/ℓ)	Bottom Deposit Zinc (Zn) (µg/g)
				Line 610		
Apr 25, 75	1500	40	0.3	80	—	—
			4.9	40	—	20.0
Jun 24, 75	1245	40	0.3	110	—	—
			4.9	110	—	—
				Line 620		
Apr 25, 75	1430	40	0.6	40	—	<10.0
Jun 24, 75	1400	40	0.3	60	—	—
				Line 630		
Apr 25, 75	1415	40	1.1	60	—	<10.0
Jun 24, 75	1345	40	0.3	110	—	—
				Line 640		
Apr 25, 75	1330	40	0.3	40	—	—
			1.4	40	—	<10.0
Jun 24, 75	1320	40	0.3	30	—	—
			1.4	80	—	—

Table 8

Bolivar Peninsula Test Site Data; Insecticide and Herbicide Analyses*

Date of Collection	Time	Site	Depth (m)	Total Aldrin (µg/ℓ)	Bottom Deposit Aldrin (µg/kg)	Total Chlordane (µg/ℓ)	Bottom Deposit Chlordane (µg/kg)	Total DDD (µg/ℓ)	Bottom Deposit DDD (µg/kg)	Total DDE (µg/ℓ)	Bottom Deposit DDE (µg/kg)
						Line 610					
Apr 25, 75	1500	40	0.3	0.00	—	0.0	—	0.00	—	0.00	—
			4.9	0.00	0.0	0.0	0.0	0.00	0.0	0.00	0.0
Jun 24, 75	1245	40	0.3	0.00	—	0.0	—	0.00	—	0.00	—
			4.9	0.00	—	0.0	—	0.00	—	0.00	—
Aug 06, 75	1040	40	4.6	—	0.0	—	0.0	—	0.0	—	0.0
						Line 620					
Apr 25, 75	1430	40	0.6	0.00	—	0.0	—	0.00	—	0.00	—
Jun 24, 75	1400	40	0.3	0.00	—	0.0	—	0.00	—	0.00	—
Aug 06, 75	1245	40	0.5	—	0.0	—	0.0	—	0.0	—	0.0
						Line 630					
Apr 25, 75	1415	40	0.3	0.00	—	0.0	—	0.00	—	0.00	—
			1.1	—	0.0	—	0.0	—	0.0	—	0.0
Jun 24, 75	1345	40	0.3	0.00	—	0.0	—	0.00	—	0.00	—
						Line 640					
Apr 25, 75	1330	40	0.3	0.00	—	0.0	—	0.00	—	0.00	—
			1.4	0.00	0.0	0.0	0.0	0.00	0.4	0.00	0.0
Jun 24, 75	1320	40	0.3	0.00	—	0.0	—	0.00	—	0.00	—
			1.4	0.00	—	0.0	—	0.00	—	0.00	—
Aug 06, 75	1215	40	1.2	—	0.0	—	0.0	—	0.0	—	0.0

(Continued)

* Taken from U. S. Geological Survey open-file report.

Table 8 (Continued)

Date of Collection	Time	Site	Depth (m)	Total DDT (µg/ℓ)	Bottom Deposit DDT (µg/kg)	Total Dieldrin (µg/ℓ)	Bottom Deposit Dieldrin (µg/kg)	Total Endrin (µg/ℓ)	Bottom Deposit Endrin (µg/kg)	Total Heptachlor (µg/ℓ)	Bottom Deposit Heptachlor (µg/kg)
						Line 610					
Apr 25, 75	1500	40	0.3	0.00	—	0.00	—	0.00	—	0.00	—
			4.9	0.00	0.0	0.00	0.1	0.00	0.0	0.00	0.0
Jun 24, 75	1245	40	0.3	0.00	—	0.00	—	0.00	—	0.00	—
			4.9	0.00	—	0.00	—	0.00	—	0.00	—
Aug 06, 75	1040	40	4.6	—	0.0	—	0.0	—	0.0	—	0.0
						Line 620					
Apr 25, 75	1430	40	0.6	0.00	—	0.00	—	0.00	—	0.00	—
Jun 24, 75	1400	40	0.3	0.00	—	0.00	—	0.00	—	0.00	—
Aug 06, 75	1245	40	0.5	—	0.0	—	0.0	—	0.0	—	0.0
						Line 630					
Apr 25, 75	1415	40	0.3	0.00	—	0.00	—	0.00	—	0.00	—
			1.1	—	0.0	—	0.0	—	0.0	—	0.0
Jun 24, 75	1345	40	0.3	0.00	—	0.00	—	0.00	—	0.00	—
						Line 640					
Apr 25, 75	1330	40	0.3	0.00	—	0.00	—	0.00	—	0.00	—
			1.4	0.00	0.0	0.00	0.0	0.00	0.0	0.00	0.0
Jun 24, 75	1320	40	0.3	0.00	—	0.00	—	0.00	—	0.00	—
			1.4	0.00	—	0.00	—	0.00	—	0.00	—
Aug 06, 75	1215	40	1.2	—	0.0	—	0.0	—	0.0	—	0.0

(Continued)

Table 8 (Continued)

Date of Collection	Time	Site	Depth (m)	Total Heptachlor Epoxide (µg/ℓ)	Bottom Deposit Heptachlor Epoxide (µg/kg)	Total Lindane (µg/ℓ)	Bottom Deposit Lindane (µg/kg)	Total Parathion (µg/ℓ)	Total Methyl Parathion (µg/ℓ)	Total Malathion (µg/ℓ)	Total Diazin (µg/ℓ)
						Line 610					
Apr 25, 75	1500	40	0.3	0.00	--	0.00	--	0.00	0.00	0.00	0.00
			4.9	0.00	0.0	0.00	--	0.00	0.00	0.00	0.00
Jun 24, 75	1245	40	0.3	0.00	--	0.00	--	0.00	0.00	0.00	0.00
			4.9	0.00	--	0.00	--	0.00	0.00	0.00	0.10
Aug 06, 75	1040	40	4.6	--	0.0	--	0.0	--	--	--	--
						Line 620					
Apr 25, 75	1430	40	0.6	0.00	--	0.00	--	0.00	0.00	0.00	0.00
Jun 24, 75	1400	40	0.3	0.00	--	0.00	--	0.00	0.00	0.00	0.00
Aug 06, 75	1245	40	0.5	--	0.0	--	0.0	--	--	--	--
						Line 630					
Apr 25, 75	1415	40	0.3	0.00	--	0.00	--	0.00	0.00	0.00	0.00
			1.1	--	0.0	--	0.0	--	--	--	--
Jun 24, 75	1345	40	0.3	0.00	--	0.00	--	0.00	0.00	0.00	0.00
						Line 640					
Apr 25, 75	1330	40	0.3	0.00	--	0.00	--	0.00	0.00	0.00	0.00
			1.4	0.00	0.0	0.00	--	0.00	0.00	0.00	0.00
Jun 24, 75	1320	40	0.3	0.00	--	0.00	--	0.00	0.00	0.00	0.00
			1.4	0.00	--	0.00	--	0.00	0.00	0.00	0.00
Aug 06, 75	1215	40	1.2	--	0.0	--	0.0	--	--	--	--

(Continued)

Table 8 (Continued)

Date of Collection	Time	Site	Depth (m)	Total PCB (μg/ℓ)	Bottom Deposit PCB (μg/kg)	Total 2,4-D (μg/ℓ)	Bottom Deposit 2,4-D (μg/kg)	Total 2,4,5-T (μg/ℓ)	Bottom Deposit 2,4,5-T (μg/kg)	Total Silvex (μg/ℓ)	Bottom Deposit Silvex (μg/kg)
					Line 610						
Apr 25, 75	1500	40	0.3	0.0	--	0.00	--	0.00	--	0.00	--
			4.9	0.0	--	0.00	0.0	0.00	0.0	0.00	0.0
Jun 24, 75	1245	40	0.3	0.0	--	0.01	--	0.01	--	0.00	--
			4.9	0.0	--	0.01	--	0.01	--	0.00	--
Aug 06, 75	1040	40	0.3	--	--	0.02	--	0.01	--	0.00	--
			4.6	--	0.0	--	--	--	--	--	--
					Line 620						
Apr 25, 75	1430	40	0.6	0.0	--	0.00	--	0.00	--	0.00	--
Jun 24, 75	1400	40	0.3	0.0	--	0.00	--	0.00	--	0.00	--
Aug 06, 75	1245	40	0.5	--	0.0	0.02	--	0.00	--	0.00	--
					Line 630						
Apr 25, 75	1415	40	0.3	0.0	--	0.00	--	0.00	--	0.00	--
			1.1	--	0.0	--	0.0	--	0.0	--	0.0
Jun 24, 75	1345	40	0.3	0.0	--	0.01	--	0.01	--	0.00	--
			1.2	--	--	0.01	--	0.00	--	0.00	--
					Line 640						
Apr 25, 75	1330	40	0.3	0.0	--	0.00	--	0.00	--	0.00	--
			1.4	0.0	--	0.00	0.0	0.00	0.0	0.00	0.0
Jun 24, 75	1320	40	0.3	0.0	--	0.00	--	0.01	--	0.00	--
			1.4	0.0	--	0.01	--	0.01	--	0.00	--
Aug 06, 75	1215	40	0.3	--	--	0.02	--	0.01	--	0.00	--
			1.2	--	0.0	--	--	--	--	--	--

(Continued)

Table 8 (Concluded)

Date of Collection	Time	Site	Depth (m)	Total Toxaphene (µg/ℓ)	Bottom Deposit Toxaphene (µg/kg)	Total Ethion (µg/ℓ)	Bottom Deposit Ethion (µg/kg)	Total Methyl Trithion (µg/ℓ)	Bottom Deposit Methyl Trithion (µg/kg)	Total Trithion (µg/ℓ)	Bottom Deposit Trithion (µg/kg)
					Line 610						
Apr 25, 75	1500	40	0.3	0.0	--	--	--	--	--	--	--
			4.9	0.0	0.0	--	--	--	--	--	--
Jun 24, 75	1245	40	0.3	0.0	--	--	--	--	--	--	--
			4.9	0.0	--	--	--	--	--	--	--
Aug 06, 75	1040	40	4.6	--	0.0	--	--	--	--	--	--
					Line 620						
Apr 25, 75	1430	40	0.6	0.0	--	--	--	--	--	--	--
Jun 24, 75	1400	40	0.3	0.0	--	--	--	--	--	--	--
Aug 06, 75	1245	40	0.5	--	0.0	--	--	--	--	--	--
					Line 630						
Apr 25, 75	1415	40	0.3	0.0	--	--	--	--	--	--	--
			1.1	--	0.0	--	--	--	--	--	--
Jun 24, 75	1345	40	0.3	0.0	--	--	--	--	--	--	--
					Line 640						
Apr 25, 75	1330	40	0.3	0.0	--	--	--	--	--	--	--
			1.4	0.0	0.0	--	--	--	--	--	--
Jun 24, 75	1320	40	0.3	0.0	--	--	--	--	--	--	--
			1.4	0.0	--	--	--	--	--	--	--
Aug 06, 75	1215	40	1.2	--	0.0	--	--	--	--	--	--

Table 9

Bolivar Peninsula Test Site Data; Organic Carbon Analyses*

Date of Collection	Time	Site	Depth m	Dissolved Organic Carbon mg/ℓ	Suspended Organic Carbon mg/ℓ	Total Organic Carbon mg/ℓ
			Line 610			
Apr 5	1500	40	0.3	5.9	1.2	7.1
			4.9	7.3	1.1	8.4
Jun	1245	40	0.3	---	---	9.4
			4.9	---	---	6.8
Aug 6, 75	1040	40	0.3	7.0	0.6	7.6
			4.6	5.8	0.8	6.6
			Line 620			
Apr 25, 75	1430	40	0.6	5.0	1.4	6.4
Jun 24, 75	1400	40	0.3	---	---	6.2
Aug 6, 75	1245	40	0.5	7.0	0.7	7.7
			Line 630			
Apr 25, 75	1415	40	1.1	5.9	1.3	7.2
Jun 24, 75	1345	40	0.3	---	---	9.8
Aug 6, 75	1230	40	1.1	15	1.0	16
			Line 640			
Apr 25, 75	1330	40	0.3	6.4	1.3	7.7
			1.4	8.[illegible]	---	---
Jun 24, 75	1320	40	0.3	---	---	12
			1.4	---	---	11
Aug 6, 75	1215	40	0.3	6.8	0.6	7.4
			1.2	9.0	0.7	9.7

* Taken from U. S. Geological Survey open-file report.

Table 10

Bolivar Peninsula Test Site Data; Radiochemical Analyses*

Collection	Time	Site	Depth m	Dissolved RA-226, Radon Method pc/ℓ	Dissolved Uranium (U) μg/ℓ	Dissolved Gross Alpha as U-NAT μg/ℓ	Dissolved Gross Beta as SR 90/Y 90 pc/ℓ	Dissolved Gross Beta as CS-137 pc/ℓ
					Line 610			
Apr 25, 75	1500	40	4.9	0.18	1.1	<95	85	110
					Line 640			
Apr 25, 75	1330	40	1.4	0.18	1.2	<97	130	170

Collection	Time	Site	Depth m	Total Filterable Residue mg/ℓ	Suspended Gross Alpha as U-NAT μg/ℓ	Suspended Gross Beta as SR 90/Y 90 pc/ℓ	Suspended Gross Beta as CS-137 pc/ℓ	Total Non-filterable Residue mg/ℓ
					Line 610			
Apr 25, 75	1500	40	4.9	13,000	0.9	0.6	0.7	15
					Line 640			
Apr 25, 75	1330	40	1.4	13,000	2.0	1.6	1.8	14

* Taken from U. S. Geological Survey open-file report.

Table 11

Current Velocity and Gage Height Observations at Bolivar Peninsula Test Site, 14-16 May 1975*

Line 620, Site 40

Date	Hour	Average Velocity cm/sec	Gage Height cm
May 14	1405	12.19 SW*	58.22
	1510	17.98 SW	59.74
	1600	17.98 SW	59.74
	1710	7.92 SW	55.17
	1800	10.97 SW	56.69
	1900	13.11 SW	56.69
	2005	23.47 SW	55.71
	2100	---	---
	2200	---	---
	2300	---	---
	2400	---	---

Line 640, Site 40

Date	Hour	Average Velocity cm/sec	Gage Height cm	Date	Hour	Average Velocity cm/sec	Gage Height cm
May 14	1425	16.15 SW	56.69	May 15	0800	3.05 NE	21.64
	1500	17.98 SW	56.69		0930	25.91 NE	27.74
	1610	20.12 SW	58.22		1000	27.43 NE	30.78
	1700	15.54 SW	55.71		1100	21.95 NE	35.36
	1805	12.19 SW	56.69		1200	21.03 NE	38.40
	1900	12.19 SW	56.69		1300	20.73 SW	36.88
	2000	23.16 SW	55.71		1400	18.29 SW	38.40
	2100	---	53.64		1500	23.16 NE	42.98
	2200	27.74 SW	58.22		1600	24.69 NE	39.93
	2300	27.74 SW	38.40		1700	27.43 SW	41.45
	2400	30.78 SW	30.78		1800	22.55 SW	39.93
15	0100	29.56 SW	27.74		1900	29.87 SW	38.40
	0200	24.99 SW	21.64		2000	30.78 SW	38.40
	0300	22.25 SW	15.54		2100	38.10 SW	33.83
	0400	27.12 SW	9.45		2200	32.00 SW	30.78
	0500	25.60 SW	7.92		2300	32.92 SW	26.21
	0600	24.38 SW	7.92		2400	25.91 SW	18.59
	0700	20.42 SW	12.50	16	0100	28.35 SW	12.50

* SW--flow southwesterly; NE--flow northeasterly.

Table 12

Current Velocity and Gage Height Observations at Bolivar Peninsula Test Site, 25-26 June 1975*

Line 620, Site 40				Line 640, Site 40			
Date	Hour	Average Velocity cm/sec	Gage Height cm	Date	Hour	Average Velocity cm/sec	Gage Height cm
Jun	1315	10.06 NE*	62.79	Jun	1300	14.02 NE	62.79
25	1400	12.50 NE	64.31	25	1405	11.28 NE	64.31
	1505	7.62 NE	64.31		1500	9.14 NE	64.31
	1605	8.53 SW	61.26		1600	11.58 NE	61.26
	1710	8.23 SW	58.22		1700	13.41 NE	59.74
	1800	7.92 SW	53.64		1805	17.37 SW	52.12
	1945	9.75 SW	47.55		1920	15.85 SW	50.60
	2000	--	--		2000	19.81 SW	47.55
	2100	8.53 SW	41.45		2100	15.24 SW	41.45
	2200	7.92 SW	33.83		2210	14.02 SW	33.93
	2310	2.74 SW	29.26		2300	16.15 SW	29.26
	2400	0.00	26.21		--	--	--
26	--	--	--	26	0010	12.80 SW	24.69
	0100	--	--		0100	5.79 SW	23.16
	0200	--	--		0200	5.49 SW	21.64
	0300	--	--		0300	4.27 NE	23.16
	0400	--	--		0400	6.71 NE	24.69
	0510	11.58 NE	30.78		0500	15.85 NE	30.70
	0610	7.92 NE	35.36		0600	19.81 NE	35.36
	0705	5.49 NE	46.02		0700	19.51 NE	46.02
	0810	10.58 NE	42.98		0800	18.29 NE	42.98
	0900	10.36 NE	52.12		0905	14.02 NE	52.12
	1005	10.67 NE	49.07		1000	12.19 NE	49.07
	1100	10.67 NE	52.12		1105	9.75 NE	52.12
	1205	12.19 NE	50.60		1200	8.23 NE	50.60

* SW--flow southewesterly; NE--flow northeasterly.

Table 13

Deviations from Mean Water Stage Due to Wind
Galveston Bay at Hanna Reef, 1974*

Wind Velocity km/hr	Deviation, m							
	North	Northeast	East	Southeast	South	Southwest	West	Northwest
16–23	0.15	<0.15	<0.15	<0.15	<0.15	<0.15	0.15–0.30	0.15–0.30
24–32	0.15–0.30	0.15–0.30	—	0.15	<0.15	0.30	0.15–0.30	—
>32	—	—	—	0.15–0.30	—	—	0.30–0.45	—
Direction of stage change	down	down	either	up	up	up	either	down
Days Compared	17	17	11	45	26	2	3	10

* Adapted from U. S. Geological Survey open-file report.

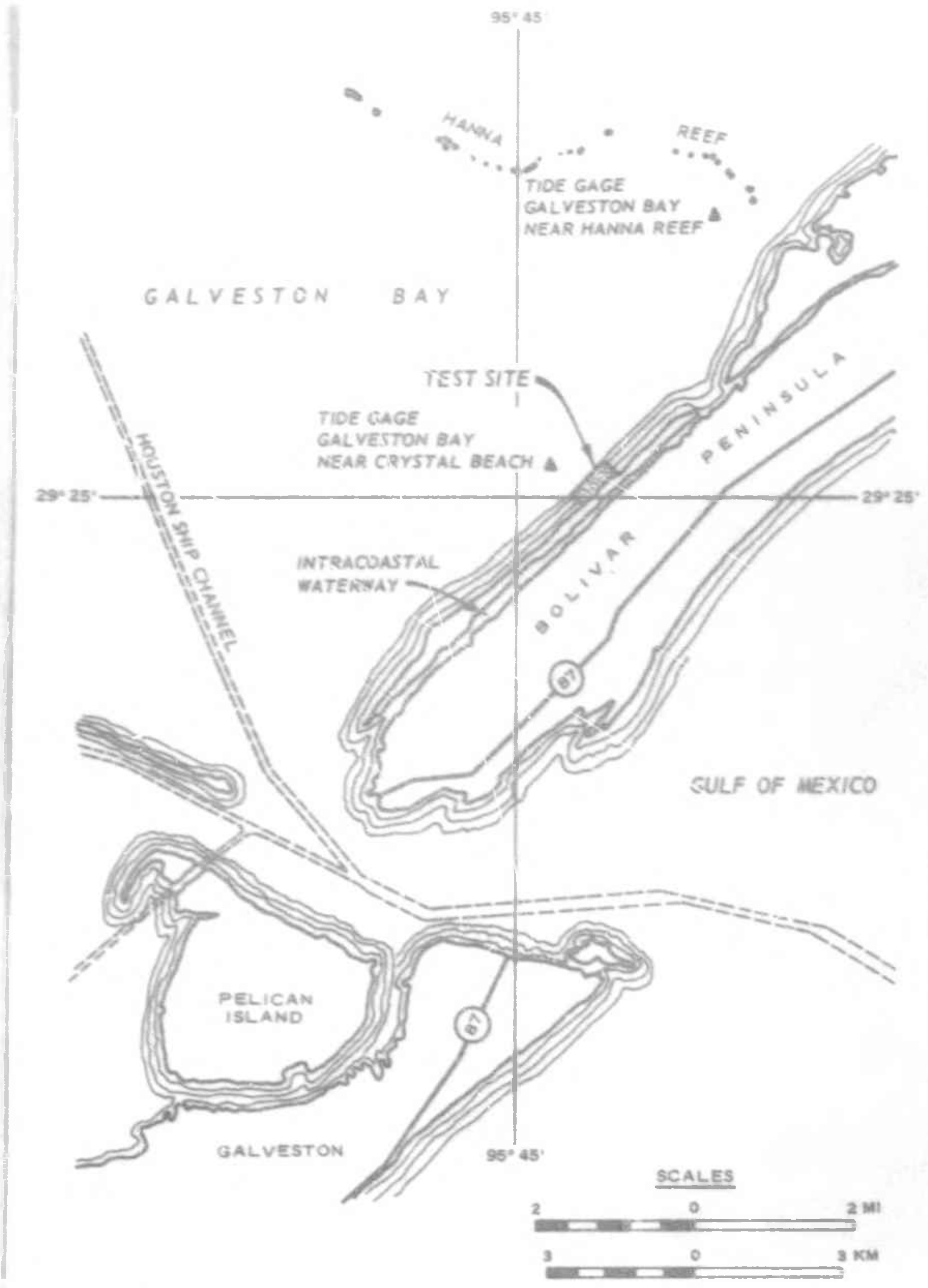

Figure 1. Location of the Bolivar Peninsula test site (taken from the U. S. Geological Survey open-file report)

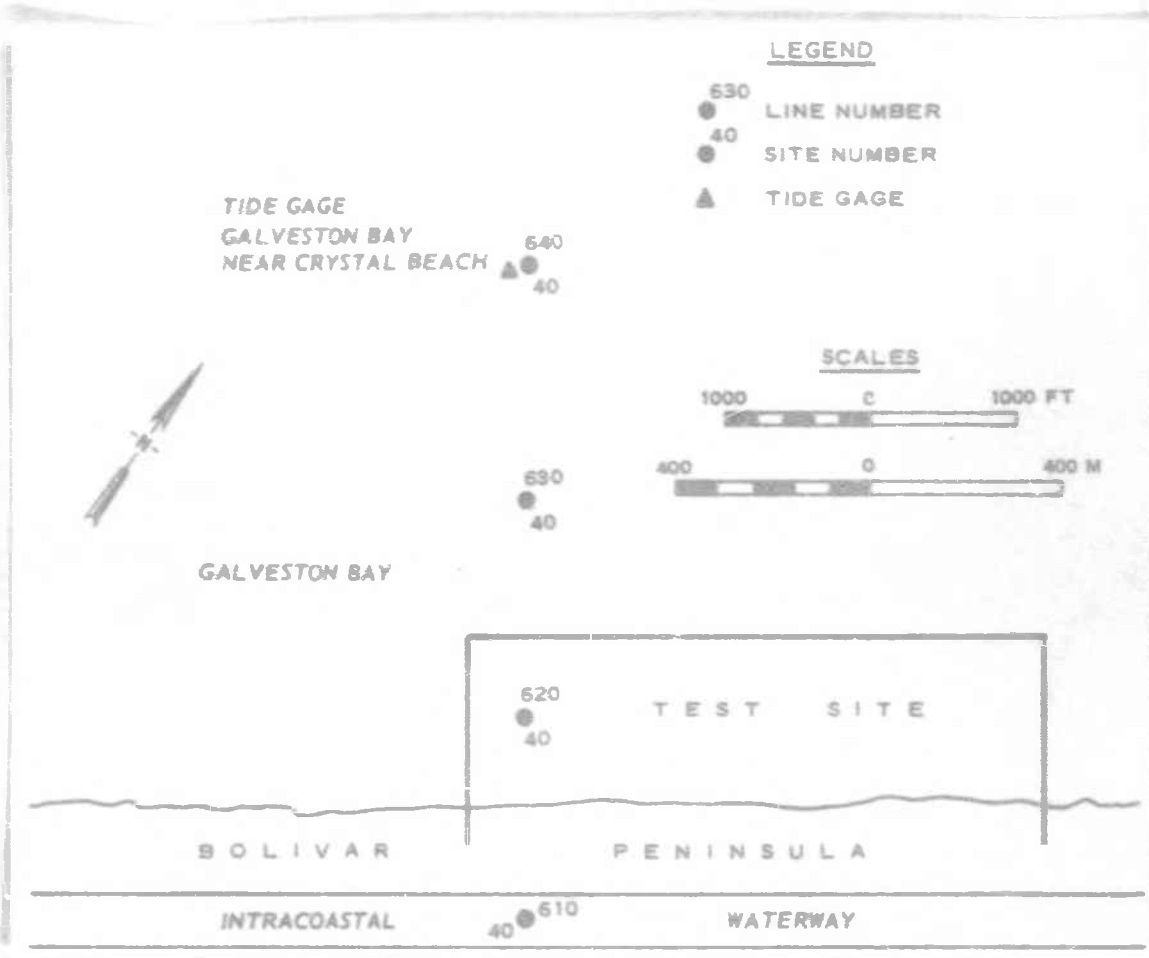

Figure 2. Sampling locations at the Bolivar Peninsula test site (taken from the U. S. Geological Survey open-file report)

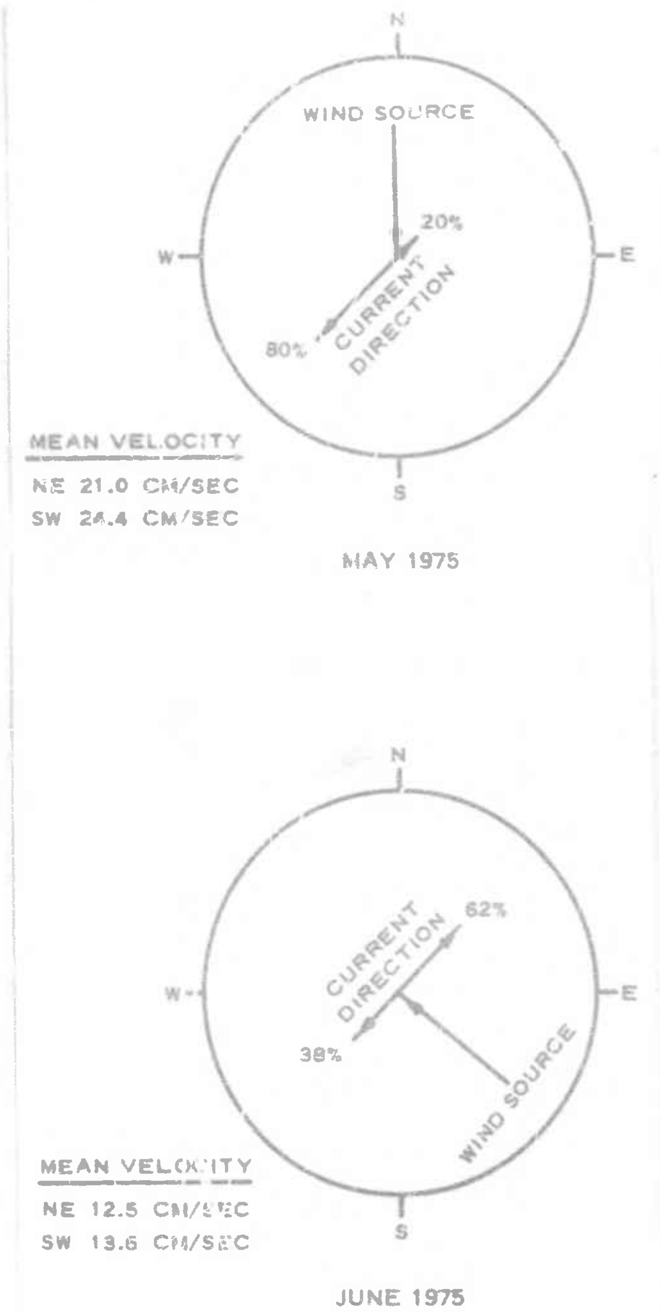

Figure 3. Comparison of water velocities and directions at line 640, site 40 (offshore)

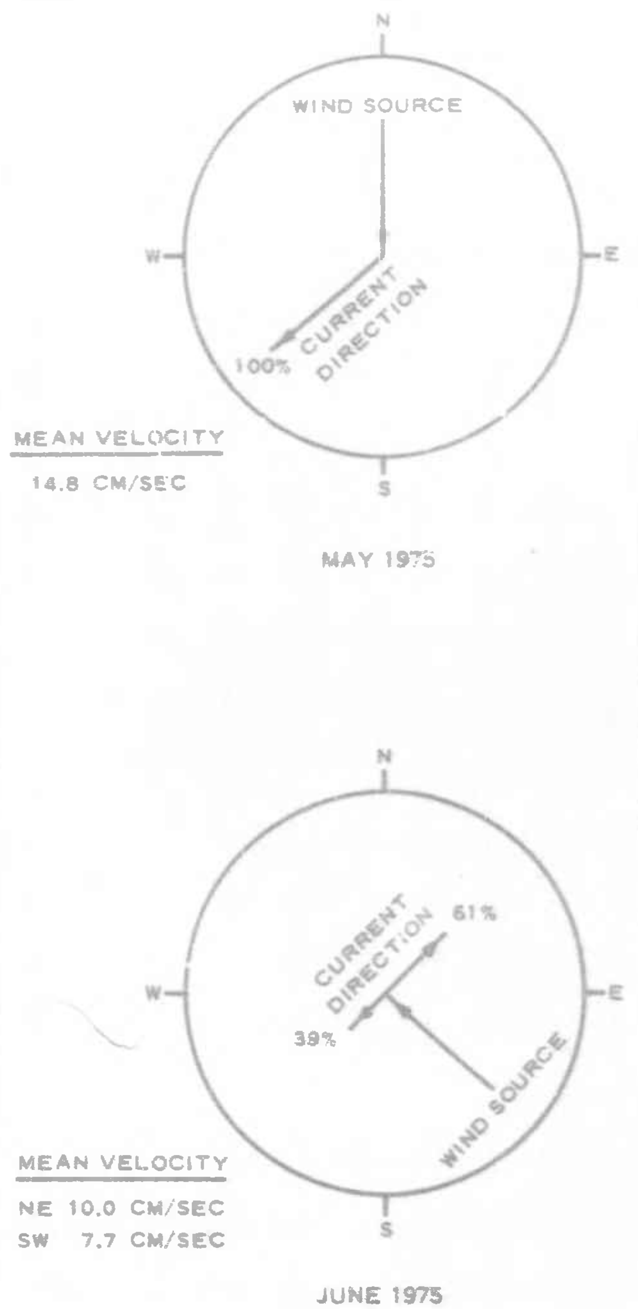

Figure 4. Comparison of water velocities and directions at line 620, site 40 (nearshore)

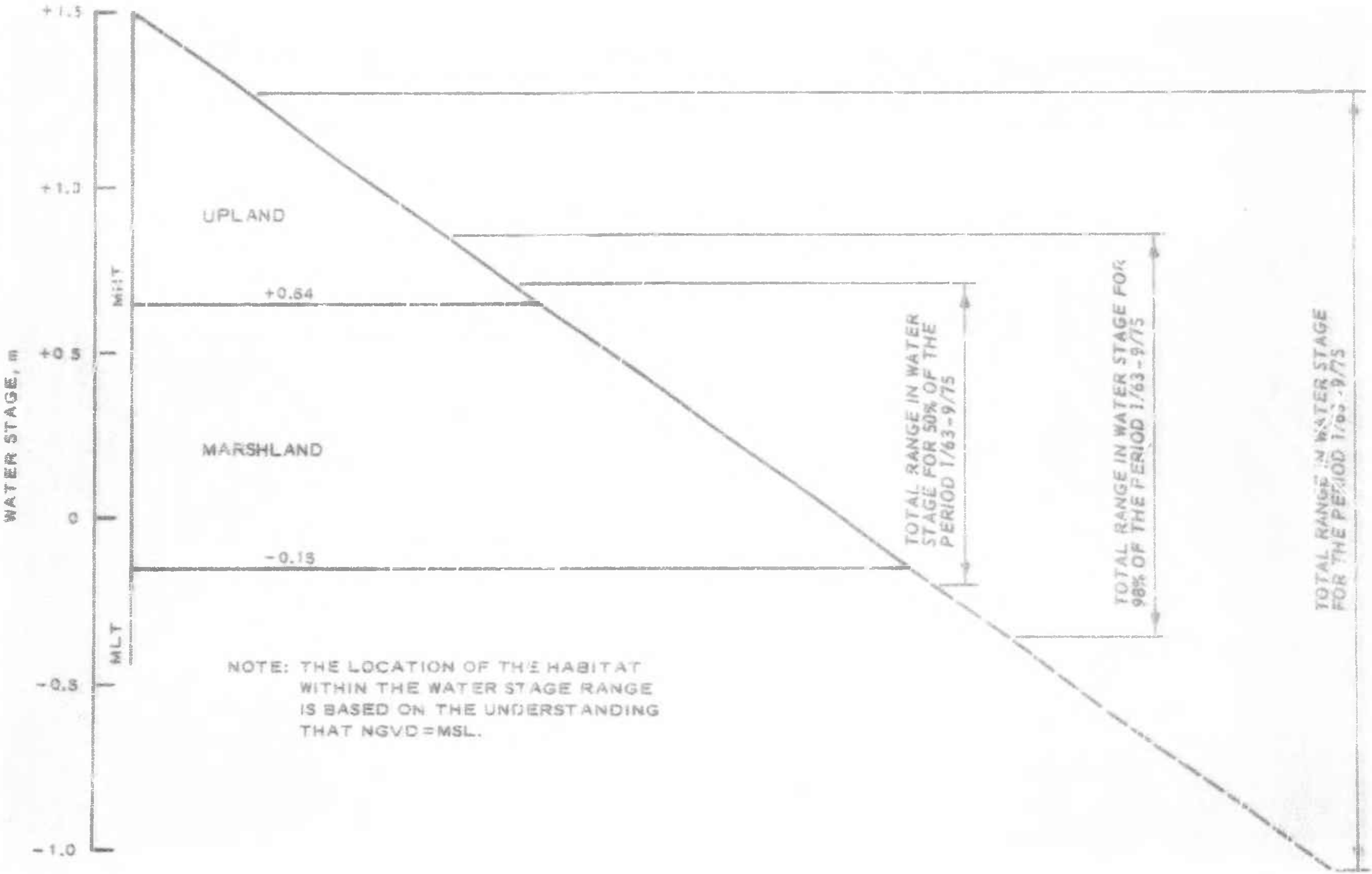

Figure 5. Proposed habitat location in the historical water stage range

In accordance with letter from DAEN-RDC, DAEN-ASI dated 22 July 1977, Subject: Facsimile Catalog Cards for Laboratory Technical Publications, a facsimile catalog card in Library of Congress MARC format is reproduced below.

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Habitat development field investigations, Bolivar Peninsula marsh and upland habitat development site, Galveston Bay, Texas: Appendix A: Baseline inventory of water quality, sediment quality, and hydrodynamics / by John D. Lunz, Ellis J. Clairain, Jr., John W. Simmers. Vicksburg, Miss. : U. S. Waterways Experiment Station ; Springfield, Va. : available from National Technical Information Service, 1978.

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1. Bolivar Peninsula. 2. Dredged material. 3. Field investigations. 4. Galveston Bay. 5. Habitat development. 6. Habitats. 7. Hydrodynamics. 8. Marshes. 9. Sediment. 10. Water quality. I. Clairain, Ellis J., joint author. II. Simmers, John W., joint author. III. United States. Army. Corps of Engineers. IV. Series: United States. Waterways Experiment Station, Vicksburg, Miss. Technical report ; D-78-15, Appendix A.

TA7.W34 no.D-78-15 Appendix A

DREDGED MATERIAL RESEARCH PROGRAM

TECHNICAL REPORT D-78-15

HABITAT DEVELOPMENT FIELD INVESTIGATIONS BOLIVAR PENINSULA MARSH AND UPLAND HABITAT DEVELOPMENT SITE GALVESTON BAY, TEXAS

APPENDIX B: BASELINE INVENTORY OF TERRESTRIAL FLORA, FAUNA, AND SEDIMENT CHEMISTRY

by

J. D. Dodd, D. J. Herlocker, B. W. Cain
B. J. Lee, L. R. Hossner, C. Lindau

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May 1978

Final Report

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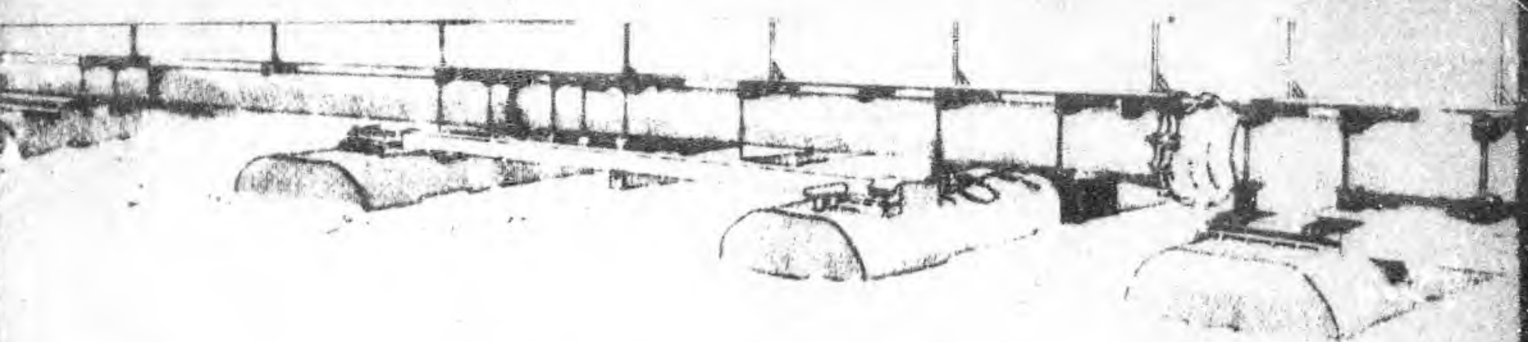

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U. S. Army Engineer Waterways Experiment Station
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HABITAT DEVELOPMENT FIELD INVESTIGATIONS, BOLIVAR PENINSULA
MARSH AND UPLAND HABITAT DEVELOPMENT SITE
GALVESTON BAY, TEXAS

Appendix A: Baseline Inventory of Water Quality, Sediment Quality, and Hydrodynamics

Appendix B: Baseline Inventory of Terrestrial Flora, Fauna, and Sediment Chemistry

Appendix C: Baseline Inventory of Aquatic Biota

Appendix D: Propagation of Vascular Plants and Postpropagation Monitoring of Botanical, Soil, Aquatic Biota, and Wildlife Resources

Unclassified

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

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Sediment sampling
Soil chemistry

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

This study involved collection of flora, fauna, and sediment chemistry baseline data prior to habitat development with dredged material. The specific purposes were to (a) survey and evaluate pertinent historical data and literature; (b) inventory vegetation and prepare a vegetation map; (c) inventory avian, mammal, and macroinvertebrate populations; and (d) determine specific soil chemical properties.

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SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

20. ABSTRACT (Continued)

A total of 74 plant species representing 61 genera and 20 families were present at the study site. The dominant grasses were Spartina patens (marshay) and Andropogon spp. (bluestem). Forb density was over 435,000 plants/acre with Heterotheca subaxillaris (camphorweed) the most common. The Compositae contributed the greatest number of species. A woody plant density of over 3,250 plants/acre occurred. The dominant was Sesbania drummondii (drummond sesbania). The only other woody species that occurred was Croton punctatus (gulf croton). Standing crop biomass production on the study site exceeded 3,000 pounds/acre. The following six major plant communities were mapped, in order of area occupied: (a) Andropogon perangustatus, (b) Spartina patens, (c) Sesbania-mixed grass, (d) Sporobolus virginicus-Distichlis spicata, (e) Monarda citriodora, and (f) Spartina alterniflora.

A total of 98 bird species were identified, with red-winged blackbirds the most numerous species. Thirteen mammal species were recorded, 3 of them domestic. The most common were hispid cotton rat, raccoon, and domestic goat. A total of 31 individuals representing 11 species of reptiles and amphibians were observed. Eighteen orders of macroinvertebrates were collected and identified.

Soil and sediment samples were sandy in texture to a depth of 107 cm. Total organic carbon was generally less than 0.2 percent. Extractable ammonium and extractable orthophosphate varied but were present in low quantities. Values of Eh varied from +500 mv for oxidized horizons to near -240 mv in the intertidal area. The pH values of the sediments ranged from 7.00 to 8.50. Interstitial water did not contain excessive concentrations of ammonium-, nitrite- or nitrate-nitrogen. Total inorganic nitrogen never exceeded 6.14 mg/ℓ. Total phosphorus and orthophosphate concentrations were less than 3.25 and 0.625 mg/ℓ, respectively. Total dissolved carbon ranged between 2.0 and 9.55 mg/ℓ. Excessive nutrient concentrations were not found in this series of core samples. Metal concentrations of lowland interstitial water were similar to those interstitial water values from the profiles located in the intermediate areas. Magnesium, potassium, sodium, and calcium concentrations for interstitial water from the lowland areas were high compared to those for the intermediate sites. Heavy metal concentrations (iron, manganese, zinc, copper, lead, cadmium, and mercury) were low.

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SUMMARY

This study involved the collection of flora, fauna, and sediment chemistry baseline data prior to habitat development with dredged material. The specific purposes were to (a) survey and evaluate pertinent historical data and literature; (b) inventory vegetation and prepare a vegetation map; (c) inventory avian, mammal, and macroinvertebrate populations; and (d) determine specific soil chemical properties.

Seventy-four plant species representing 61 genera and 20 families were collected and identified. Vegetation of the study area had a basal cover of 13.2 percent and a litter cover of 15.8 percent. The Gramineae and Cyperaceae families accounted for most of the basal cover. Spartina patens (marshay)* and Andropogon spp. (bluestem) were the dominant grasses. Forb density on the study area was 437,778 plants/acre. The Compositae contributed more plants to forb density than any other family. Heterotheca subaxillaris (camphorweed) had the highest relative density and frequency. Woody plant species had a density of 3,279 plants/acre. September biomass production was 3,071 pounds/acre for the study area; bluestem and marshay dominated with 30.8 percent and 28.7 percent of the total production, respectively.

Six plant communities were delineated on the basis of basal cover by dominants. These were: (a) Andropogon perangustatus, (b) Spartina patens, (c) Sesbania-mixed grass, (d) Sporobolus virginicus-Distichlis spicata, (e) Monarda citriodora, and (f) Spartina alterniflora. The Andropogon perangustatus and Spartina patens communities were the most extensive accounting for 37 percent and 25 percent of the study area, respectively. Each also produced over 4,100 pounds/acre biomass.

Forty-one bird species were recorded on the site during July, and the number increased to 50 in September. Overall the total was 98, with red-winged blackbirds the most numerous species. Thirteen mammal species were recorded on the site (three of them domestic), and the most common species were raccoon, hispid cotton rat, and domestic goat. There were

* This grass is also known as saltmeadow cordgrass in other regions of the nation.

11 species of reptiles and amphibians observed represented by a total of 31 individuals. Eighteen orders of macroinvertebrates were collected and identified. The most common forms were grasshopper, land snail, mud fiddler crab, and tiger beetle.

Soil and sediment samples were all sandy in texture to a depth of 107 cm. The least amount of sand reported at any depth was 88 percent. Total organic carbon was generally less than 0.2 percent. Extractable ammonium and orthophosphate were variable but generally present in low quantities. Values of Eh varied from +500 mv for oxidized horizons located in the upland region to near -240 mv in the intertidal area. The Eh was closely related to moisture content. The pH values of the sediments ranged from 7.00 to 8.50.

Interstitial water samples did not contain excessive concentrations of ammonium-, nitrite-, or nitrate-nitrogen. Total inorganic nitrogen never exceeded 6.14 mg/ℓ and was generally much lower. Total phosphorous and orthophosphate concentrations were less than 3.25 and 0.625 mg/ℓ, respectively. Total dissolved carbon ranged between 1.0 and 9.55 mg/ℓ.

Chemical composition of the sediments generally corresponded to the sandy nature of the material. Excessive nutrient concentrations were not found in this series of core samples. Metal concentrations of lowland interstitial water are similar to those interstitial water values from the profiles located in the intermediate areas. Magnesium, potassium, sodium, and calcium concentrations for interstitial water from the lowland areas were high compared to the intermediate sites. Heavy metal concentrations (iron, manganese, zinc, copper, lead, cadmium, and mercury) were low.

PREFACE

This report presents the results of an investigation to describe quantitatively the flora, fauna, and sediment chemistry of a disposal site on Bolivar Peninsula, Galveston Bay, Texas. The investigation was conducted as a part of the Corps of Engineers' Dredged Material Research Program (DMRP) under Contract No. DACW64-75-C-0101, entitled "Inventory and Assessment of Terrestrial Flora, Fauna, and Sediment Chemistry at Bolivar Peninsula Habitat Development Site, Galveston Bay, Texas, dated 12 June 1975, between the U. S. Army Engineer District, Galveston, and the College of Agriculture, Texas A&M University, College Station, Texas. The DMRP was sponsored by the Office, Chief of Engineers, U. S. Army, and was monitored by the Environmental Laboratory (EL) of the U. S. Army Engineer Waterways Experiment Station (WES), Vicksburg, Miss. The Galveston District administered the contract for WES. Contracting Officer was COL D. S. McCoy, CE.

Parts I, II, III, IV, and VII were prepared by D. J. Herlocker and J. D. Dodd, Research Associate and Professor, respectively, in Range Science, Texas A&M University. B. W. Cain and B. J. Lee, Assistant Professor and Research Assistant, respectively, in Wildlife and Fisheries Sciences, Texas A&M University, prepared Part V. "Sediment Chemistry," Part VI, was prepared by L. R. Hossner and C. Lindau, Associate Professor and Research Assistant, respectively, in Soil and Crop Sciences, Texas A&M University.

The contract monitors at WES were J. S. Boyle and H. H. Allen, EL. Project manager was H. K. Smith, Manager, Habitat Development Project, EL. John Harrison was Chief, EL.

The authors express appreciation to personnal of WES and the Galveston District for their cooperation during this project. Special appreciation is extended to S. L. Hatch and F. Waller for their assistance in plant identification.

COL G. H. Hilt, CE, and COL J. L. Cannon, CE, were Directors of WES during the conduct of the contract and the preparation of this report. Mr. F. R. Brown was Technical Director.

CONTENTS

LIST OF FIGURES

LIST OF TABLES

CONVERSION FACTORS, U. S. CUSTOMARY TO

METRIC (SI) UNITS OF MEASUREMENT

U.S. customary units of measurement used in this report can be converted to metric (SI) units as follows:

Multiply	By	To Obtain
inches	2.54	centimetres
feet	0.3048	metres
miles (U.S. statute)	1.609344	kilometres
square feet	0.09290304	square metres
square miles (U.S. statute)	2.589988	square kilometres
acres	4046.856	square metres
cubic yards	0.7645549	cubic metres
pounds (mass)	0.4535924	kilograms
miles (U.S. statute) per hour	1.609344	kilometres per hour

BASELINE INVENTORY OF TERRESTRIAL
FLORA, FAUNA, AND SEDIMENT CHEMISTRY

PART I: INTRODUCTION

1. Coastal marsh comprises 1,250 square miles* and is the most important land resource area on the Texas coast (Godfrey et al. 1973). Marsh is important in flood control and water quality, provides excellent wildlife habitat, and is a valuable source of nutrients for livestock and marine life (National Aeronautics and Space Administration (NASA) 1974). One-third of the population and nearly one-third of the industry of Texas is located on the Gulf coast (Fisher et al. 1972). This has had a serious impact on coastal marshes. Hundreds of acres are filled each year and the land use changed (NASA 1974). Thus, it is important to consider ways and means of maintaining and/or reestablishing marsh.

2. Approximately 2.3 percent of the coast marsh resource area has been set aside for dredged material sites (U.S. Army Corps of Engineers (USCE) 1975a). These sites provide substrates for marsh development (especially open-water sites, which comprise about 48 percent of the total). In these areas, few other competitive land uses exist. Thus, an opportunity is provided to investigate the feasibility of marsh establishment on dredged material disposal sites.

3. This study involves the feasibility of using dredged material as a substrate for development of salt marshes along the upper Texas coast. Phase I involves collection of baseline data prior to development. Objectives include (a) survey and evaluation of historical data and literature pertinent to the study site, (b) inventory of avian, mammal, and macroinvertebrate populations inhabiting the study site, (c) inventory of vegetation including preparation of a vegetation map, and (d) determination of specific soil chemical properties of the study area prior to deposition of dredged material.

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*A table of factors for converting U.S. customary units of measurements to metric (SI) units is given on page 9.

PART II: DESCRIPTION OF AREA

4. Bolivar Peninsula forms the eastern end of a chain of sand barriers that extend almost 600 miles along the Mexican and Texas coasts. The Bolivar Peninsula has developed as an offshore sand bar since the post-Pleistocene rise in sea level about 4000 years ago (Lankford and Rehkemper 1969). It is maintained by marine sedimentation processes, primarily on the Gulf shore. However, some sediment is also transported by sea water washing over the barrier to the bay (NASA 1974). River-transported sediments are negligible (USCE 1968). The peninsula is typically level with occasional elevations of 5 to 10 feet where old dunes occur (U.S. Geological Survey (USGS) 1954a, 1954b, 1954c, 1962a, 1962b).

5. The Galveston area annually receives about 40 inches precipitation, primarily between May and August. High humidities and moderate temperatures reflect proximity to the Gulf (National Oceanic and Atmospheric Administration (NOAA) 1974). Most of the year, prevailing winds are from the south and southeast (USCE 1968). Average velocity is about 11 mph (Lankford and Rehkemper 1969).

6. North of the Bolivar Peninsula, tides in Galveston Bay average about 6 feet and range about 1 foot in amplitude (0.79-1.81 feet above mean sea level) (USCE 1975b). Prevailing south and southeast winds may raise this level 2-3 feet while north winds may lower it as much as 4 feet (Lankford and Rehkemper 1969).

7. Hurricanes are an important factor in the local climate. Since 1871, five tropical storms and seven hurricanes have passed over or near Bolivar Peninsula. There is a 23-percent chance of hurricane occurrence in any one year (Henry et al. 1975). Storm surge associated with hurricanes strongly influences erosional and depositional processes and often results in barrier washover (Lay and O'Neil 1942, NASA 1974, Henry et al. 1975). Storm surges over 8 feet are common, and surges from 15-20 feet have occurred at Galveston. The Bolivar Peninsula, which lies entirely below 15-foot elevation, is thus a prime area for flooding (Henry et al. 1975).

8. Bolivar Peninsula occurs within a soil association comprising the Harris, Veston, and Galveston soil series (Godfrey et al. 1973). These are saline clayey and loamy soils of marshes and sandy soils of beaches. Heavy, saline clays generally overlain by peat occur under marsh vegetation (Lay and O'Neil 1942).

9. Composition of vegetation primarily reflects topography and ground water salinity. Barrier flat vegetation dominated by *Spartina patens* (marshay) and *S. spartinae* (gulf cordgrass) occupies the seeward half of the Peninsula. Two large salt marshes occur on the bay side (NASA 1974).

10. Lists of important plant species have been compiled for marsh vegetation along the Texas coast (Gould 1975) and for eastern Galveston County (Waller 1974). The principal coastal marsh communities of East Texas have been described by Lay and O'Neil (1942). These are: saline marshes, dominated by *Spartina alterniflora* Loisel. (smooth cordgrass), brackish marshes dominated by marshay and *Distichlis spicata* (L.) Green (seashore saltgrass), and fresh marshes dominated by *Typha angustifolia* L. (narrowleaf cattail), *T. latifolia* L. (common cattail), *Scirpus californicus* (California bulrush), and *Eleocharis quadrangulata* (Michx.) R.&S. (squarestem spikesedge).

11. Texas marshes overlie a heavy mineral soil (often saline) topped by a peaty layer. They are generally formed through subsidence (0.2 foot/century in the Galveston area) and lie behind beach ridges that prevent direct influx of seawater except during hurricanes (Lay and O'Neil 1942, Lankford and Rehkemper 1969).

12. Muskrat populations were exploited on Bolivar Peninsula until a few decades ago (Lay and O'Neil 1942). Present land use includes livestock ranching (Lay and O'Neil 1942, NASA 1974), exploitation of oil and natural gas fields (Holstrum and Williams 1971), and permanent and summer residences and commercial establishments (USCE 1968). Oyster beds lie immediately offshore on the bay side. This is also a nursery area for fishes of Galveston Bay. It is used extensively for recreational boating and fishing (USCE 1968, 1970, Holstrum and Williams 1971). In addition, commercial shipping uses the Gulf Intra-Coastal Waterway (GIWW), which runs along the entire bay side of the peninsula. Dredging associated with the GIWW has been almost continuous along this stretch since completion in 1933 (Lay and O'Neil 1942, USCE 1975c). Selected areas are dredged about every 2 years. The average quantity of materials dredged per contract is 1.6 million cubic yards (USCE 1975c).

13. The study site is located on Galveston Bay between Marsh and Baffle Points near the west end of Bolivar Peninsula. It ranges in elevation from -0.2 feet to about +10.0 feet mean sea level (USCE 1975d).

The location is between the GIWW and the bay in dredged material disposal area No. 41. This area has no containing levee system, unlike some other disposal areas (USCE 1970). Dredged material deposition occurs about every 4 years on this site; the last disposal was in 1971.

PART III: PLOT AND SAMPLING DESIGN

14. The study area is rectangular, 2,000 by 600 feet, 27.5 acres in area. Of this, 14 acres is intertidal and supports little vegetation. The study area has been extended back to the GIWW to include upland vegetation communities. This added 14 acres to the total area.

15. A surveyed baseline forms the south edge of the study area (Figure 1). Thirty-nine topographic transects have been established at 50-foot intervals along and at right angles to the baseline and were surveyed to the bay side of the study area. These have been extended nontopographically back to the GIWW. This system of transects was a reference for subsequent surveys of vegetation, soils, and wildlife.

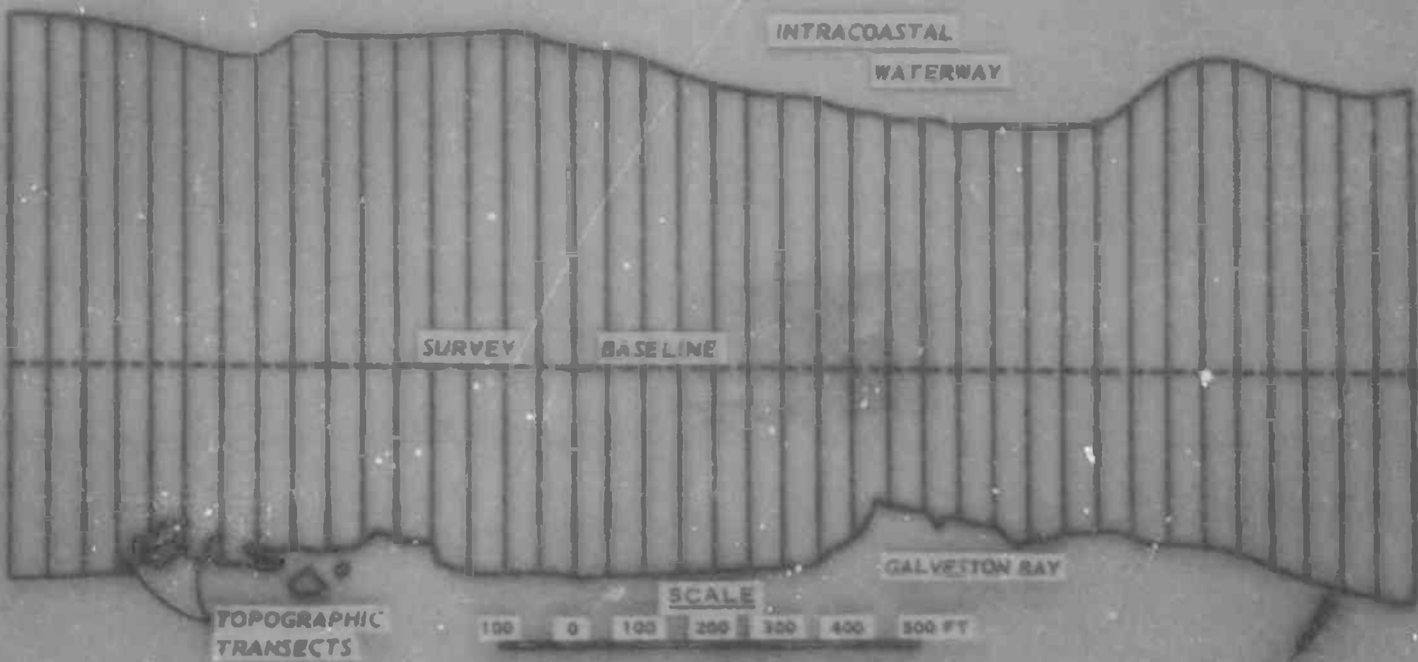

Figure 1. Study area at Bolivar Peninsula. The study area is located between the baseline and Galveston Bay

PART IV: FLORA

16. The purpose of this research was to describe vegetation of the study area quantitatively. This included compiling a species list as well as defining the contribution of these species to the cover and production of the area. The major plant communities were identified and delineated.

Methods

17. The study area was periodically and systematically searched for new plant species. All species encountered were pressed and later identified. All scientific and common names follow Gould (1975).

18. Vegetation sampling was conducted along three transects chosen at random in each of four 500-foot sections along the baseline. The surveyed baseline provided locations for the randomly located transects.

Phytosociological parameters

19. Basal cover and composition by species of grass and sedge, and the abundance of forb species were sampled with a 10-point frame (Levy and Madden 1933). Hits recorded included bare ground, litter, and plant species contacted at the soil surface (National Academy of Science-National Research Council (NAS-NRC) 1962). Density and frequency of forbs were determined with a square-foot quadrat (NAS-NRC 1962). Sample size and number were determined by the species-area curve (Oosting 1956). Density of woody plants was determined with an 11-square-foot quadrat. All of the above parameters were measured in August 1975. Sampling location was systematic along each transect. Thirty 10-point frame sets were utilized on each of the 12 transects (total sets = 360) to determine basal cover and plant composition. Twenty square-foot quadrats (total quadrats = 240), and five 11-square-foot (total quadrats = 60) quadrats were used per transect (from baseline to bay) to determine forb density and woody plant density, respectively.

Biomass

20. Biomass production was determined by techniques similar to Wiegert and Evans (1964). Plants were clipped at ground level on five 5.5-square-foot quadrats per transect (total quadrats = 60). Plant material was separated into important species. The remainder was placed

into miscellaneous categories of grass, sedge, and forb. Plant material on the soil surface was collected and placed in a litter category. All material was dried for 30 hours at 80° C, weighed, and reported as production in pounds per acre. Vegetation sampling and clipping for production were conducted at the close of vegetative growth periods in September and November 1975.

Communities

21. Boundaries between plant communities were visually noted along transects during vegetation sampling. These were used to stratify recorded data into plant communities for further analysis. In addition, a preliminary vegetation map was prepared for the study area. A final vegetation map was prepared by (a) establishing a 50-by-50-foot grid of stakes throughout the study area based on the 39 surveyed transect lines, and (b) using these to reference visually determined boundaries of plant communities. Procedures for mapping generally followed Brown (1954) and Kuchler (1967).

Results

22. A total of 74 species representing 61 genera and 20 families have been collected and identified from the study site (Appendix A'). Over 62 percent of the flora occurred in three families, Gramineae, Cyperaceae, and Compositae (Table 1). This species list is incomplete since vegetation on the study site exhibits considerable seasonal variability. Thus, collection and identification must extend over a full year to ensure that all major species in the flora have been observed.

Basal cover

23. Overall, vegetative basal cover was 13.2 percent, litter was 15.8 percent, and bare soil surface 71 percent in August 1975. Dominance, in terms of high basal cover, was expressed primarily by species of the Gramineae and Cyperaceae (Table 2). Spartina patens (Marshay) and Andropogon perangustatus (bluestem) dominated the vegetation, contributing 20.1 percent and 13.6 percent of the basal cover, respectively. Five other species contributed 5 percent or more. One of these was from the Compositae, Heterotheca subaxillaris (camphorweed). Forb species contributed less to basal cover than did grass or sedge species.

Table 1

Vegetation Composition by Major Families

on the Bolivar Peninsula Study Site

(Sampled in August 1975)

Family	No. Species	Total Flora (%)
Gramineae	22	29.7
Compositae	15	20.3
Cyperaceae	9	12.2
Leguminosae	7	9.5
Euphorbiaceae	3	4.1
Verbenaceae	3	4.1
Chenopodiaceae	2	2.7
Solanaceae	2	2.7
Total	63	85.3

Table 2

Major Species Contributing to the Vegetation of the Bolivar Peninsula

Study Site Based on Basal Cover

Species	Common Name	Species Composition (% Basal Cover)	Family
Spartina patens	Marshay	20.1	Gramineae
Andropogon perangustatus	Bluestem	13.6	Gramineae
Fimbristylis carolinianum	Fimbry	8.6	Cyperaceae
Sporobolus virginicus	Seashore dropseed	6.5	Gramineae
Scirpus americanus	American bulrush	5.9	Cyperaceae
Distichlis spicata	Seashore saltgrass	5.4	Gramineae
Heterotheca subaxillaris	Camphorweed	5.0	Compositae
Andropogon glomeratus	Bushy bluestem	3.8	Gramineae
Eragrostis oxylepis	Red lovegrass	2.7	Gramineae
Monarda citriodora	Lemon beebalm	2.5	Labiatae
Paspalum setaceum	Thin paspalum	2.1	Gramineae

Note: Data collected with 10-point frame.

The most important forbs were camphorweed (5 percent), Monarda citriodora (lemon beebalm) (2.5 percent), and Chenopodium ambrosioides (wormseed goosefoot) (1 percent).

Frequency and density

24. Forb density was over 10 plants/square foot (437,738 plants/acre) in August 1975 (Table 3). The ratio of stems to plants was about 1.2 to 1. This indicated that single-stemmed plants were generally characteristic. Camphorweed contributed most to forb density (35.8 percent) and also was the most frequently occurring forb species in the study area (Table 3), indicating uniform distribution. The Compositae contributed more plants to forb density than any other family. The occurrence of colonies (aggregation of individuals of the same species) was not indicated since all important forb species had higher frequencies than relative densities. Wormseed goosefoot showed the greatest divergence between relative density and frequency, indicating uniform dispersal.

25. Only two species of woody plants were collected, Sesbania drummondii (drummond sesbania) and Croton punctatus (gulf croton). Density of woody plants over 2 feet tall was 3,279 plants/acre in August 1975. The most important species was drummond sesbania with 3,117 plants/acre, 95 percent of the total woody plant density. The stem-to-plant ratio of drummond sesbania was about 1.3:1, similar to that for most forb species. A stem-to-plant ratio of about 1.5 for all woody species reflected the numerous stems typical of gulf croton plants.

Biomass

26. Herbage biomass production for the study was area was over 3,070 pounds/acre in September 1975 (Table 4). Bluestem and marshay dominated in contribution to biomass production (30.8 and 28.7 percent of the total, respectively). The relative importance of both species in terms of production (Table 4) was greater than that expressed by basal cover (Table 2). The relative importance of most secondary species was similar for both basal cover and production; exceptions were that Fimbristylis carolinianum (fimbry) was less important for production and camphorweed was more important for production than indicated by basal cover. There

Table 3

Relative Density and Frequency of Occurrence of Important Forb Species on the Bolivar Peninsula Study Site

Scientific Name	Common Name	Family	Absolute Density (No./acre)	Relative Density (%)	Frequency (%)
Heterotheca subaxillaris	Camphorweed	Compositae	156,816	35.8	45.0
Aphanostephus skirrhobasis	Coast dozedaisy	Compositae	65,340	14.9	22.1
Monarda citriodora	Lemon beebalm	Labitae	60,984	13.9	20.4
Erigeron myrionactis	Corpus Christi fleabane	Compositae	56,628	12.9	33.7
Chenopodium ambrosioides	Wormseed goosefoot	Chenopodiaceae	21,780	5.0	29.6
Gaillardia pulchella	Rosering gaillardia	Compositae	17,424	<5.0	8.7
Trifolium sp.		Leguminosae	17,424	<5.0	11.2
Ambrosia psilostachya	Western ragweed	Compositae	13,068	<5.0	15.4

Table 4

Herbage Aerial Biomass Production by Species on the

Bolivar Peninsula Study Site

(Sampled in September 1975)

Species	Common Name	Dry weight (pounds/acre)	Percent of Total
Andropogon perangustatus	Bluestem	945.9	30.8
Spartina patens	Marshay	881.2	28.7
Sporobolus virginicus	Seashore dropseed	125.5	4.1
Scirpus americanus	American bulrush	103.9	3.4
Heterotheca subaxillaris	Camphorweed	101.2	3.3
Andropogon glomeratus	Bushy bluestem	85.0	2.8
Distichlis spicata	Seashore saltgrass	78.3	2.6
Monarda citriodora	Lemon beebalm	71.5	2.3
Fimbristylis carolinianum	Fimbry	64.8	2.1
Eustachys petraea	No common name	39.1	1.3
Spartina alterniflora	Smooth cordgrass	27.0	0.9
Paspalum setaceum	Thin paspalum	18.9	0.6
Misc. grasses		334.6	10.9
Misc. forbs		186.2	6.0
Misc. sedges		8.1	0.2
Total		3,071.2	
Litter		887.9	

were no data available for comparing the September herbage biomass to other areas along Galveston Bay or the gulf coast.

27. The increase in relative importance of bluestem and marshay as expressed by biomass production over basal area was due to the relatively large clone size of some species. This was particularly evident in bluestem. In camphorweed the increase was due to the presence of multiple stems and large leaves.

Community delineation

28. Five major plant communities were delineated in the study area on the basis of species composition (Table 5 and Figure 2). These communities were named according to dominant species and were: (a) Andropogon perangustatus, (b) Spartina patens, (c) Sesbania-mixed grass, (d) Sporobolus virginicus-Distichlis spicata, and (e) Monarda citriodora. An additional community, dominated by Spartina alterniflora, also was apparent but covered only a small area that yielded only limited data.

29. In general, plant communities were clearly evident from both field surveys and vegetation data since each was dominated by species that were not abundant elsewhere (Table 6). Exceptions did occur in both the Andropogon perangustatus and Sesbania-mixed grass communities. Each contained a number of species important in both communities.

30. The Andropogon perangustatus and Spartina patens communities were the most extensive within the study area (baseline to bay), contributing 37 and 25 percent of the total study area, respectively (Table 5).

Cover, density, and frequency within communities

31. As shown in Table 6, vegetative basal cover within communities ranged from 7.8 percent (Sesbania-mixed grass) and 8 percent (Monarda citriodora) to 15.7 percent (Sporobolus-Distichlis and Spartina patens). Litter cover ranged from 1.9 percent (Sporobolus-Distichlis) to over 43 percent (Monarda citriodora) (Table 6).

32. The Sesbania-mixed grass community had the highest forb density (17.9 plants/square foot), while the Spartina patens community had the lowest (3.4 plants/square foot) (Table 7). Forb density of a community varied inversely with the grass basal cover. Low forb densities in the

Table 5

Major Plant Communities and Area Occupied on the Bolivar Peninsula Study Site (Baseline to Bay)

Community	Common Name	Total Area (Acres)	Percent of Total
Andropogon perangustatus	Bluestem	5.0	37
Spartina patens	Marshay	3.4	25
Sesbania-mixed grass	Sesbania	2.3	17
Sporobolus virginicus - Distichlis spicata	Seashore dropseed - Seashore saltgrass	2.0	15
Monarda citriodora	Lemon beebalm	0.7	5
Spartina alterniflora	Smooth cordgrass	0.1	1
Total		13.5	