EPA

United States Environmental Protection Agency

Region IV

345 Courtland Street

Atlanta, Georgia 30365

FINAL ENVIRONMENTAL IMPACT STATEMENT

for

the Designation of an

Ocean Dredged Material Disposal Site

Located Offshore

Fort Pierce, Florida

July, 1993

UNITED STATES ENVIRONMENTAL PROTECTION AGENCY

REGION IV

345 COURTLAND STREET, N.E.
ATLANTA, GEORGIA 30365

July 26, 1993

To Whom It May Concern:

Please find enclosed the Final Environmental Impact Statement (EIS) for an Ocean Dredged Material Disposal Site (ODMDS) offshore Fort Pierce, Florida.

Pursuant to 40 CFR 1501.5, EPA is the lead Federal agency for preparing this EIS for designation of a new ODMDS in the Atlantic Ocean east of Fort Pierce, Florida. The U.S. Army Corps of Engineers (CE) is designated as a cooperating agency as defined in 40 CFR 1501.6. This EIS also provides the National Environmental Policy Act (NEPA) documentation for the transportation of dredged material to the ocean from the existing Fort Pierce Harbor Federal Navigation Project and other non-CE navigation projects. These actions are taken under Section 103 of the Marine Protection, Research, and Sanctuaries Act (MPRSA) of 1972, as amended. As cooperating agency, the CE ensures that the EIS contains all the information required by NEPA for their decision-making processes. Communication regarding the Federal navigation project and dredged material disposal should be addressed to the CE, while communication regarding site designation should be directed to EPA.

The proposed action will be conducted in accordance with the MPRSA, Ocean Dumping Regulations (40 CFR 220-229) and all other applicable laws and regulations. Options for management of the site are contained within the EIS and its appendices. In addition, this EIS will serve as a Biological Assessment for purposes of Section 7 of the Endangered Species Act.

Comments on the Final EIS must be received by EPA at the address below by Sep 9, 1993 or 45 days after publication of the Notice of Availability in the Federal Register.

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FINAL
ENVIRONMENTAL IMPACT STATEMENT
FORT PIERCE
OCEAN DREDGED MATERIAL DISPOSAL
SITE DESIGNATION

Cooperating Agency

U.S. Army Corps of Engineers

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JUL 09 1993
Date

FINAL
ENVIRONMENTAL IMPACT STATEMENT
FOR THE DESIGNATION OF AN OCEAN DREDGED
MATERIAL DISPOSAL SITE LOCATED OFF
FORT PIERCE HARBOR, FLORIDA

SUMMARY SHEET

FINAL ENVIRONMENTAL IMPACT STATEMENT
FOR DESIGNATION OF AN
OCEAN DREDGED MATERIAL
DISPOSAL SITE LOCATED OFFSHORE
FORT PIERCE HARBOR, FLORIDA

( ) Draft
(X) Final
( ) Supplement to Draft
( ) Supplement to Final

1. Type of Action.

(X) Administrative/Regulatory Action
( ) Legislative action

2. Description of the Proposed Action. The proposed action is the U.S. Environmental Protection Agency's (EPA) permanent designation of an environmentally acceptable, adequately sized and economically feasible Ocean Dredged Material Disposal Site (ODMDS) for the Fort Pierce Harbor, Florida area. This action complies with the Marine Protection, Research, and Sanctuaries Act (MPRSA) of 1972, as amended, by providing an environmentally acceptable ODMDS in compliance with the Ocean Dumping Regulations (40 CFR 220-229). The site will be managed in accordance with an approved Site Management and Monitoring Plan (SMMP). The draft SMMP can be found in Appendix D. Because the use of suitable dredged material for beach disposal is the preferred disposal alternative for all dredging projects, the placement of beach quality material in the Fort Pierce Harbor ODMDS is subject to agreement between the State of Florida and the US Army Corps of Engineers as described in the dredged material disposal plan.

3. Environmental Effects of the Proposed Action. Use of the proposed site is expected to produce the following adverse environmental effects: (1) water quality perturbations (turbidity plumes, release of chemicals, lowering dissolved oxygen concentration); (2) smothering of the site's benthic biota; (3) changing the site bathymetry; and (4) altering the site's sediment composition. Generally, effects of water quality perturbations should be local and short-term and should have minimal effect on the region. Recovery of the benthic community should occur rapidly following disposal. In addition, the present Site Management and Monitoring Plan (SMMP) will allow for detection of any significant effects and for modifications to be made to insure there is no unreasonable degradation of the marine environment.

4. Need for the Proposed Action. Limited upland disposal sites in the Fort Pierce area and the need to dredge 30,000 cy of material annually with annual ocean disposal of 21,000 cy justify the need for an offshore disposal site.

5. Alternatives to the Proposed Action. The alternatives to the proposed action are: (1) nc action, i.e., the EPA interim-designation of the existing Fort Pierce site would not achieve final designation and no new ODMDS would be designated, or (2) designation of a new ODMDS.

FINAL
ENVIRONMENTAL IMPACT STATEMENT
FOR THE DESIGNATION OF AN OCEAN DREDGED
MATERIAL DISPOSAL SITE LOCATED OFF
FORT PIERCE HARBOR, FLORIDA

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FOR THE DESIGNATION OF AN OCEAN DREDGED
MATERIAL DISPOSAL SITE LOCATED OFF
FORT PIERCE, FLORIDA

1.00 SUMMARY

1.01 Major Findings and Conclusions. Investigations of the interim-designated ocean dredged material disposal site (ODMDS) and of environmental amenities considered to be within its zone of influence were conducted. Studies at the site included physical, chemical and biological characteristics and their interactive effects (Conservation Consultants, Inc., 1985). The probable dispersion characteristics of dredged materials that might be dumped at the site was also modeled (Scheffner and Swain, 1989). A recent survey of the interim site in 1991 revealed hard bottom communities near and within the northern site boundary (Appendix E). This resulted in a shift of the site 0.5 NM southward. The resulting site has undergone additional physical, chemical and biological analyses since the publication of the Draft EIS. This included a Benthic Communities study (Appendix I) and a Sediment Mapping study (Appendix J). All information was compared with relevant provisions of Section 103 of the Marine Protection, Research and Sanctuaries Act of 1972 (MPRSA). The conclusion herein documented is that the proposed site is suitable for disposal of dredged material and meets all evaluation criteria for designation as an ocean dredged material disposal site.

1.02 Areas of Controversy. No areas of controversy have been identified.

1.03 Unresolved Issues. There are no major unresolved issues.

1.04 Relationship of Alternative Actions to Environmental Protection Statutes, Executive Orders, and Other Requirements. The relationship of the alternative actions to environmental protection statutes and other environmental requirements is presented in Table 1.

2.00 PURPOSE AND NEED FOR ACTION

2.01 National Environmental Policy Act. The National Environmental Policy Act (NEPA) of 1969, as amended, requires that an Environmental Impact Statement (EIS) be prepared for major Federal actions that may significantly affect the quality of the human environment. This EIS has been prepared to fulfill the NEPA requirements of the U.S. Environmental Protection Agency (EPA) and the U.S. Army Corps of Engineers. This EIS carries out the EPA's policy to prepare EIS's (30 FR 16186 [May 7, 1984]) as part of the designation process of an Ocean Dredged Material Disposal Site (ODMDS) under Section 102 of the Marine Protection, Research, and Sanctuaries Act (MPRSA) of 1972, as amended, and it will satisfy the U.S. Army Corps of Engineers need for NEPA documentation relating to permitting under Section 103 of the MPRSA.

2.02 Marine Protection, Research, and Sanctuaries Act. The dumping of all types of materials into ocean waters is regulated by the MPRSA. Section 102 of the Act authorizes the EPA to designate sites for ocean disposal pursuant to criteria established in this section. EPA's site designation does not, by itself, authorize any dredging or dumping of dredged material. EPA Ocean Dumping Regulations and Criteria (40 CFR 220-229) establish procedures and criteria for selection and management of ocean disposal sites and evaluation of permits. Section 103 of the Act authorizes the Corps of Engineers to issue permits for the transportation of dredged material for the purpose of dumping it into ocean waters. The purpose of the action is to comply with the provisions of the MPRSA and 40 CFR 220-229 by providing the information required to evaluate the suitability of the proposed site for designation as an ocean disposal site as well as providing information required in the Corps of Engineers permitting process.

TABLE 1

RELATIONSHIP OF ALTERNATIVES TO ENVIRONMENTAL REQUIREMENTS

	NO ACTION	CANDIDATE SITE
FEDERAL STATUTES		
Archeological & Historic Preservation Act, as amended 16 USC 469, et seq. PL 93-291	F/C*	F/C
Clean Air Act, as amended, 42 USC 1857h-7, et seq. PL 91-604	F/C	F/C
Clean Water Act, as amended, (Federal Water Pollution Control Act) 33 USC 1251, et seq. PL 92-500	F/C	F/C
Coastal Barrier Resources Act, 16 USC 3501 et seq. PL 97-348	N/A**	N/A
Coastal Zone Management Act, as amended, 16 USC 1451, et seq. PL 92-583	F/C	F/C
Endangered Species Act, as amended, 16 USC 1531, et seq. PL 93-205	F/C	F/C
Estuary Protection Act, 16 USC 1221, et seq. PL 90-454	N/A	N/A
Federal Water Project Recreation Act, as amended, 16 USC 460-1(12), et seq. PL 89-72	F/C	F/C
Fish and Wildlife Coordination Act, as amended, 16 USC 661, et seq. PL 85-624	F/C	F/C
Land and Water Conservation Fund Act, as amended, 16 USC 4601-4601-11, et seq. PL 88-578	F/C	F/C
Marine Mammal Protection Act 16 USC 1361, et seq. PL 92-522	F/C	F/C
Marine Protection, Research and Sanctuaries Act, 33 USC 1401, et seq. PL 92-532	F/C	F/C
National Historic Preservation Act, as amended, 16 USC 470a, et seq. PL 89-655	F/C	F/C
National Environmental Policy Act, as amended, 42 USC 4321, et seq. PL 91-190	F/C	F/C
River and Harbor Act, 33 USC 401, et seq.	F/C	F/C
Watershed Protection and Flood Prevention Act, 16 USC 1001, et seq. PL 83-566	N/A	N/A
Wild and Scenic Rivers Act, as amended, 16 USC 1271, et seq. PL 90-542	N/A	N/A
EXECUTIVE ORDERS		
Floodplain Management (EO 11988)	N/A	N/A
Protection of Wetlands (EO 11990)	N/A	N/A
Protection and Enhancement of Environmental Quality (EO 11514, as amended EO 11991)	F/C	F/C
Protection and Enhancement of the Cultural Environment (EO 11593)	N/A	N/A
Federal Compliance with Pollution Control Standards	F/C	F/C
STATE POLICIES		
Florida Coastal Management Program	F/C	F/C

NOTES: For each item listed enter one of the following:

* F/C Full Compliance. Having met all requirements of the statute, EO, or other environmental requirements in the current stage of planning (either pre or post authorization).

**N/A. Not applicable.

2.03 Fort Pierce Harbor, Florida. The EPA has designated the Fort Pierce Harbor Ocean Dredged Material Disposal Site (ODMDS) as an approved interim disposal site for the disposal of sediments from permitted dredging operations in the Ft. Pierce vicinity. Final EPA approval is contingent upon evaluation of the baseline data for this site described in paragraphs 4.01 through 4.55.

3.00 ALTERNATIVES

3.01 Introduction. The proposed action is the final designation of an environmentally and economically acceptable ocean disposal site offshore of Fort Pierce Harbor, Florida. The designation of an ocean dredged material disposal site does not preempt any other disposal options but does ensure that an ocean disposal option is available. The site has been used for ocean disposal since 1949. Approximately 30,300 CY of material have been dredged annually from Fort Pierce Harbor. Of this, about 21,000 CY have been disposed of annually in the interim ODMDS. Individual disposal actions will continue to be evaluated on a case-by-case basis and the method of disposal that best serves the public interest will be selected.

3.02 Non-Ocean Disposal Alternatives. During the Fort Pierce navigation channel improvement study, (Corps of Engineers, Final Feasibility Report, 1984) three categories of non-ocean disposal sites were considered: (a) upland; (b) nearshore; (c) beach; and (d) open water disposal. An excerpt from this study is attached as Appendix H.

3.03 Upland Disposal. Seven upland disposal sites have been investigated. Three of the sites are sanitary landfills requiring cover material, two are undeveloped land, one is vacant land zoned for light industrial use and one is vacant land zoned for residential development. One of the landfill sites was eliminated from consideration due to the recent cleanup effort and development in the area. The other two landfill sites were eliminated due to contamination by hazardous and toxic wastes. The acquisition of these sites would likely include the acceptance of the existing contamination problem which would include a costly and time consuming effort prior to using the site for disposal. A cost analysis was performed on the four remaining sites for a volume of 650,000 cubic yards. A cost comparison of the offshore disposal costs with the remaining upland sites shows that offshore disposal is less expensive by $533,000 than the least cost upland alternative. More detailed information on the upland disposal sites can be found in the General Revaluation Report for Fort Pierce Harbor prepared by the U.S. Army Corps of Engineers Jacksonville, Florida District, scheduled to be released in draft form in November 1992.

3.04 Nearshore Disposal. A nearshore disposal alternative was considered for placement of sand mixed with rock to accomplish two objectives: (a) placement of sand in an area where wave action would, over a period of time, cause it to move onshore and nourish the beach; and (b) create ecological habitat diversity with the rock portion. This alternative was eliminated at the suggestion of Harbor Branch Consortium scientists who suggested that sand placement and later movement had a high potential to smother adjacent reefs, and that hard bottom habitat was already abundant in the area.

3.05 Beach Disposal. The use of suitable dredged material for beach disposal is usually the preferred disposal alternative for all dredging projects. Consequently, the placement of beach quality material in the Fort Pierce ODMDS is subject to agreement between the State of Flórida and the US Army Corps of Engineers as described in a dredged material disposal plan. The estimated beach fill capacity of the 2,000-foot beach disposal areas currently used for beach disposal is a maximum of 220,000 cubic yards.

3.06 Open Water Disposal. Consideration of the Indian River Lagoon disposal areas has been dropped because of objectives raised by the Florida Department of Environmental Regulation.

3.07 Alternative Mid-Shelf Sites. The Fort Pierce interim ODMDS has been in use since 1949. Its location minimizes dredged material transport costs for harbor dredging sites. Its use has produced no apparent adverse impact on resources in the vicinity, and it satisfies the 11 specific criteria listed in the Ocean Dumping Regulations. For these reasons, alternative mid-shelf sites were not considered.

3.08 Alternative Outer-Shelf Sites. Environmentally sensitive reefs and hard bottom areas are scattered intermittently both east and north of the interim ODMDS (Figure 3). Relocation of the ODMDS to a shelf site beyond the current ODMDS would disrupt an additional area and could pose a risk to coastal fishery resources. Disposal on the outer shelf or beyond would increase transport costs substantially over the base cost of using the interim site.

3.09 Alternative Sites Located at the Shelf-Break or Beyond. The continental shelf extends approximately 17 nmi (32 km) off Fort Pierce Inlet. The transport of materials to the edge of the shelf or beyond is considered economically impractical as it would increase the cost substantially over the base cost of using the interim site.

3.10 Selected Site. The proposed site is shown on Figure 1. The center of this site is one-half (1/2) nautical mile due south of the center of the interim site. The site was moved following a field survey and video mapping on January 29-30, 1991, which revealed a considerable area of low relief outcrops/ledges and live bottom located generally along the northern quarter of the interim site (Figure 3). Surveys one-half mile to the south of and contiguous to the interim site revealed bare sand bottom. Therefore, to avoid the rock ledges and live bottom, the site was moved to the south. the new coordinates are:

27°28'00"N, and 80°12'33"W;
27°28'00"N, and 80°11'27"W;
27°27'00"N, and 80°11'27"W;
27°27'00"N, and 80°12'33"W;

The proposed site meets the general criteria for selection as set forth in Section 228.5 of EPA's Final Revision of Ocean Dumping Regulations and Criteria (40 CFR) of January 11, 1977.

3.11 The selected site also meets the 11 specific ocean disposal site criteria set forth in Section 228.6 (see 5.02 through 5.28 and Table 3). This site has been used, without evidence of environmental degradation, since 1949. Sediments at the selected site are compatible with sediments from Fort Pierce Harbor, the materials most likely to be disposed at the site (see 5.08-5.10 for a description of materials coming from the harbor). This site is also suitable in terms of practicality and economic feasibility.

3.12 No Action. The No Action alternative would not provide a final EPA-approved ODMDS offshore Fort Pierce, Florida, but it would allow the continued use of the existing interim site.

4.00 AFFECTED ENVIRONMENT

4.01 Introduction. This EIS describes the environmental characteristics of the area which may be affected by the continued disposal of dredged materials at the Fort Pierce Harbor interim ODMDS. A general location map of the area is presented in Figure 1.

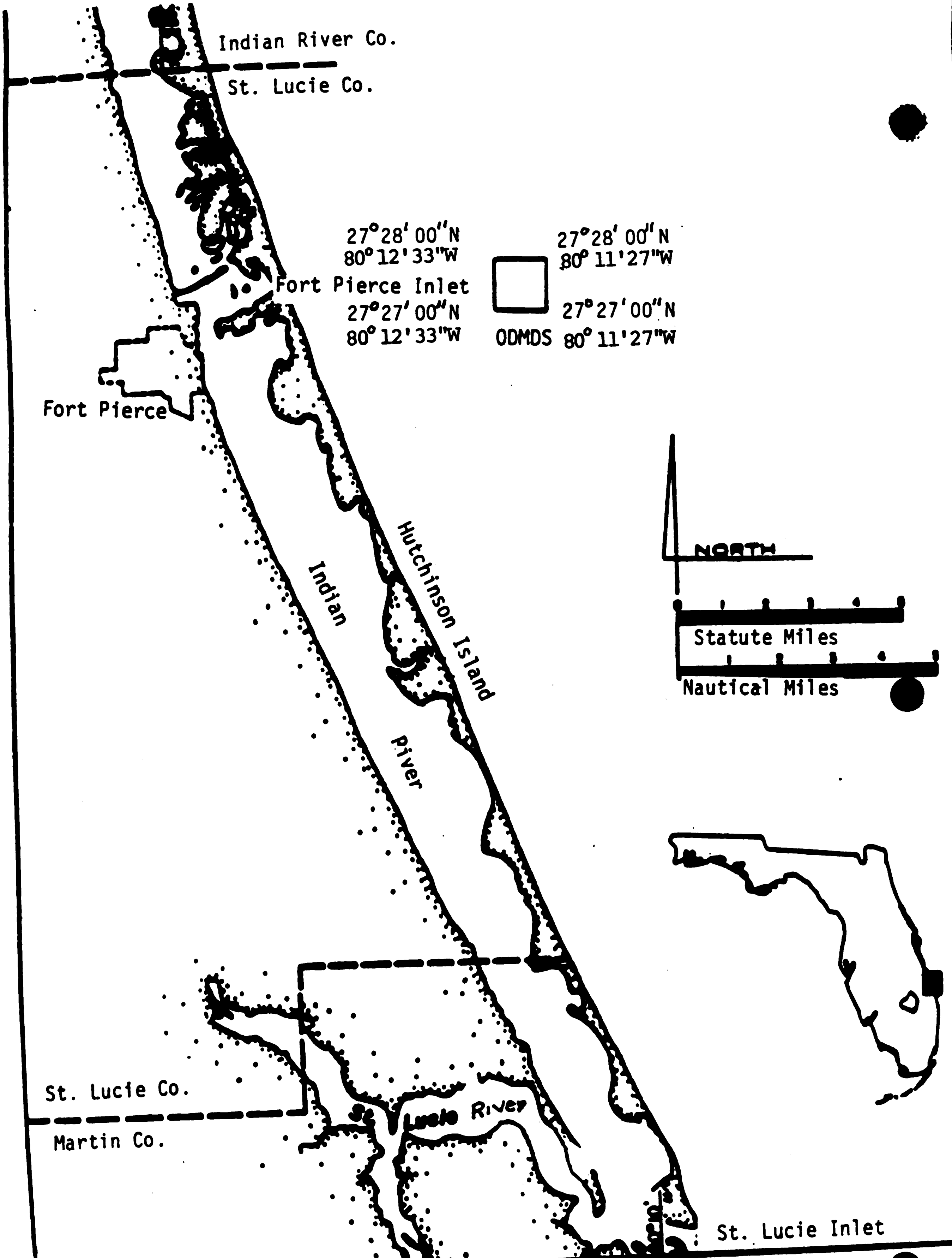

FIGURE 1

GENERAL LOCATION MAP

OCEAN DREDGED MATERIAL DISPOSAL SITE, FORT PIERCE, FLORIDA

4.02 Geological Characteristics. The bottom topography at the proposed ODMDS, shown in Figure 2, is relatively flat. Depths at the disposal site range from 4[illegible] to 54 feet. The average declivity of the continental shelf in the ODMDS vicinity is about eight feet per nautical mile. A December 1985 survey (Appendix A) found surficial sediments in the ODMDS vicinity to be primarily comprised of moderately sorted, coarse to medium sands. Shell material was also a major constituent of the sediments. The 1991 Video Survey revealed the presence of hard rock formations in the northern half of the interim site (Appendix E).

4.03 The November 18, 1992 study, Mapping of Sediment Chemistry at the Proposed Fort Pierce, Florida ODMDS and Postdisposal Mapping at the Interim ODMDS concluded that the proposed ODMDS appeared to be very uniform in gamma activity, elemental, and physical content. The site appears to consist of medium to very coarse calcium carbonate sand. No distinct signs of fine sediment were detected during the sediment mapping survey. Any dredged material deposited within the interim ODMDS must have been similar to the sediment found at the disposal site or has since been removed from the area due to ocean transport. This report is included as Appendix J.

4.04 No differences in sediment texture were noted between stations located within the ODMDS and those in the surrounding area. The results of this survey agree with those previously reported for the area. Meisburger and Duane (1971) found the surficial sediments off Fort Pierce between the 40 and 60-foot depth contours to consist primarily of coarse, brown shell/sand, forming an irregular blanket deposit of varying thickness. Gallagher (1977) described the surficial sediments midway between the ODMDS and Hutchinson Island as being primarily coarse, clean, poorly sorted sands with a high shell content.

4.05 Tides and Currents. Over most continental shelves, circulation is primarily governed by tides and winds. The Florida current lies 32 miles from the site and therefore is expected to have a minimal effect. (Paragraphs 5.12 through 5.17 contain a theoretical dispersion rate for dredged material placed [illegible] the ODMDS).

4.06 Current directions and velocities on the Continental Shelf off Fort Pierce have been reported by Florida Power and Light Company (1970); Lee, et al. (1977); Worth and Hollinger (1977); Kerr (1980); and Smith (1982, 1985 pers. comm.). The predominant directions of flow are north-south. Nearshore currents are generally directed longshore toward the south. More intense, northerly directed currents prevail on the mid-shelf. These currents display periodic north-to-south reversals that are correlated with wind stress. Tidally driven currents in this area are generally of low velocity and are also oriented parallel to the coastline.

4.07 Kerr (1980) reported prevailing northerly currents for two stations in the ODMDS vicinity. Mean current velocities of 8.8 centimeters per second (cm/sec) were reported for a mid-shelf station located approximately eight nmi offshore of Hutchinson Island. Mean current velocities were 2.8 cm/sec at a site located about 3 nmi from shore. Maximum current velocities at both stations were directed along the north-south axis and were approximately 60 cm/sec in both directions. Much weaker currents, averaging 1.7 cm/sec, occurred along the east-west axis. While prevailing cross-shelf currents were to the east for much of the year, the strongest currents occurred during on-shore reversals.

4.08 Surface currents in the study area have been described by Worth and Hollinger (1977). These authors reported average annual surface speeds of about 20 cm/sec for sites located midway between the ODMDS and Hutchinson Island. Surface flow was controlled by winds and was primarily directed along the north-south axis, with northerly flow patterns generally predominating.

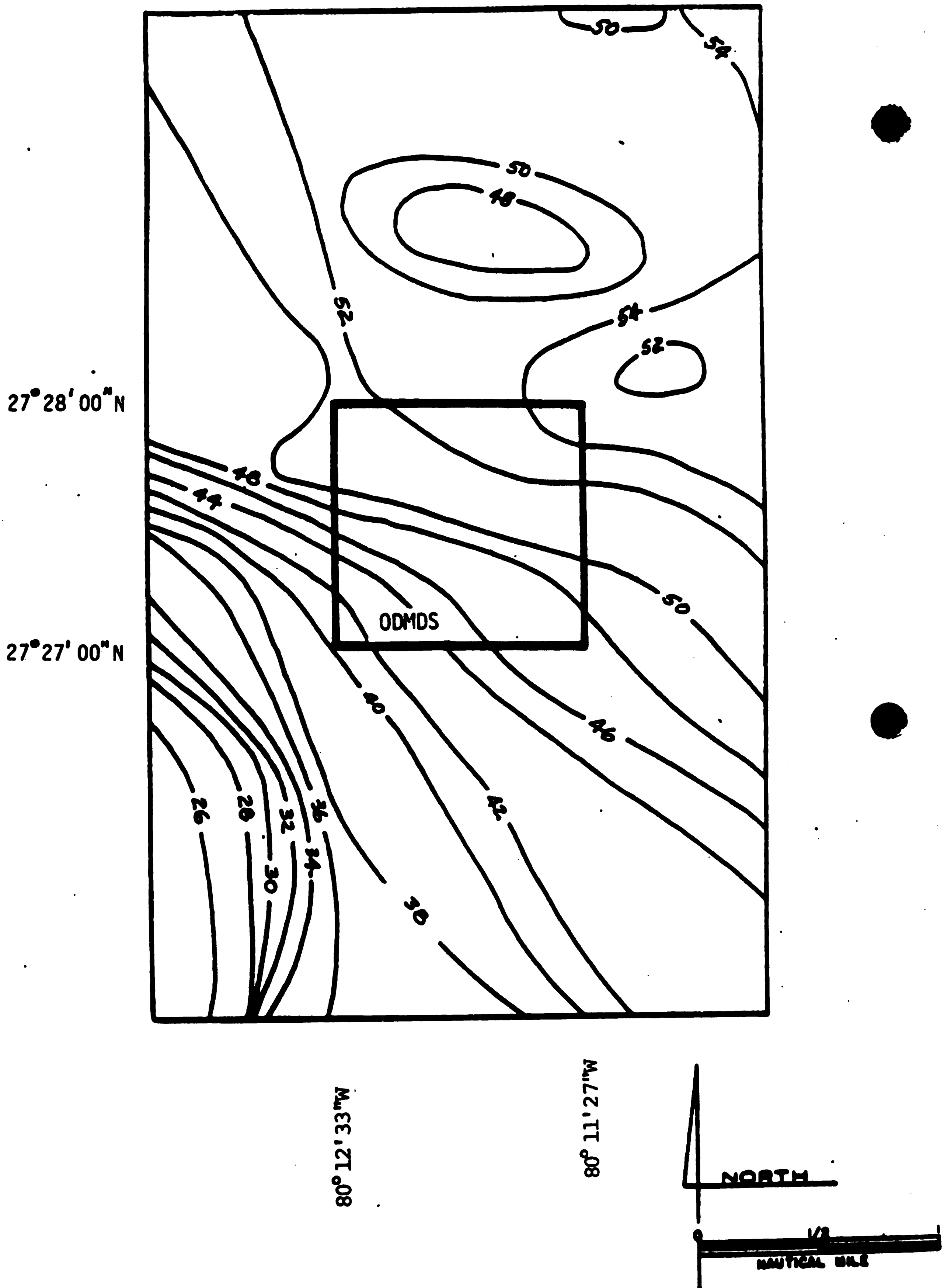

FIGURE 2

BATHYMETRIC MAP

OCEAN DREDGED MATERIAL DISPOSAL SITE, FORT PIERCE, FLORIDA

4.09 Tides in the Fort Pierce ODMDS vicinity are semidiurnal. The U.S. Department of Commerce (USDC, 1985) reports a mean tidal range of 2.6 ft. and a spring tide range of 3.1 ft (1.9m) for Fort Pierce Inlet.

4.10 Water Temperature. EPA (1973) has reported surface water temperatures for the disposal site vicinity ranging from a low of around 20° Celsius (C) in February to a high of about 29°C in July. Worth and Hollinger (1977) report an annual range of 16°C to 27°C for nearshore area waters. Coastal waters in the area are essentially isothermal. Throughout the year, variation in surface and bottom water temperatures in the ODMDS vicinity rarely exceeds 1°C (Worth and Hollinger, 1977).

4.11 Salinity. EPA (1973) reports a mean salinity of 35.4 parts per thousand (ppt) for ocean waters off Fort Pierce, and Worth and Hollinger (1977) report nearshore salinities off Hutchinson Island ranging from 33 to 38.5 ppt. Salinities measured in the ODMDS vicinity in December 1985 (Appendix A) ranged between 36.2 and 36.4 ppt.

4.12 Salinity stratification is not expected to occur in the disposal site vicinity. Little tendency for stratification was observed by EPA (1973) in studies of southeast Florida continental shelf waters. Worth and Hollinger (1977) report maximum surface-to-bottom salinity differences in nearshore waters of about 3 ppt. Differences, when they occur, are generally temporary and associated with increased freshwater discharge.

4.13 Physical and Chemical Characteristics. Chemical and physio-chemical water quality parameters that are relevant to this ODMDS evaluation include dissolved oxygen, suspended solids, turbidity, trace metals, pesticides, polychlorinated biphenyls (PCB's) and high molecular weight (HMW) hydrocarbons. The results of testing are discussed below and in Appendix A.

4.14 Dissolved oxygen (DO) concentrations in the disposal site vicinity were measured in December 1985 (Appendix A). Concentrations were similar at sites within the ODMDS and in surrounding areas. DO concentrations measured in disposal area surface waters between midmorning and midafternoon averaged about 7.4 ppm. No DO stratification was noted. Concentrations generally decreased less than 0.5 ppm between the surface and bottom. DO concentrations were above saturation and did not vary from saturation by more than 15 percent.

4.15 Total suspended solids (TSS) concentrations measured in disposal area bottom waters in December 1985 (Appendix A) ranged from 5 to 24 mg/l. No differences were observed between sites located within the ODMDS and those in the surrounding area. Turbidity samples were collected from surface, mid-depth, and bottom waters at stations in the ODMDS vicinity in December 1985 (Appendix A). Turbidity values were low, ranging from 0.6 to 2.2 nephelometer units, and were characteristic of shelf waters. No zone of elevated turbidity was found, and no differences between stations located within the ODMDS and those in the surrounding areas were observed.

4.16 The potential for water quality impacts resulting from dredged material disposal depends upon the specific constituents present and their concentrations, ambient water quality characteristics, and mixing and dilution rates. Dredged materials shown to contain toxic constituents in significant concentrations is not approved for disposal under EPA's Ocean Dumping Regulations and Criteria.

4.17 In December 1985, samples were collected from surface and near-bottom waters in the Fort Pierce Harbor interim ODMDS vicinity to identify water quality impacts that may have resulted from prior use of the site and to establish baseline conditions (Appendix A). The specific groups of potential contaminants selected for investigation included trace metals, pesticides, PCB's, and hmw hydrocarbons. None of these compounds was found in significant concentrations in surface or near-bottom waters sampled at sites outside and within the boundaries of the designated interim ODMDS. A similar study took place in March 1992. The completed analysis and reports will be added as appendices in the FEIS.

4.18 Sediments from the ODMDS vicinity were collected in December 1985 and analyzed to determine concentrations of selected trace metals, pesticides, PCBs, HMW hydrocarbons, total organic carbon (TOC), and oil and grease. The results of these analyses are summarized below and are detailed in Appendix A.

4.19 Concentrations of the trace metals, mercury, cadmium, and lead were low in seawater elutriates of sediments collected from the disposal site and the surrounding area. When subjected to weak acid extraction, a sediment sample from the ODMDS yielded higher concentrations of cadmium and lead and a lower concentration of mercury than a sample collected from a site outside the disposal area.

4.20 No chlorinated hydrocarbon pesticides or pesticide derivatives were detected in area sediments. PCB's were detected at low levels in samples taken from sites located outside the ODMDS.

4.21 Sediment concentrations of HMW hydrocarbons exhibited no consistent pattern of distribution. Highest total HMW hydrocarbon concentrations were found in sediments collected outside the ODMDS. However, component HMW hydrocarbon fractions were generally higher in disposal site sediments than in sediments from the surrounding area.

4.22 Oil and grease concentrations varied widely and do not appear to be related to prior disposal site utilization. Highest, and comparable, concentrations were found in sediments from sites located both within and upstream (south) of the disposal area.

4.23 TOC content of area sediments was low, ranging from 3.7 to 7.6 mg/g, and exhibited no definitive spatial trends. The highest TOC concentration was measured in sediments taken from the disposal area.

4.24 <u>Biological Characteristics</u>. The biological communities addressed in this section include benthic macroinfauna, benthic meiofauna, epibenthic invertebrates, and fishes. Species of special concern which may utilize the interim ODMDS are also addressed. Biota restricted to the benthic environment are of principal concern in disposal area investigations. Disposal impacts on planktonic communities are generally considered to be temporary; larger, motile organisms (nekton) are likely able to avoid dredged material disposal operations.

4.25 A December 1985 survey of the benthos of the ODMDS vicinity (Appendix A) found that polychaetes accounted for about 51 percent of the area's macroinfauna. Other major groups contributing to benthic community numbers were nematodes (13 percent), turbellarians (7 percent), crustaceans (6 percent), molluscs (6 percent), oligochaete worms (5 percent), and echinoderms (4 percent).

4.26 Polychaete Families characteristic of the area included Syllidae, Goniadidae, Dorvilleidae, and Eunicidae. The Family Sabellidae was locally abundant at one site on the disposal area's western boundary.

4.27 Species diversity is an index which is frequently used as an indicator of stability to identify disturbed areas, and to compare communities. Results of a December 1985 survey (Appendix A & B) do not indicate consistent differences in benthic macroinvertebrate diversity between stations located within the ODMDS and those located in nearby environs.

4.28 Faunal similarity indices did not reveal consistent differences between benthic communities located within the ODMDS and those in surrounding areas (Appendix A). It was noted, however, that one station within the disposal site and one station on the ODMDS boundary supported communities uncharacteristic of the overall area. Macroinfauna at the site within the disposal area were dominated by deposit feeding taxa, while suspension feeding taxa were found to be dominant at a site on the western boundary of the ODMDS. Carnivores were predominant at other sites within and outside the ODMDS. The dominance of deposit feeders at the station within the ODMDS may be in response to localized increases in sediment organic content resulting from prior disposal operations. The dominance of suspension feeders at the ODMDS boundary may reflect the relatively coarse sediment texture of the local area and is probably not related to previous dredged material deposition.

4.29 The meiofaunal invertebrates of the ODMDS vicinity were characterized in a survey conducted in December 1985 (Appendix A). Nematodes and harpacticoid copepods were the dominant meiofaunal taxa. Other groups characteristic of the area include polychaete larvae, cyclopoid copepods, crustacean nauplii, turbellarians, and representatives of the phylum Gastrotricha. No differences in abundance or diversity between the meiofauna of the ODMDS and the meiofauna of the surrounding area were noted.

4.30 The ratio between nematodes and copepods or harpacticoid copepods has been proposed as an indicator of sediment organic content (Raffaelli and Mason, 1981). In theory, as the organic content of sediments increases, deposit-feeding nematodes increase and/or copepods decrease, resulting in a higher nematode: copepoda or nematode: harpacticoid ratio. Nematode: copepoda ratios calculated for the meiofauna of the Fort Pierce Harbor ODMDS vicinity were diverse and exhibited no trends. Nematode:harpacticoid ratios were highest within the ODMDS. While potentially indicative of the prior disposal of organic sediments, based on meiofaunal variability and the paucity of data available this observation is inconclusive. Meiofaunal ratios were unrelated to grain size distributions or measured concentrations of organic carbon in area sediments.

4.31 In a study of the shallow shelf between the ODMDS and Hutchinson Island, Camp et al. (1977) found several crustacean species to be characteristic of the sandy offshore environment. These included two crabs, Portunus gibbesii and Portunus spinimanus, and the shrimp, Trachhypenaeus constrictus.

4.32 Few epibenthic invertebrates were collected in a December 1985 survey of the disposal site vicinity (Appendix A). All epibenthos collected during this survey were echinoderms. Taxa represented included the sea urchin (Lytechinus variegatus), starfish (Eschinaster sp. and Luidia clathrata), and brittle stars.

4.33 Few demersal fish were collected in the December 1985 survey of the ODMDS vicinity (Appendix A). Species collected were lane snapper (Lutianus synagris), sand perch (Diplectrum formosum), lizardfish (Synodus foetens), bay whiff (Citharicthys spilopterus), striped grunt (Haemulon striatum), leopard sea robin (Prionotus scitulus), sea catfish (Arius felis), striped burrfish (Chilomycterus schoepfi), and planehead filefish (Monacanthus hispidus).

4.34 Futch and Dwinell (1977) also report poor returns from trawl sampling on the shallow shelf off Fort Pierce. Benthic fish listed by these authors as characteristic of the sandy offshore environment and common to the December 1985 survey were lizardfish, leopard sea robin, and sea catfish. Other fish frequently represented in collections from this environment were spotted flounder (Bothus robinsi), spotted whiff (Citharicthys macrops), dusky flounder (Syacium papillosum), and rock sea bass (Centropristis philadelphica). Reef fish were also common in, but not endemic to, this sandy offshore environment.

4.35 Threatened and Endangered Species. Aquatic species classified by the State of Florida or the U.S. Fish and Wildlife Service (FWS) as endangered or threatened found in the coastal waters off Fort Pierce include the green turtle (Chelonia mydas), hawksbill turtle (Eretmochelys imbricata), Kemp's (Atlantic) ridley turtle (Lepidochelys kempii), leatherback turtle (Dermochelys coriacea), loggerhead turtle (Caretta caretta), and the West Indian (Florida) manatee (Trichechus manatus). The regulatory status of these animals is given in Table 2.

4.36 Hutchinson Island is one of the major nesting beaches on the east coast for the Atlantic loggerhead sea turtle, the leatherback sea turtle, and the green sea turtle (U.S. Fish and Wildlife Service (FWS), 1980).

4.37 The West Indian manatee frequents the Indian River and nearshore waters. Manatees are most abundant in these warm, protected waters in the winter months (FWS, 1980).

Table 2. Species of the Fort Pierce Harbor ODMDS Area that Are Classified as Endangered or Threatened by Federal Agencies

Common Name	Scientific Name	Federal
REPTILES		
Green turtle	Chelonia mydas	T
Hawksbill turtle	Eretmochelys imbricata	E
Kemp's (Atlantic) ridley turtle	Lepidochelys kempii	E
Leatherback turtle	Dermochelys coriacea	E
Loggerhead turtle	Caretta caretta	T
MAMMALS		
West Indian manatee	Trichechus manatus	E
Finback whale	Balaenoptera physalus	E
Humpback whale	Megaptera novaeangliae	E
Right whale	Eubalaena glacialis	E
Sei whale	Balaenoptera borealis	E
Sperm whale	Physeter macrocephalus	E

Federal: Listed by the U.S. Fish and Wildlife Service (FWS) or the National Marine Fisheries Service (NMFS)

Legend: E = Endangered
T = Threatened

4.38 Several endangered species of whales may occur on a transitional basis in area waters. These are the humpback whale (Megaptera novaeangliae), right whale (Balaena glacialis), sei whale (Balaenoptera borealis), finback whale (Balaenoptera physalus), and sperm whale (Physeter macrocephalus). Use of the proposed ODMDS is not expected to affect any of these species.

4.39 This EIS will serve as a Biological Assessment for purposes of Section 7 of the Endangered Species Act coordination. Site designation of the Fort Pierce ODMDS will not, and use of this site is not expected to adversely impact any threatened or endangered species. However, in conformance with the Endangered Species Act each proposed use of the site for disposal will be evaluated in consultation with the National Marine Fisheries Service (NMFS) and the FWS. Letters of concurrence from the NMFS and, if appropriate, the FWS are requested by EPA.

4.40 Commercial Fisheries. Little commercial fishing activity is concentrated in the Fort Pierce ODMDS vicinity. The low-relief Continental Shelf of the study area does not support a commercial bottom fishery. Capron Shoal, located approximately 1 nmi southwest of the study area, is fished commercially for pelagic species in the winter months. Spanish mackerel (Scomberomorus maculatus) is the principal fish taken by gill net at this site.

4.41 Shrimp are harvested for both food and bait from coastal waters in the disposal site vicinity. Species collected include brown shrimp (Penaeus aztecus), white shrimp (Penaeus setiferus), and pink shrimp (Penaeus duorarum). Commercial shrimping in the area is limited. Muncy (1984) reports that St. Lucie Inlet is the southern extent of the geographic range of the white shrimp. Pink shrimp are not commercially abundant in area waters (Bielsa, et al., 1983).

4.42 The coastal waters off St. Lucie County are believed to be the southern extent of the known range of the calico scallop (Argopecten gibbus) on the southeastern Atlantic coast. Populations have been discovered further south (Biscayne Bay) but have not been demonstrated to occur in commercial concentrations in the area.

4.43 Recreational Fishing. The coastal waters of St. Lucie County support an active recreational fishery. Much of the recreational fishing is concentrated in inshore waters and along area beaches. Most offshore activity is concentrated around artificial reefs, natural reefs, and shoals.

4.44 Two artificial reef areas are located in the general ODMDS vicinity (Figure 3). An inshore reef begins approximately 1 nmi north of Fort Pierce Inlet and 1.5 nmi from shore and runs 1 nmi to the NNE. Depths on this reef range from 26 ft to 28 ft. Another artificial reef area is located approximately 1.5 nmi southeast of the disposal area at a depth of about 55 ft.

4.45 Florida Sea Grant (1979) has noted the position of natural reefs in the area extending from the northern border of St. Lucie County to St. Lucie Inlet. One of these reef areas is located approximately 1.3 nmi due east of the Ft. Pierce ODMDS. This reef site is described as a flat bottom with heavy coral growth.

4.46 Figure 3 shows the locations of documented natural and artificial reefs in the ODMDS area. Also shown are areas that are utilized by local recreational fishing interests. These areas include reefs, shoals, obstructions, and areas where bottom relief promotes the aggregation of recreational fishes.

4.47 Recreation. The waters of the Fort Pierce Harbor area support a wide variety of recreational activities. Fishing has been addressed in previous sections of this document. Inshore and coastal waters are also utilized for swimming, skiing, sailing, boating, surfing, skin diving, and SCUBA diving.

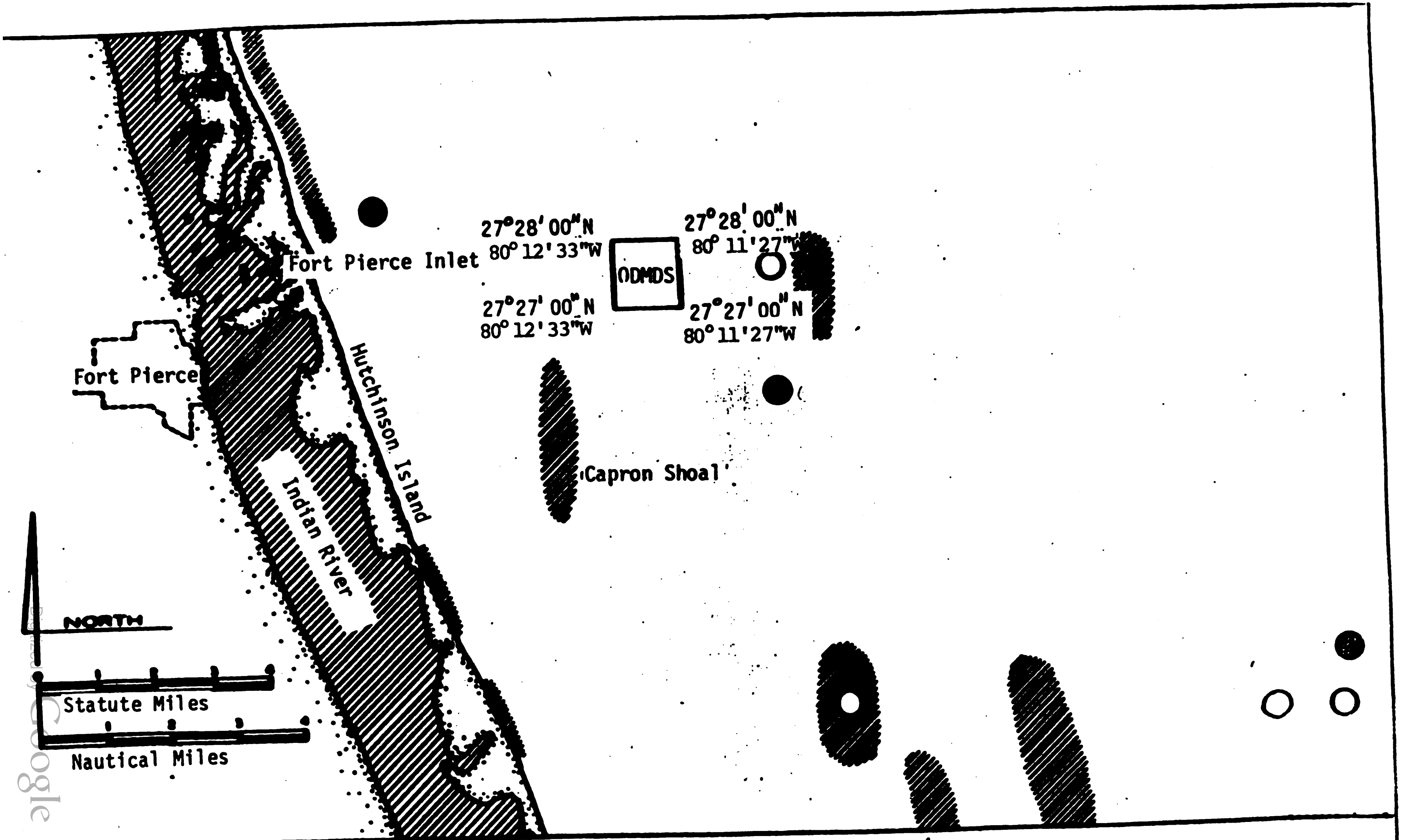

FIGURE 3

FISHING SITES

OCEAN DREDGED MATERIAL DISPOSAL SITE, FORT PIERCE, FLORIDA

Natural Reef (Sea Grant)

Artificial Reef Site

Other Recreational Fishing

4.48 Inshore and nearshore waters are subject to intense recreational use. Designated recreational areas include the Indian River Aquatic Preserve, the North Fort St. Lucie Aquatic Preserve, the Savannas State Preserve, Pepper Beach State Park, and Fort Pierce Inlet State Park. The location of these protected areas is shown in Figure 4.

4.49 Shipping. The Fort Pierce Harbor ODMDS is not located in proximity to any designated shipping channel. The disposal site is located about 2.5 nmi outside the seaward extent of the Fort Pierce Inlet entrance channel.

4.50 Military Usage. The Atlantic Ocean off Fort Pierce is used by the United States armed forces for training, testing, and research activities. The ODMDS lies near the southern boundary of the designated fleet operating area off the east coast of Florida as defined by the U.S. Department of the Interior (1977).

4.51 Mineral Resources. There are no known mineral resources in the Fort Pierce Harbor ODMDS vicinity.

4.52 Underwater Video Narrative. An underwater video survey of the candidate Fort Pierce Ocean Dredged Material Disposal Site (ODMDS) was done on May 20 and 21, 1987. Depths at the site range from 40 feet on the western (shoreward) side to 55 feet on the eastern (seaward) side. Approximately 8 hours of film were used to record the survey. Ten video transects were surveyed, each corresponding to a previously established bathymetric transect. Each transect was approximately 2 nautical miles long and oriented along an east-west axis between longitude 80°10'54"W and 80°13'06"N.

4.53 The bottom topography is rather flat, with a series of low, parallel ridges throughout the area (Ref. Section 4.02). Surface sediments in and adjacent to the ODMDS appear to be coarse to medium sand, with shells a large constituent of the material. There is no apparent difference between sediments in and adjacent to the ODMDS.

4.54 The entire ODMDS appears to support a sparse to moderate population of burrowing organisms, sea urchins, crabs, shrimp, small fishes and other invertebrates. Occasional larger fishes such as small snapper, sand perch, lizardfish, flounders and sea robins were observed. No large concentrations or schools of fish were seen during the 1987 video survey.

4.55 A field survey and video mapping performed by EPA on January 29-30, 1991 (Appendix E), revealed a considerable area of low relief, outcrops and ledges and live bottom located generally in the northern one-quarter of the interim site. Video observations indicated that the live bottoms consisted of various assemblages of sponges, hydroids, hard corals, octocorals encrusting low relief (.05m) limestone outcrops. Where ledges occurred, black sea bass were observed in large numbers.

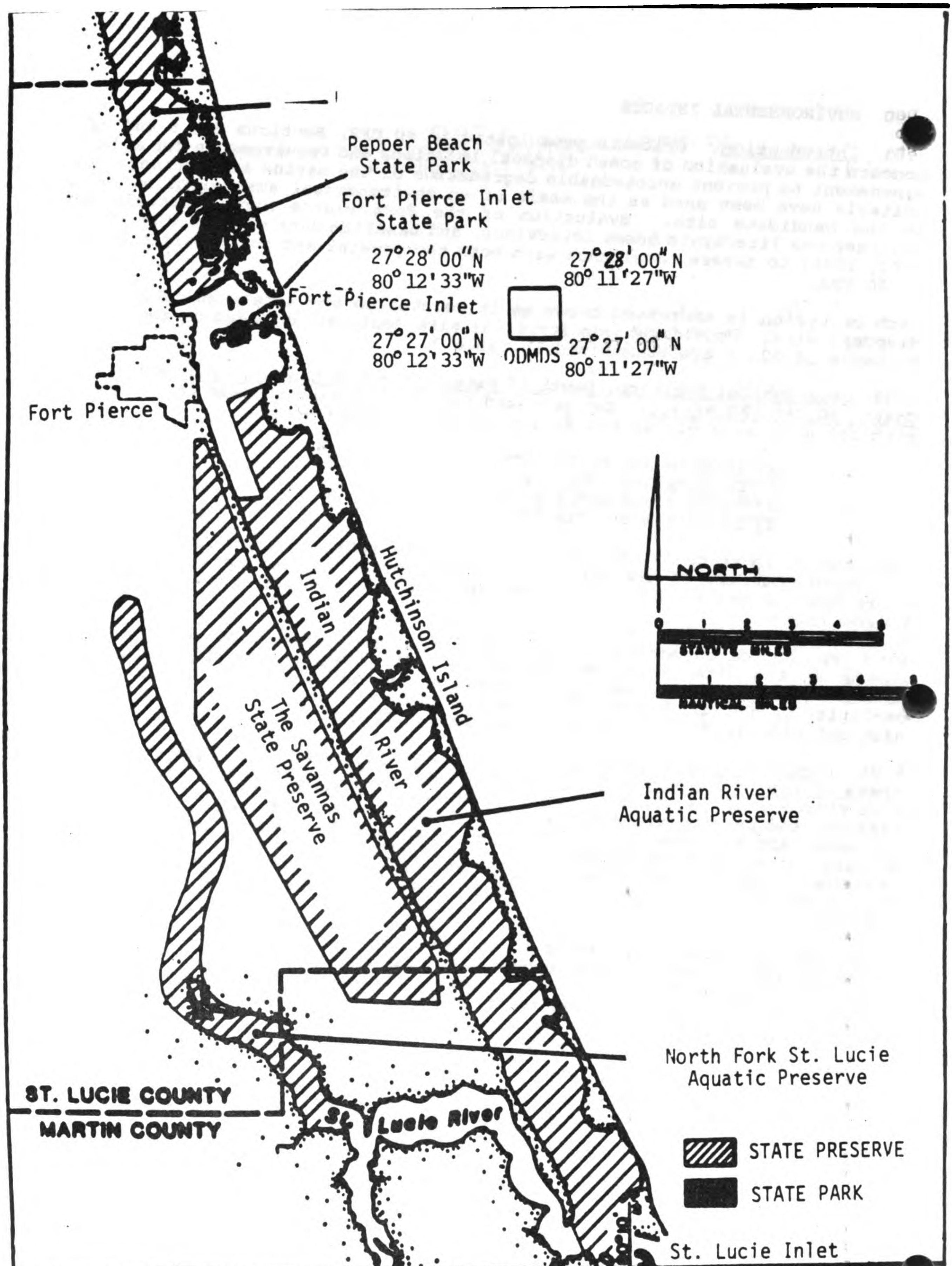

FIGURE 4

PARKS AND PRESERVES

OCEAN DREDGED MATERIAL DISPOSAL SITE, FORT PIERCE, FLORIDA

5.00 ENVIRONMENTAL IMPACTS

5.01 Introduction. Criteria promulgated in 40 CFR, Sections 228.5 and 228.6, concern the evaluation of ocean disposal locations and requirements for effective management to prevent unreasonable degradation of the marine environment. These criteria have been used as the basis of an environmental assessment of impacts at the candidate site. Evaluation of the Fort Pierce Harbor interim ODMDS utilized the literature base, interviews, and baseline data collected at the site (CCI, 1985) to assess compliance with both the general and the specific criteria of 40 CFR.

Each criterion is addressed below as it relates to the site's suitability as a disposal site. Considerations for final site designation based on the specific criteria of 228.6 are summarized in Table 3.

5.02 Geographical Position, Depth of Water, Bottom Topography and Distance From Coast [40 CFR 228.6(a)1]. The proposed Fort Pierce Harbor ODMDS is a one square nautical mile area within the following corner coordinates:

27°28'00"N and 80°12'33"W
27°28'00"N and 80°11'27"W
27°27'00"N and 80°11'27"W
27°27'00"N and 80°12'33"W

The general location of the Fort Pierce Harbor ODMDS is shown in Figure 1. The shoreward boundary of the disposal site is located approximately 4.5 nmi from shore and 5.0 nmi (9.2 km) from the northern end of Hutchinson Island and Fort Pierce Inlet.

5.03 The bottom topography (Figure 2) at the disposal site is relatively flat. Depths at the site range from 40 to 54 feet. Depths are shallowest at the southwest corner of the site and deepest at the northeast corner. The average declivity of the Continental Shelf in the ODMDS vicinity is about eight feet per nautical mile (1.85 km/nmi) (Ref. Sections 4.52-4.55).

5.04 Location in Relation to Breeding, Spawning, Nursery, Feeding or Passage Areas of Living Resources in Adult or Juvenile Phases [40 CFR 228.6(a)2]. The Fort Pierce ODMDS is located in general proximity to breeding, spawning, nursery, feeding, and passage areas for a wide variety of marine and estuarine organisms. The most active breeding and nursery areas are located in the Indian River estuary and along adjacent beaches or in offshore waters and reef areas. While breeding, spawning, and feeding activities may take place in the ODMDS, these activities are not believed to be confined to, concentrated in, or dependent on this area.

5.05 Specific migratory routes in the area are largely unknown. While marine and estuarine species would be expected to pass through the ODMDS, passage is not geographically restricted to this area. The motility of organisms passing through the area makes significant impacts from dredged material disposal unlikely.

TABLE 3
SUMMARY OF THE SPECIFIC CRITERIA AS APPLIED TO THE CANDIDATE SITE

Criteria as Listed in 40 CFR 228.6(a)	Candidate Site
1. Geographical position, depth of water, bottom topography and distance from coast.	See Figure 1 and 2. Depths at the site range from 40 to 54 ft. (12.2 to 16.5 m). The site exhibits little topographic relief and gradually deepens from the southwest to the northeast. The site lies about 4.5 nmi (8.4 km) from the coast.
2. Location in relation to breeding, spawning, nursery, feeding or passage areas of living resources in adult or juvenile phases.	Most breeding, spawning, nursery, and feeding activities take place in inshore waters or at reef areas located seaward of the site. Passage through the ODMDS is not geographically restricted.
3. Location in relation to beaches and other resource areas.	The candidate site is located about 4.5 nmi (8.4 km) from coastal beaches and approximately 6.0 nmi (11.1 km) from protected inshore waters. Hard bottom communities have been identified near and within the northern interim site boundary. (Appendix E, Figure 1)
4. Types and quantities of waste proposed to be disposed of, and proposed methods of release, including methods of packing the waste, if any.	Dredged materials complying with the applicable evaluation criteria of 40 CFR 227, Subparts A and B, will be transported and discharged by hopper dredge or barge. Anticipated Fort Pierce Harbor dredging would primarily involve sand, fine sand, and silt. Annual disposal since 1949 has averaged 21,400 cubic yds/yr, however, quantities are expected to increase in the future to an annual maximum of 67,000 cy/yr. (See Table 4) Special methods of disposal are discussed in Appendix D.
5. Feasibility of surveillance and monitoring.	Surveillance and monitoring programs can be readily implemented at the site.

6. Dispersal, horizontal transport, and vertical mixing characteristics of the area, including prevailing current direction and velocity, if any.	Prevailing currents parallel the coast and are generally oriented along a north-south axis. Northerly flow predominates with mean velocitise between 2.8 and 20 cm/sec and maximum velocities generally less than 60 cm/sec. Waters of the area are well-mixed. Vertical stratification at the candidate ODMDS has not been observed and is unlikely to occur. A dredged material dispersion study conducted by the Corps for both short and long-term fate of material disposed at the proposed site indicates little possibility of disposal material affecting near-shore reefs. (See paragraphs 5.12-5.17)
7. Existence and effects of current and previous discharges and dumping in the area (including cumulative effects).	The designated interim site has been in use since 1949 (see Table 4). Previous use has not resulted in apparent on-site or off-site long-term, adverse impacts to water quality, the physical and chemical composition of sediments, or biological communities (See Appendix A).
8. Interference with shipping, fishing, recreation, mineral extraction, fish and shellfish culture, areas of special scientific importance, and other legitimate uses of the ocean.	No interference has been noted or is anticipated. No fishing areas are located within 1.0 nmi (1.85 km) of the site.
9. The existing water quality and ecology of the site as determined by available data, or by trend assessment or baseline surveys.	Coastal waters in the site vicinity are influenced by both estuarine and oceanic intrusions. The interim site and the surrounding area support species characteristic of sandy shelf environments.
10. Potential for the development of nuisance species in the disposal site.	No evidence of undesirable organisms noted in literature or survey as a result of previous disposal activity (Appendix A).
11. Existence at or in close proximity to the site of any significant natural or cultural features of historical importance.	No known significant cultural resources noted, however, hard bottom communities were observed in the northern half of the interim site resulting in a shift in location 0.5 miles to the south (Appendix E).

5.06 Location in Relation to Beaches and Other Recreational, Cultural, and Protected Areas [40 CFR 228.6(a)3]. Beaches and adjacent nearshore areas approximately 5.0 nmi west of the ODMDS support a wide variety of recreational activities. Several protected areas lie inshore west of the ODMDS (see Figure 4). The largest of these is the Indian River Aquatic Preserve that encompasses almost all inshore waters between the barrier islands and the west Florida mainland. Other protected areas in the Fort Pierce ODMDS vicinity include the North Fork St. Lucie Aquatic Preserve, the Savannas State Preserve, Pepper Beach State Park, and Fort Pierce Inlet State Park. The Florida Department of Environmental Regulation (FDER) has given the waters of these areas special protection by designating them as Outstanding Florida Waters (OFWs).

5.07 Past surveys indicated one natural reef and one artificial reef site are located in the Fort Pierce ODMDS vicinity (Figure 3). The natural reef area is located approximately 1.3 nmi due east of the disposal site and has been described by Florida Sea Grant (1979) as a flat bottom with heavy coral growth. The artificial reef site has been established approximately 1.5 nmi southeast of the ODMDS. More recent investigations have revealed the presence of hard bottom communities in the northern portion of the interim site resulting in a shift in location of the proposed site to 0.5 miles to the south (Appendix E). The model indicates that it is unlikely that any disposed material would be transported as far as these sites from the disposal area (paragraphs 5.12-5.17 describe results of dredged material dispersion modeling).

5.08 Types and Quantities of Waste to Be Disposed of and Proposed Methods of Release, Including Methods of Packing the Waste, If Any [40 CFR 228.6(a)4]. Materials to be disposed of at the site are natural sediments dredged from the Fort Pierce Harbor entrance channel and turning basin. These sediments are variable in composition. Sediments of the entrance channel are predominantly sand, while those of the turning basin are finer sands, shell and silt. All dredged materials dumped in ocean disposal sites must comply with applicable EPA dredged material criteria as specified in Section 227, Subparts A and B, of the Ocean Dumping Regulations and Criteria (40 CFR).

5.09 Disposal methods currently practiced at the existing Fort Pierce Harbor ODMDS are acceptable for future disposal operations. Dredged materials are transported to the disposal site by barge or hopper dredge and discharged at the surface or from underwater ports while the vessel is underway. Details of the disposal technique are given in Appendix D. Because of the shallowness of the disposal site and the weakness of the currents in the vicinity, disposed material settles within a short distance of the disposal point (paragraphs 5.12-5.17).

5.10 Since September 1949, approximately 900,000 cubic yards of dredged material have been discharged at the interim site. Removal of accumulated sediments from the Fort Pierce Harbor complex is usually required every two to three years. Annual dredging volumes have averaged 30,300 CY with average annual ocean disposal of 21,000 cy for the period of record (Table 4). At the existing channel depth, maximum annual dredging volumes of 153,000 cy with maximum annual ocean disposal of 53,000 cy have been estimated. At the proposed deepening depth, maximum annual dredging volumes of 217,000 cy with maximum annual ocean disposal of 67,000 cy have been estimated.

5.11 Feasibility of Surveillance and Monitoring [40 CFR 228.6(a)5]. The geographic and physical setting of the candidate site poses no special problems for monitoring or surveillance. Water depth at the site is amenable to diver collection or surface sampling and does not require use of a large, specialized surface vessel. The areal extent of the site allows use of towed trawls for bottom and water column sampling. Baseline data collected at the site can serve as reference information for future monitoring and aid in assessing possible perturbations resulting from disposal at the site. A detailed Site Management and Monitoring Plan is presented in Appendix D.

5.12 Dispersion Characteristics Modeling Study. In 1989, the Army Corps of Engineers Waterways Experiment Station (WES) performed a technical study of the Gulf Stream meanders, spin-off eddies and prevailing tides and currents off the east coast of Florida with respect to the potential for contamination of nearshore amenities by dredged material placed in the Fort Pierce ODMDS (Appendix C). A numerical modeling approach was used for estimating both short-term and long-term rate of dredged material dispersal at the proposed ODMDS. The modeling of the short-term dumping operation was performed using the disposal from an Instantaneous Dump (DIFID) model. Long-term simulations were conducted to determine whether non-storm related currents are capable of transporting sediments outside of the proposed ODMDS over long periods of time. The effects of storm erosion were separately modeled by simulating the passage of a storm surge over the site. Current velocities used were estimated, not measured. For the study, the dredged material was assumed to be 90 percent sand (fine to medium) and 10 percent silt and clay. The results of the study indicate that the Fort Pierce ODMDS poses no threat to reef areas.

5.13 Short-Term Modeling Results. The short-term modeling of the disposal operation shows that most of the material from the disposal load settles into a mound within several hours after the initial release of the sediment from the dredge. Model results indicate the maximum distance from the barge showing deposition in excess of 0.01 feet was 400 feet. The silt and clay portion of the disposal load creates a suspension cloud or turbidity plume which is transported toward the reefs by the specified ambient currents. This cloud increases in size and decreases in concentration with distance from the point of disposal. The concentration of the suspended sediment cloud was computed at five specific depths for each silt simulation. The results indicate concentrations of suspended materials, at the time they reach the reef, to be below ths practical range of detectability, i.e., the local ambient velocity fields are not adequate in magnitude to transport any significant amount of material from the dumping operation onto the reef area.

5.14 Additional Short-Term Modeling Results. Additional short-term modeling of the disposal operation using worst case properties of the disposal material was performed by EPA Region IV using the Instantaneous Dump (DIFID) model mentioned in paragraph 5.12 (Appendix F). For this model, the dredged material was assumed to be 10 percent sand (fine to medium) and 90 percent cohesive silt and clay. All other parameters used were equivalent to those in the WES technical study. Results indicate for a single dump the maximum distance from the barge showing deposition in excess of 0.01 ft was 650 feet. The nearest amenity, hard bottom communities in the northern portion of the interim site, are at a distance of 1.2 nmiles from the fine material dump location.

5.15 The concentration of the suspended sediment cloud was computed at five specific depths for each silt simulation as in the WES study. In addition, above ambient suspended sediment concentrations were computed as a function of time for the four amenities discussed in paragraphs 4.43 to 4.46 for three hour cycle periods for dumping. For the three nearest amenities, suspended sediment concentrations drop below detection between dumps and remain above 4 mg/l for periods of less than one half hour every three hours. For the furthest reef community, concentrations remain above detectable limits after the first dump due to the dispersiveness of the sediment clouds at that distance. However, peak concentrations are below 1.7 mg/l. Limited ambient suspended sediment data collected in this area (Appendix A), ranged from five to 24 mg/l with a mean value of 12 mg/l. Consequently, the dredge disposal operation should not significantly increase suspended sediment concentrations above ambient conditions.

5.16 The natural and artificial reefs referred to in paragraphs 4.43 to 4.46 are not scleractinian coral reefs and therefore are not dependent upon the same water quality conditions commonly associated with tropical reef building corals, i.e. clear, low nutrient, warm waters. Most of the organisms comprising the communities found nearby the proposed ODMDS are not likely to be adversely affected by such low predicted suspended sediment loadings.

5.17 Long-Term Modeling Results. The long-term modeling effort was conducted to determine whether a disposal mound is stable over long periods of time. Results of the simulation show that the mound at Fort Pierce erodes, deforms and migrates at a rate of approximately 2-3 feet a day. These results were based on a one-year simulation in which the centroid of the mound moved approximately 700 feet. Additional shorter duration simulations were made to investigate storm-related transport of material from the mound onto the sensitive areas. Results for a 24-hour sustained storm surge of 4.0 ft/second show that material was moved a maximum distance of approximately 550 feet in that time. Conclusions of the long-term simulation indicate that sediment will be transported from the Fort Pierce site during both ambient and storm conditions, but that the rate and distance of movement should not affect the reef system.

5.18 Existence and Effects of Current and Previous Discharges and Dumping in the Area (Including Cumulative Effects) [40 CFR 228.6(a)7]. Dredged materials have been disposed at the Fort Pierce Harbor interim ODMDS since 1949 (Table 4). An environmental survey of the Fort Pierce Harbor ODMDS was conducted in December 1985 (CCI, 1985 in Appendix A). This survey detected no consistent differences in water quality, sediment quality, or sediment composition between the ODMDS and nearby areas. Potential disposal-induced changes in benthic macro-invertebrate community structure were localized within the ODMDS and did not extend beyond ODMDS boundaries.

5.19 Prior disposals at the ODMDS have resulted in minor localized changes in the community structure of the area. Deposit feeding macroinfauna are dominant at the disposal site while suspension feeding macroinfauna are dominant in the surrounding area. This may be due to higher organic content in the discharged materials (see paragraph 4.30). If this is the case, it would be an indication of the high level of stability of the discharged materials since the last disposal took place in May 1983. There are no differences in the abundance or diversity of the meiofauna of the disposal area, although nematode:harpacticoid ratios are highest within the disposal area, which may be a further indication of the higher organic content of the discharged materials. No differences in epibenthic invertebrate, fish, or plankton populations are evident. It is expected that any further discharge at the site would not significantly change these conditions.

5.20 Interference with Shipping, Fishing, Recreation, Mineral Extraction, Desalination, Fish and Shellfish Culture, Areas of Special Scientific Importance, and Other Legitimate Uses of the Ocean [40 CFR 228.6(a)8]. The Fort Pierce Harbor ODMDS is located about 2.5 nmi outside the seaward extent of the Fort Pierce Inlet entrance channel. Use of this site to date has not interfered with shipping and continued intermittent use of the site should not disrupt either commercial shipping or recreational boating.

5.21 Most commercial and recreational fishing activity is concentrated in inshore and nearshore waters or at offshore natural or artificial reefs. The nearest natural reef is located 1.3 nmi east of the disposal site (Florida Sea Grant, 1979). Because of the north-south orientation of the prevailing currents, no adverse impacts to this reef area have occurred from dredged material disposal operations. An artificial reef area has recently been established approximately 1.5 nmi southeast of the ODMDS.

5.22 No mineral extraction, desalination, or mariculture activities occur in the immediate area. Recreational and scientific resources are extensive throughout the area but are not geographically limited to the disposal site or nearby waters.

Table 4. Dredged Material Disposal Record, Fort Pierce Harbor.

Completion Dates	Quantity(cy)	Type of Material	Disposal Site
1949	164,423	Not Known	Ocean
1951	63,412	Not Known	Ocean
1954	153,190	Not Known	Ocean
1955	76,700	Not Known	Ocean
1956-1957	73,656	Not Known	Ocean
1958	6,587	Not Known	Ocean
1959	23,988	Not Known	Ocean
1966	184,916	Not Known	Ocean
1973-74	219,000	Not Known	Beach/Upland
1974	12,276	Sand	Ocean
1976	14,566	Sand	Ocean
1978	49,773	Sand	Beach
1980	14,592	Shell, Sand	Ocean
1[illegible]	106,268	Silty Sand	Ocean
1985	11,000	Shell, Sand	Ocean
1987	29,773	Sand	Beach
1988-1989	47,792	Sand	Beach
1990	55,700	Sand	Beach
TOTAL:	1,307,612		

5.23 Existing Water Quality and Ecology of the Site as Determined by Available Data or by Trend Assessment or Baseline Surveys [40 CFR 228.6(a)9]. Water quality at the ODMDS is variable and influenced both by discharges from inshore estuarine systems and by periodic oceanic intrusions. Estuarine discharges are greatest during the wet season, from late summer to early fall, and may deliver both nutrients and anthropogenic contaminants to coastal waters. Nutrients may also be introduced to shelf waters by upwellings (Worth and Hollinger, 1977). Surface and bottom waters sampled in the ODMDS vicinity in December 1985 (Appendix A) did not contain measurable concentrations of selected trace metals, pesticides, hydrocarbons, or PCBs.

5.24 Benthic communities in the ODMDS vicinity have been described from a survey conducted in December 1985 (Appendix A). Nematodes, copepoda crustaceans, and larval polychaetes are the most abundant representatives of the meifaunal community. The area's diverse benthic macroinvertebrate fauna are dominated by carnivorous polychaete worms of the family Syllidae. Other abundant macroinfaunal groups included nematodes, oligochaete worms, molluscs, amphipod crustaceans and turbellarians.

5.25 Epibenthic invertebrates characteristic of the disposal site vicinity include the crabs Portunus gibbesi and Portunus spinimanus, the shrimp, Trachypenaeus constrictus, the sea urchin, Lytechinus variegatus, starfish and brittle stars (Camp el al., 1977; Appendix A).

5.26 The demersal fish fauna of the area are not abundant (Futch and Dwinell, 1977; Appendix A). Fish characteristic of the sandy offshore ODMDS environment include leopard sea robin (Prionotus scitulus), sand perch (Diplectrum formosum), and lizardfish (Synodus foetens).

5.27 Potential for the Development or Recruitment of Nuisance Species in the Disposal Site [40 CFR 228.6(a)10]. The Fort Pierce Harbor ODMDS has been utilized since 1949. To date, no nuisance species have been reported from the interim ODMDS or nearby previously utilized disposal sites. The potential for the development or recruitment of nuisance species at this site is considered quite low. A December 1985 survey of the ODMDS vicinity (Appendix A) yielded no evidence of undesirable organisms.

5.28 Existence at or in Close Proximity to the Site of Any Significant Natural or Cultural Features of Historical Importance [40 CFR 228.6(a)11]. It is unlikely that significant natural or cultural features of historical importance exist at the disposal site. In the unlikely event that historical features are present on site, they will have been covered with sand and would be further covered by continued disposal operations.

5.29 The dumping of materials into the ocean will be permitted only at sites or in areas selected to minimize the interference of disposal activities with other activities in the marine environment, particularly avoiding areas of existing fisheries or shellfisheries, and regions of heavy commercial or recreational navigation [40 CFR 228.5(a)]. The Fort Pierce Harbor ODMDS does not support either commercial or recreational fisheries. The closest artificial and natural reef sites lie approximately 1.5 nmi from the ODMDS boundary. The locations of commercial and recreational fishing sites with respect to the preferred disposal site are shown in Figure 3.

5.30 The Fort Pierce Harbor ODMDS is not located in proximity to any designated shipping channel, safety fairway, or anchorage. The disposal site is located about 2.5 nmi outside the seaward extent of the Fort Pierce Inlet entrance channel. Use of this site to date has not interfered with shipping and continued intermittent use of the site should not disrupt either commercial shipping or recreational boating.

5.31 Locations and boundaries of disposal sites will be so chosen that temporary perturbations in water quality or other environmental conditions during initial mixing caused by disposal operations anywhere within the site can be expected to be reduced to normal ambient seawater levels or to undetectable contaminant concentrations or effects before reaching any beach, shoreline, marine sanctuary, or known geographically limited fishery or shellfishery [40 CFR 228.5(b)]. The temporary fluctuations in water quality resulting from disposal operations should be reduced to ambient or undetectable levels within a short distance of the release point. Waters at the site are expected to be well mixed throughout the year (Worth and Hollinger, 1977; EPA, 1973; Appendix A). Prevailing currents at this site are to the north about 4 nmi (7.4 km) from the nearest landfall. At this location, the likelihood of impacts to shoreward resources and protected areas is minimal. The disposal site does not lie in the vicinity of geographically limited fishery or shellfishery resources.

5.32 If, at any time during or after disposal site evaluation studies, it is determined that existing disposal sites presently approved on an interim basis for ocean dumping do not meet the criteria for site selection set forth in 228.5 and 228.6, the use of such sites will be terminated as soon as alternate disposal sites can be designated [40 CFR 228.5(c)]. The proposed disposal site meets the criteria for site selection set forth in 40 CFR, Sections 228.5 and 228.6. Should future investigations indicate that these criteria are not being met, alternatives will be developed and evaluated and an alternate disposal site selected.

5.33 The sizes of ocean disposal sites will be limited in order to localize for identification and control any immediate adverse impacts and permit the implementation of effective monitoring and surveillance programs to prevent adverse long-range impacts. The size, configuration, and location of any disposal site will be determined as part of the disposal site evaluation or designation study [40 CFR 228.5(d)]. An area of about 1 square nautical mile has been designated as the ODMDS. The size (1 nautical mile square), location (4.5 nautical miles from shore), and relatively shallow depth (40 to 54 feet) of the site would facilitate monitoring and surveillance operations.

5.34 EPA will, wherever feasible, designate ocean dumping sites beyond the edge of the Continental Shelf and other such sites that have been historically used [40 CFR 228.5(e)]. The proposed site has been used for disposal activities since 1949 with no discernable adverse environmental effects (Appendix A). The Continental Shelf extends approximately 17 nmi off Fort Pierce Inlet, to the 50 fathom contour. The transport of dredged materials beyond the shelf would be economically prohibitive, substantially increasing cubic yard costs over the base cost to the interim site. Monitoring and surveillance programs would also be more difficult and costly to implement at sites located in deeper offshore waters. No historically used disposal site in deep water exists in the Fort Pierce area. Disposal activities in deep water would also impact a previously undisturbed area.

5.35 Relationship Between Short-Term Uses and Long-Term Productivity. Disposal operations have been conducted at the current ODMDS since 1949. Longterm productivity in the nearby marine environment is not affected.

5.36 Irreversible or Irretrievable Commitments of Resources. Resources committed by ocean disposal operations include:

- .Use of energy and economic resources associated with disposal operations.
- .Loss of some planktonic and benthic marine organisms as a direct result of disposal.
- .Use of economic resources that will be committed to the testing of dredged materials, surveillance of disposal operations, and monitoring of the disposal sites.

5.37 Unavoidable Adverse Environmental Effects and Mitigating Measures. Adverse effects associated with disposal would include the temporary degradation of water quality at the disposal site and the smothering of a portion of the benthic community. Minor changes in bathymetry and sediment texture within the ODMDS would also occur. No mitigation measures would be necessary.

6.00 LIST OF PREPARERS. The following people were primarily responsible for the preparation of this document.

NAME	DISCIPLINE/EXPERTISE	EXPERIENCE	Project Role
Mr. Rea Boothby	Ecologist	17 years EIS studies	EIS Author
Dr. Gerald Atmar	Biologist	18 years EIS studies	EIS Supervisor
Ms. Catherine A. Fox	Environmental Scientist	Biogeochemist; 2 years, Environmental Protection Agency	EIS Coordinator and Reviewer ('91-'92)
Mr. Chris Provost	Environmental Engineer	Environmental Studies; 4 years, Environmental Protection Agency	EIS Coordination
Mr. Christopher McArthur	Environmental Engineer	Environmental Engineer, Environmental Protection Agency Project Coordinator, H.G.E., Inc. Engineers & Planners, 1 year	EIS Coordinator and Reviewer (1992-93)
Mr. William T. Marsh	Environmental Assessment, Aquatic Ecology, Coastal Systems	Staff Scientist, Environmental Science and Engineering, Inc.; 2 years Staff Scientist, Jones, Edmunds & Assoc., Inc.; 5 years Vice President, TAI Environmental Services Inc.; 3 years Senior Staff Scientist/Division Manager, Conservation Consultants, Inc.; 1 year	Project Manager, Principal Investigator
Mr. William T. Hamilton	Environmental Assessment	President, Conservation Consultants, Inc.; 17 years	Project Advisor
Mr. Lawrence J. Swanson	Fisheries Resources, Aquatic Biology	Staff Scientist, Conservation Consultants Inc.; 13 years Research Assistant, University of Miami; 1 year	Field Team Coordination; Fish and Epibenthic Invertebrate Taxonomy
Ms. Dorothy S. Morse	Chemistry	Soil Chemist, University of Florida; 3 yrs Laboratory Supervisor, Utility Service Associates, Inc; 4 years Chemist, Manatee County Pollution Control; 1 year Chief Chemist, Conservation Consultants, Inc.; 8 years	Laboratory Supervisor, Granulometry
Ms. Sherrie A. Leman	Analytical Chemistry	Staff Chemist, Conservation Consultants Inc; 3 years Laboratory Technician, Manatee County Utilities; 2 years	Granulometry

6.00 LIST OF PREPARERS (Continued). The following people were primarily responsible for the preparation of this document.

NAME	DISCIPLINE/EXPERTISE	EXPERIENCE	PROJECT ROLE
Mr. Mark A. Phillips	Environmental Technologist	Environmental Technician, Conservation Consultants, Inc.; 4 years	Technical Support
Dr. Norm Scheffner		Waterways Experiment Station	Evaluation of Dispersion Characteristics

OTHERS:

Savannah Laboratories, Inc.: Analytical Chemistry; Water, Sediments, and Tissue
Taxonomic Associates, Inc.: Benthic Macroinvertebrate Taxonomy

)0 PUBLIC INVOLVEMENT - this document will be coordinated with the following encies, groups and individuals:

Federal
Atlantic States Marine Fisheries Committee
Advisory Council on Historic Preservation
U.S. Bureau of Mines
U.S. Food and Drug Administration
U.S. Fish and Wildlife Service - Field Supervisor
U.S. Fish and Wildlife Service - Regional Director
U.S. Fish and Wildlife Service - Endangered Species Field Office
Department of the Air Force - Environmental Planning Division
Department of Energy
Department of Interior
Department of Commerce
Department of Defense
Department of Health and Human Services
Department of Health and Human Services - Environmental Health Services Division
Economic Development Administration
Federal Maritime Commission
Federal Emergency Management Administration
Federal Highway Administration
Office of Coastal Zone Management
U.S. Army Corps of Engineers - Area Engineer
U.S. Army Corps of Engineers - Division Engineer
U.S. Coast Guard - Seventh District
U.S. Department of Agriculture - State Conservationist, Soil Conservation Service
U.S. Department of Housing and Urban Development
U.S. Department of Agriculture - State Director
U.S. Department of Agriculture - Soil Conservation Service
U.S. Geological Survey - Water Resources Division
National Marine Fisheries Service - Environmental Assessment Branch
National Marine Fisheries Service - Regional Director
National Marine Fisheries Service - Protected Species Branch
Minerals Management Service - Regional Director
National Park Service - Regional Director
National Science Foundation
Naval Facilities Engineering Command - Southern Division
Naval Facilities Engineering Command
Honorable Bob Graham (U.S. Senate)
Honorable Connie Mack (U.S. Senate)
Honorable Tom Lewis (U.S. House of Representatives)
South Atlantic Fisheries Management Council

State and Local Agencies
Agricultural Advisory Council
Board of Trustees of the Internal Improvement Trust Fund
Bureau of Marine Research
Department of Archives
Department of Environmental Resources Management
State Clearinghouse
State Archaeologist
Gulf States Marine Fisheries Commission
Florida Sea Grant Extension Program
Florida Department of Natural Resources
Florida Department of Environmental Regulation
Florida Department of Environmental Regulation - Southeast District
Florida Department of Transportation
Florida Game & Freshwater Fish Committee
Florida Marine Fisheries Comm

Florida Inland Navigation District
Florida Historic Preservation Office
Honorable Lawton Chiles (Governor, State of Florida)
Florida House of Representatives
- Honorable Rick Minton (78th District)
- Honorable Charles Sembler II (80th District)
- Honorable Ken Pruitt (81st District)

Florida Senate
- Honorable Patsy Ann Kurth
- Honorable William G. Myers

South Florida Water Management District
State Health Officer
Environmental Regulation Commission
Department of Legal Affairs
Division of Forestry
Department of Natural Resources - Bureau of Beaches and Shores
Chairman of County Commissioners, St. Lucie County, Florida
St. Lucie County Board of Commissioners
Mayor, City of Ft. Pierce
Port Director, Port of Ft. Pierce

Private Organizations

Action
Continental Shelf Associations
Conservation Consultants, Inc.
Coalition to Stop Ocean Dumping
Clean Ocean Action
The Council for Clean Air
Committee on Pollution
Center for Action Endangered Species
Citizens Committee 100
Environmental Action Group
Environmental Services, Inc.
Environmental End Consultants
Tropical Audubon Society
Florida Audubon Society
Florida Coalition for Clean Water
Florida Sport Fishing Association
National Audubon Society
Florida Conservation Fund
Florida Wildlife Federation
Florida Defenders of the Environment
Florida Conservation Foundation, Inc.
Florida Trail Association Inc.
Envisors, Inc.
Ecology Unlimited
Isaak Walton League of America, Inc.
National Wildlife Federation
National Resources Defense Council
Oceanic Society
Organized Fisherman of Florida
Science Applications International Corporation
Sierra Club - Florida Chapter
Wilderness Society
World Wildlife Fund
Florida Local environmental Regulation Association
Florida Bass Chapter
Florida League of Anglers
Florida State UAW-CAP Council
International Women's Fish Association
Lemon Bay Conservancy

Nature Conservancy
Organized Fisherman of Florida
Survive

Universities and Other Sources
University of Miami - Department of Anthropology
University of Miami - Rosenstiel School of Marine & Atmospheric Science
Mote Marine Laboratory
Florida State University
Harbor Branch Oceanographic Institute
University of Florida
University of South Florida
University of West Florida
Florida Atlantic University
NOVA University
Florida Institute of Technology

Coordination with the National Marine Fisheries Service as required by Section 7 of the Endangered Species Act of 1973 has been concluded. The National Marine Fisheries Service in a letter dated March 3, 1993 concurred with the determination that populations of endangered or threatened species under their purview would not be adversely affected by the proposed action. Should additional information become available concerning possible impacts or should the activity be modified, additional consultation would be requested.

The Notice of Availability of the Draft EIS was published in the Federal Register on January 22, 1993 and the public comment period closed on March 8, 1993. A total of 15 comment letters were received during the public review period. All the comment letters are included on the following pages along with responses to the comments. The comment numbers in the left margin of the comment letter correspond to the response numbers on the pages immediately following the comment letter.

UNITED STATES D. PARTMENT OF COMMERCE
National Oceanic and Atmospheric Administration
Office of the Chief Scientist
Washington, D.C. 20230

February 25, 1993

Mr. Greer C. Tidwell
Regional Administrator
U.S. Environmental Protection Agency
345 Courtland Street, N.E.
Atlanta, Georgia 30365

Dear Mr. Tidwell:

Enclosed are comments on the Draft Environmental Impact Statement for an Ocean Dredged Material Disposal Site (ODMDS) offshore Fort Pierce, Florida. Thank you for giving us an opportunity to review the document.

Sincerely,

Donna Wieting (for)
David Cottingham
Director
Ecology and Conservation Office

Enclosures

UNITED STATES DEPARTMENT OF COMMERCE
National Oceanic and Atmospheric Administration
NATIONAL OCEAN SERVICE
Coast and Geodetic Survey
Rockville, Maryland 20852

FEB 23 1993

MEMORANDUM FOR: David Cottingham
Ecology and Environmental Conservation Office
Office of the Chief Scientist

FROM: Rear Admiral J. Austin Yeager, NOAA
Director, Coast and Geodetic Survey

SUBJECT: DEIS 9301.01 - Designation of an Ocean Dredged Material Disposal Site Located Offshore from Fort Pierce, Florida

The subject statement has been reviewed within the areas of Coast and Geodetic Survey's (C&GS) responsibility and expertise and in terms of the impact of the proposed actions on C&GS activities and projects. Since safety of navigation is one of C&GS' primary concerns, this proposal was examined with that in mind and any other impact it may have on C&GS activities and projects.

C&GS considers projects affecting navigation to be extremely important. From the navigational point of view, it is never desirable to place materials in the ocean in the vicinity of ports, harbors, and channels. Sites on shore or in deep water are always preferable from our point of view. However, considering all alternatives, the selected site appears to be a reasonable alternative.

C&GS has no objections to the proposed site. However, we are obligated to note that the proposed site is not due south of the interim site according to National Ocean Service nautical chart 11474. It is almost due southeast of the interim site. In addition, we would be very interested in being informed about the status of the interim site if this new site is approved.

This area is covered on the above noted chart, and all changes resulting from this project will be reflected on the chart. To ensure proper depiction of this area, we request clarification of the position of these sites and the status of the interim site after the proposed new site is placed into service.

For further information concerning this response, please contact the External and Cooperative Affairs Group, N/CG22x2, WSC1, room 808, Nautical Charting Division, NOAA, Rockville, Maryland 20852, telephone 301-443-8157.

cc: N/CG1x11 - R. Taylor
N/CG17 - J. Spencer
N/CG22x2 - E. Frey

FEB 25 1993
RECEIVED
EC

RESPONSE
COAST AND GEODETIC SURVEY

1. The longitudinal coordinates given in figures 1 through 4 and in the text were incorrect in the Draft EIS. The coordinates have been corrected.

March 4, 1993

Greer C. Tidwill
Regional Administrator
United States Environmental Protection Agency
Region IV
345 Courtland Street N.E.
Atlanta, Georgia 30365

Re: Draft EIS for ODMDS offshore Fort Pierce, Florida

Dear Administrator Greer:

I did not receive a copy of the draft until yesterday. I reviewed it as well as I could in two days, and have a few comments. Realizing that you perhaps can do nothing about it, I still must say that to have the U.S. Army Corps compile the information and data for this project and to rely on it for your analysis is beyond comprehension. I liken this abomination to allowing accused criminals control of the law enforcement agency in charge of investigating their crimes.

It is likely you are unaware of the controversy this project has generated in St. Lucie County. If you want copies of newspaper articles, television coverage of protests, etc., please let me know. Those opposed to the project have, by way of a lawsuit, forced the Corps to undertake a supplemental EIS and to admit the existence of valuable habitat that would be impacted. The corps has made some modifications, but due to the fragile egos of those in charge, no further admission of wrong have occurred. Those who are in favor of the project are a mix of the greedy, the political hacks, and the sincere but terribly uninformed. Perhaps you will reexamine your position on some elements of this project.

1. It is very clear that in appendix C the characteristics of dredged material are not based on the core borings obtained by the Corps. Silt and clay concentrations exceed those "assumed", and those in the analysis used, and this completely invalidates the model.

2. Historical disposal should not be used to justify current disposal as the scope and areas of dredging are not the same and the material is not the same.

3. Alternatives to ocean dumping exist; upland properties are available. This would also tremendously reduce inshore impacts from clamshell dredge and hopper operations. The corps simply does not want to spend the additional funds for alternatives, even though substantial savings in project cost have already been made through modifications in scope.

Economic analysis used to justify the project have been skewed and do not reflect reality. The expansion, or any activity over and above maintenance of the existing channel and basin, should not be permitted. It is classic pork barrel spending, and the damage to existing sport and commercial fisheries is not acceptable.

The Indian River Lagoon is an Estuary of National Significance, and although the inlet channel and basin have been exempted from the designation, the lines of separation are on paper, and in reality the expansion of port facilities directly effects the Lagoon.

Two days ago, cement dust was dumped into the basin. Unsubstantiated reports say the total spill was several tons. Because of the limited depth, ship size is restricted. With expansion, widening and deepening, the potential dangers to the environment increase exponentially.

Overall, you should not permit the use of the use of the ODMDS for this project. The sediment dispersal models are not useful or accurate, environmentally sound alternatives exist, and immediate and long term impacts to the Lagoon system are not justifiable.

Sincerely yours,

Blaine Williams
2822 NW 44 Th Place
Gainesville, Fl 32605-1557

Enclosed is the mailing label from the package containing the draft showing the postmark date.

UNITED STATES DEPARTMENT OF COMMERCE
National Oceanic and Atmospheric Administrat
NATIONAL MARINE FISHERIES SERVICE
Southeast Regional Office
9450 Koger Boulevard
St. Petersburg, Florida 33702

February 10, 1993

Mr. Robert B. Howard
Chief, Coastal Regulatory Unit
U.S. Environmental Protection Agency
Region IV
345 Courtland Street NE
Atlanta, Georgia 30365

Dear Mr. Howard:

This is in response to your letter dated December 4, 1992, requesting comments regarding the Draft Environmental Impact Statement (DEIS) for Ocean Dredged Material Disposal Site (ODMDS) Designation offshore Fort Pierce, Florida.

The National Marine Fisheries Service has reviewed the subject DEIS and generally found that the document is clear and well written. We have no specific comments to provide regarding marine fishery habitat issues with respect to the area to be used as an ODMDS. If we can be of further assistance, please contact Mr. David N. Dale of our Panama City Branch Office at 904/234-5061.

Sincerely,

Andreas Mager, Jr.
Assistant Regional Director
Habitat Conservation Division

RESPONSE
BLAINE WILLIAMS

The response received from Mr. Blaine Williams contained comments regarding both the Draft EIS for an ODMDS and the authorized modifications to the existing Federal Project at Fort Pierce Harbor. Because these are separate independent actions, only the ODMDS Draft EIS comments will be addressed here.

1. The short-term modeling described in Appendix C used a dredged material composition characteristic of typical dredge material. This composition consisted of 63 percent sand, 7 percent silt-clay, and 30 percent water, volumetrically. The Fort Pierce ODMDS however will typically receive finer grained dredge material since sandy material will typically be placed as beach renourishment. Therefore, additional modeling was performed using a revised conservative dredged material composition consisting of 3 percent sand, 27 percent silt-clay and 70 percent water volumetrically. This corresponds to 90 percent silt-clay and 10 percent sand on a solids basis. This additional modeling was presented in Appendix F of the Draft EIS.

The long-term modeling described in Appendix C used a 0.2mm material in the transport computations to provide a threshold indication of fine material transport and to yield a "worst case" prediction of sediment erosion from the mound.

2. The Fort Pierce ODMDS will undergo monitoring to determine the environmental effects of dredge disposal. Based on the type and volume of material disposed, various monitoring surveys will be used to determine if and where the disposed material is moving, and what environmental effect the material is having on the site and adjacent area. More detail on the monitoring plan is given in Appendix D, <u>Site Management and Monitoring Plan.</u>

3. A discussion of non-ocean disposal alternatives was presented on the Fort Pierce Harbor General Reevaluation Report. Alternatives considered were beach disposal, Indian River disposal, Offshore disposal and upland disposal. A discussion of these alternatives, as taken from the Fort Pierce Harbor Report, is presented in Appendix H.

DEPARTMENT OF HEALTH & HUMAN SERVICES

Public Health Service

Centers for Disease Control
Atlanta GA 30333

March 3, 1993

Robert B. Howard, Chief
Coastal Regulatory Unit
U.S. Environmental Protection Agency
Region IV
345 Courtland Street, NE
Atlanta, Georgia 30365

Dear Mr. Howard:

We have completed our review of the Draft Environmental Impact Statement (DEIS) for the Fort Pierce Ocean Dredged Material Disposal Site Designation. We are responding on behalf of the U.S. Public Health Service.

We note that dredged materials shown to contain toxic constituents in significant concentrations is not approved for disposal under EPA's Ocean Dumping Regulations and Criteria. The proposed site meets the eleven specific ocean disposal site criteria, and has been used since 1949 without evidence of environmental degradation. If future dredged material continues to be similar in physical and chemical characteristics, we would not anticipate adverse impacts from the proposed designation and continued use of the site.

Thank you for the opportunity to review and comment on this draft document. Please ensure that we are included on your mailing list to receive a copy of the Final EIS, and future DEIS's which may indicate potential public health impacts and are developed under the National Environmental Policy Act (NEPA).

Sincerely yours,

Kenneth W. Holt

Kenneth W. Holt, M.S.E.H.
Special Programs Group (F29)
National Center for Environmental
Health

U.S. Department of Housing and Urban Development
Atlanta Regional Office, Region IV
Richard B Russell Federal Building
75 Spring Street, S.W.
Atlanta, Georgia 30303-3388

Mr. Robert B. Howard
U. S. EPA
Coastal Programs Section
345 Courtland Street, NE
Atlanta, Georgia 30365

Dear Mr. Howard:

This refers to your memorandum dated December 4, 1992, transmitting the Draft Environmental Impact Statement (DEIS) for an Ocean Dredge Material Disposal Site (ODMDS) offshore Fort Pierce, Florida.

Our review indicates there will be no significant adverse impact on any HUD programs as a result of this project.

Thank you for the opportunity to review and comment on your proposed project.

Sincerely,

Warren J. Howze
Director
Program Support Division
Regional Environmental
Clearance Officer

cc:
Rea Boothby
U. S. Army Corps of Engineers
Environmental Resources Branch
P. O. Box 4970
Jacksonville, Florida 33232-0019

NATIONAL SCIENCE FOUNDATION
WASHINGTON, D.C. 20550

OFFICE OF THE
ASSISTANT DIRECTOR
FOR GEOSCIENCES

FEB - 8 1993

Dr. Robert B. Howard
Chief
Coastal Regulatory Unit
U.S. Environmental Protection Agency
Region IV
345 Courtland Street, N.E.
Atlanta, Georgia 30365

Dear Dr. Howard:

The National Science Foundation has no comment on the Draft Environmental Impact Statement (EIS) for an Ocean Dredge Material Disposal Site offshore Fort Pierce, Florida.

Sincerely,

Vanessa Richardson

Vanessa Richardson
Chairperson
Committee on Environmental
Matters

26 January 1993
17 Fairglen Drive,
Titusville, FL 32796

Mr. Robert B. Howard, Chief
Coastal Regulatory Unit
U.S. EPA, Region IV
345 Courtland Street, NE
Atlanta, Georgia 30365

Dear Mr. Howard:

Responding to your request for comments, dated 4 Dec 92, our organization has reviewed the Draft Environmental Impact Statement (EIS) for an ocean Dredge Material Disposal Site (ODMDS) offshore Fort Pierce, Florida. We forward the following comments for your consideration.

We have no doubt that studies previous to this one have determined that Ocean Dumping is the least cost option for the Corps of Engineers and the local cooperating agency. However since we are dealing with local, state, national and world resources, the real question should be "What is the most beneficial option considering the human, natural and economic needs and resources of all parties concerned?" While our small organization does not have the resources to provide a definitive answer to that complex question, we fear that the present proposal is not the answer.

There is a real need to make an asset out of what is now considered a liability to be disposed of in the least cost manner which produces only acceptable damage. As is the case with most natural resources, this resource will probably become an asset only after some additional processing, the processing in this case being sorting and grading the spoil material into at least three categories:

1. rock and shell
2. sand
3. silt and fines.

Florida has a great need for each of these three items: rock and shell to be used as concrete aggregate or road base, sand to replenish our eroding beaches, and silt and fines to increase the fertility of our sterile soils and for use as fill in areas detrimentally affected by rising sea levels. What Florida does not need is to destroy any more of the ocean bottom and the benthos organisms which reside therein.

1. Since sand and rock aggregate can be economically dredged, sorted and marketed from the Ohio River channel in the vicinity of Louisville, Kentucky, can you please inform us as to why a similar system cannot be used at Fort Pierce? We would very much appreciate an answer.

Sincerely,

Jane J. Ferguson, president
N. Brevard Environmental Action Committees

Copies to: Gov. Lawton Chiles, Dept. of Nat. Resources, DER,
Chairman St. Lucie Co. Commission, Port Director

UNITED STATES DEPARTMENT OF COMMERCE
National Oceanic and Atmospheric Administration
NATIONAL MARINE FISHERIES SERVICE
Southeast Regional Office
9450 Koger Boulevard
St. Petersburg, FL 33702

March 3, 1993   F/SEO13:JEB

Wesley B. Crum
Chief, Coastal Programs Section
U.S. EPA
Coastal Programs Section
345 Courtland Street, NE
Atlanta, GA 30365

Dear Mr. Crum:

This responds to your letter of January 15, 1993 and the attached draft environmental impact statement (DEIS) for the designation of an Ocean Dredged Material Disposal Site (ODMDS) located offshore of Fort Pierce, Florida. While you do not specifically request Endangered Species Act (ESA) Section 7 consultation on this action it is clear from your letter and section 4.39 of the DEIS that this is your intention. For the purpose of this consultation the DEIS will serve as the biological assessment (BA).

We have reviewed the BA and concur the with your determination that populations of endangered/threatened species under our purview would not be adversely affected by the proposed action. The DEIS mentions that right whales may occur in the area on a transitional basis. In fact, right whales with calves may be found in the vicinity of Ft. Pierce from December through March of each year. Designation of the ODMDS would not adversely
1. affect right whales but the use of the disposal area by dredges may increase the risk of vessel/whale collisions.

This concludes consultation responsibilities under Section 7 of the ESA. However, consultation should be reinitiated if new information reveals impacts of the identified activity that may affect listed species or their critical habitat, a new species is listed, the identified activity is subsequently modified, or critical habitat is determined that may be affected by the proposed activity.

If you have any questions please contact Jeffrey Brown, Fishery Biologist, at (813) 893-3366.

Sincerely,

Charles A. Oravetz

for Andrew J. Kemmerer
Regional Director

cc: F/PR2

RESPONSE
Ms. JANE J. FERGUSON

The Corps did an analysis of cost for sorting rock, sand and fines for the Miami Harbor Channel Design Memorandum Report date October 1989. The analysis indicated that the cost of obtaining unwashed rock 2+ in diameter added $44 per cubic yard to the cost of dredging. Complete sorting of material added $144 per cubic yard. It is assumed that costs for the similar work at Fort Pierce Harbor would be similar, thus making the project prohibitively expensive.

United States Department of the Interior

TAKE PRIDE IN AMERICA

OFFICE OF THE SECRETARY
Washington, D.C. 20240

MAR 2 1993

In Reply Refer To:
ER 93/64

Mr. Robert B. Howard
Chief, Coastal Regulatory Unit
U.S. Environmental Protection Agency, Region IV
345 Courtland Street, NE
Atlanta, Georgia 30365

Dear Mr. Howard:

The Department of the Interior has reviewed the draft Environmental Impact Statement (DEIS) for the designation of an ocean dredged material disposal site located offshore Fort Pierce, Florida, as proposed by the Environmental Protection Agency (EPA).

The proposal involves dredging of the Fort Pierce Harbor entrance channel and turning basin at a maximum annual rate of 67,000 cubic yards. The dredged material will be transported about 10 miles using barges and disposed of at the designated site. The diesel fuel powered engines operating the dredge and tugboats to move barges will be emitting air pollutants which have the potential to impact onshore air quality.

The analysis in the DEIS is deficient because it neglects to
assess or discuss the impacts associated with these air emissions
on the onshore air quality. Air emissions associated with this
1. proposed action can be estimated using an EPA publication
entitled: "Compilation of Air Pollutant Emission Factors," (AP-
42, Fourth Edition, September 1985). The EPA should consider
calculating air emission impacts on the onshore air quality
likely to result from this proposal using computer models such as
the Offshore and Coastal Dispersion Model. Calculated impacts
can then be compared with the National Ambient Air Quality
Standards (NAAQS) and maximum allowable Prevention of Significant
Deterioration (PSD) increments to determine their effects on
onshore air quality.

RESPONSE
NATIONAL MARINE FISHERIES SERVICE
SOUTHEAST REGIONAL OFFICE
ANDREW J. KEMMERER

1. Insofar as possible effects on threatened or endangered species, use of the disposal area will be evaluated on a project-by-project basis.

RESPONSE
U.S. DEPARTMENT OF THE INTERIOR

1. There will be no air emissions associated with the site designation process per se. Air emission impacts for specific projects will be evaluated on a project-by-project basis.

We appreciate the opportunity to comment on the DEIS and hope that our comments are helpful. We look forward to reviewing the final EIS when it is published. If you have any questions regarding our comments, you may contact Ken Havran in the Office of Environmental Affairs at (202) 208-7116.

Sincerely,

Jonathan P. Deason
Director
Office of Environmental Affairs

LAWTON CHILES
GOVERNOR

STATE OF FLORIDA

Office of the Governor

THE CAPITOL
TALLAHASSEE, FLORIDA 32399-0001

March 29, 1993

Mr. Robert B. Howard
U.S. Environmental Protection Agency
Coastal Programs Section
345 Courtland Street, Northeast
Atlanta, Georgia 30365

RE: Draft Environmental Impact Statement (DEIS) for an Ocean Dredge Material Disposal Site (ODMDS) Offshore Fort Pierce, Florida
SAI: FL9301150134C

Dear Mr. Howard:

The State has completed its review and comment on the DEIS for the Fort Pierce interim-designated ODMDS in accordance with National Environmental Policy Act guidelines in 40 CFR 1501-1508. We are providing the following state agency suggestions (enclosed) to assist you with the completion of the preliminary document. Thank you for your patience during the review period; we look forward to working with you on subsequent versions of the EIS.

Agency concerns are itemized as follows:

* Inclusion of the 1992 surveys in body of the study
* Upland disposal property for non-beach quality material
* Fort Pierce Inlet dredged material disposal plan
* Habitat map, especial hardground and live bottom locations
* Verification of dredged material suitability in Site Management and Monitoring Plan
* Plume monitoring to verify DIFID model predictions
* Monitoring before, during and after disposal
* Long-term effects of anticipated dredged material disposal.

Please coordinate the NEPA process or federal consistency position with Don Henningsen at (904)488-8686.

Sincerely,

Estus Whitfield
Policy Coordinator
Environmental Policy/Community and Economic Development Unit

EW/dh

Enclosures

cc: Rea Boothby, Jacksonville District, COE
Lynn Griffin, Department of Environmental Regulation
Fritz Wettstein, Department of Natural Resources
Chris McCay, Department of Community Affairs

Florida Department of Environmental Regulation
Twin Towers Office Bldg. • 2600 Blair Stone Road • Tallahassee, Florida 32399-2400
Lawton Chiles, Governor
Virginia B. Wetherell, Secretary

March 26, 1993

Estus Whitfield
Executive Office of the Governor
Office of Planning and Budgeting
The Capitol
Tallahassee, Florida 32399-0001

Dear Mr. Whitfield:

Re: Draft Environmental Impact Statement,
Ocean Dredged Material Disposal Site Designation,
Ft. Pierce, Florida
SAI FL9301150134C

We previously reviewed the preliminary draft environmental impact statement (EIS) for this designation and provided comments dated May 12, 1992 (enclosed). Many of the issues and points we raised were addressed in this latest version. We have the following additional comments.

1. The results of the 1992 surveys were not included in the draft EIS as we requested. Instead, EPA plans to include this information as an appendix to the final EIS. This information may be important to a complete description of the affected environment and the impacts evaluation and should have been included in the draft document. It is inappropriate for new, basic data and information to appear for the first time in a final EIS.

2. The non-ocean disposal alternatives analysis should have evaluated the use of the 80 acres of upland property adjacent to the existing port which the port plans to use for expansion in the near future. This property would be a logical site to use for storage of material dredged for the port project.

3. Section 3.05 still needs to describe the specific provisions of the Ft. Pierce Inlet dredged material disposal plan.

4 The video survey narrative in Sections 4.52-4.55 still needs to be supplemented with a habitat map as requested in our earlier comments. The map should show the locations of the hardground and live bottom areas documented in the 1991 surveys along with any other features discovered in the 1992 surveys.

5. The site management and monitoring plan (SMMP) (Appendix D) still needs to explain the details of the three year verification of dredged material suitability. We continue to recommend the SMMP include plume monitoring or tracking in order to verify the predictions of the DIFID model.

Based on the information available at this time, we have no objections to this site designation and consider it to be consistent with the Department's statutory authorities in the Florida Coastal Management Program. However, there are several improvements which should be made to the draft EIS before it is finalized. The comments made above should be addressed by making appropriate changes in the final EIS. We would like an opportunity to review the results of the 1992 surveys prior to the release of the final document.

We appreciate the opportunity to comment on this draft and will review the final EIS when it is prepared. If there are any questions concerning these comments, please contact me at 488-0784.

Cordially,

Lynn Griffin

Lynn Griffin
Environmental Specialist
Intergovernmental Programs

LG/l
Enclosure
cc: Tom Franklin
Marlene Stern

Virginia B. Wetherell
Executive Director

FLORIDA DEPARTMENT OF NATURAL RESOURCES

Marjory Stoneman Douglas Building
3900 Commonwealth Boulevard
Tallahassee, Florida 32399

March 15, 1993

Janice L. Alcott, Director
State Clearinghouse
Office of Planning and Budgeting
Executive Office of the Governor
The Capitol
Tallahassee, FL 32399-0001

RE: Fort Pierce Ocean Dredge Material Disposal Site (ODMDS), Draft Environmental Impact Statement

SAI #: FL9301150134C

Dear Ms. Alcott:

The Department of Natural Resources has completed its second
review of this document. The Department finds the Draft EIS
generally complete, with the following reservations. First, the
1. need for the site has not yet been conclusively demonstrated.
Upland disposal of dredged material not of beach quality should be
given more serious consideration. Second, the site must be
intensively monitored before, during, and after disposal in order
2. that the effects of disposal can be traced. Funding sources for
the monitoring should be identified. Third, the Department has the
following specific comments on the document:

3. 4.02-4.04: There is no difference in sediment composition between the ODMDS and surrounding areas most probably because previously deposited silt has been transported out of the site, dispersed, and intermixed with the sediments of adjacent areas.

4. 4.05: There is most likely some influence from the Florida current (Gulf stream).

5. 4.15: Turbidity during periods of stronger currents or storms is not assessed.

6. 4.45: The Florida Sea Grant publication referred to (Recreational use of reefs in Florida: Artificial and natural, 1979) is too general for the purpose of this document. It also does not mention the hardbottom, low-relief reef located in the interim ODMDS.

7. 5.13: The site will be used for disposal of dredged material for years to come. This is not a one-time

RESPONSE
FLORIDA DEPARTMENT OF ENVIRONMENTAL REGULATION

1. The results of the 1992 survey have been distributed to concerned parties for review prior to printing and distribution of the Final EIS. The results have been incorporated in this Final EIS and are attached as Appendix ?

2. A discussion of non-ocean disposal alternatives was presented on the Fort Pierce Harbor General Reevaluation Report. Alternatives considered were beach disposal, Indian River disposal, Offshore disposal and upland disposal. A discussion of these alternatives, as taken from the Fort Pierce Harbor Report, is presented in Appendix H.

3. The dredged material disposal plan is an agreement between the State of Florida and the U.S. Army Corps of Engineers for determining the disposal alternatives of dredged material on a project by project basis. The designation of the ODMDS provides one disposal alternative for dredged material that meets ocean disposal criteria, therefore, specific provisions outlining State of Florida and Corps of Engineers procedures for determining individual project preferred disposal alternatives is beyond the scope of this EIS.

4. A habitat map has been added to the survey report in Appendix E.

5. The summary of the three year verification process of dredged material suitability has been expanded in the SMMP in Appendix D. Further details of the process can be found in the 1991 EPA/COE Dredged Material Testing Manual (The Green Book). An interagency SMMP team, consisting of representatives of EPA, COE, State of Florida and the user(s) has been established to finalize the SMMP to recommend monitoring techniques, level of monitoring, significance of results and potential management options. How plume monitoring or tracking will be incorporated in the monitoring and management plan will be determined by the interagency SMMP team.

RESPONSES
FLORIDA DEPARTMENT OF NATURAL RESOURCES

1. A discussion of non-ocean disposal alternatives was presented on the Fort Pierce Harbor General Reevaluation Report. Alternatives considered were beach disposal, Indian River disposal, Offshore disposal and upland disposal. A discussion of these alternatives, as taken from the Fort Pierce Harbor Report, is presented in Appendix H.

2. Site monitoring is discussed in the SMMP in Appendix D. An interagency SMMP team, consisting of representatives of EPA, COE, State of Florida and the user(s) is being established to finalize the SMMP to recommend monitoring techniques, level of monitoring, significance of results and potential management options.

3. Previously disposed dredged material could have been removed from the area due to transport processes or the dredged material could have been similar to the sediment found at the disposal site. Historical records, given in Table 4 of the DEIS, show that the type of material deposited in the past has consisted mostly of shell and sand. In either case, the findings of little variability in sediment composition suggests that past dredge disposal in the interim ODMDS has had little adverse affect on the surrounding geological characteristics.

4. There is likely some influence from the Florida current. However, because the current lies 32 miles from the site, the influence is most likely minimal compared to other forces such as wind and tides. Paragraph 4.05 has been corrected.

5. The 1985 Environmental Survey of the Fort Pierce ODMDS included turbidity sampling but did not include current measurement. Therefore, no correlation between current speed and ambient turbidity could be obtained. The turbidity sampling taken represent general background levels and do not correspond to periods of weak or strong currents. Computer modeling results presented in paragraph 5.14 estimated suspended sediment loads as a result of dredged material disposal.

6. This section is in reference to recreational fishing. There is no documentation nor indications that the live bottom areas found in the northern area of the interim ODMDS provide habitat or affect recreational fish species.

7. Additional short-term modelling using worst case properties of dredged material (90% fines) was performed. This was discussed in paragraphs 5.14, 5.15 and Appendix F of the Draft EIS.

8. This section is intended to deal only with short term perturbations in water quality. Possible long-term effects are addressed in paragraph 5.17 and will be monitored as part of the Site Management and Monitoring Plan.

occurrence. The percentage of silt in sediments off Fort Pierce has probably already increased from dredged-material disposal.

3. 5.31: This section does not take long-term effects into consideration.

Thank you for the opportunity to comment. If you have any questions, please call (904) 488-1555 or write Mail Station 10 of the letterhead address.

Sincerely,

John F. Wettstein
Senior Management Analyst

JFW/mag

cc: Kalani Cairns, BSLP-IRLAP
George Henderson, FMRI

8.00 REFERENCES

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APPENDIX A

Environmental Survey in the Vicinity of
An Ocean Dredged
Material Disposal Site
Fort Pierce Harbor, Florida

December, 1985

CONSERVATION CONSULTANTS, INC.
Environmental Scientists and Engineers
Post Office Box 35
Palmetto, Florida 33561

APPENDIX A

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APPENDIX A

This report details the methods and results of an environmental survey of the Fort Pierce Harbor interim Ocean Dredged Material Disposal Site (ODMDS) vicinity. This survey was conducted by Conservation Consultants, Inc. (CCI) on December 3 through 7, 1985. Site bathymetry was determined on a supplemental survey conducted on May 20 and 21, 1986.

A.1 METHODS

A.1.1 Location of Study Area and Sampling Locations

The Fort Pierce Harbor interim ODMDS is a one square nautical mile area with the following corner coordinates:

(NW)	27°28'30" N 80°12'33" W	(NE)	27°28'30" N 80°11'27" W
(SW)	27°27'30" N 80°12'33" W	(SE)	27°27'30" N 80°11'27" W

The general location of the ODMDS is shown in Figure A-1. Nine sampling stations were located in the Fort Pierce Harbor study area. The relationship of these stations to the designated interim ODMDS is shown in Figure A-2. The location and the type of sampling conducted at each of these stations is given in Table A-1.

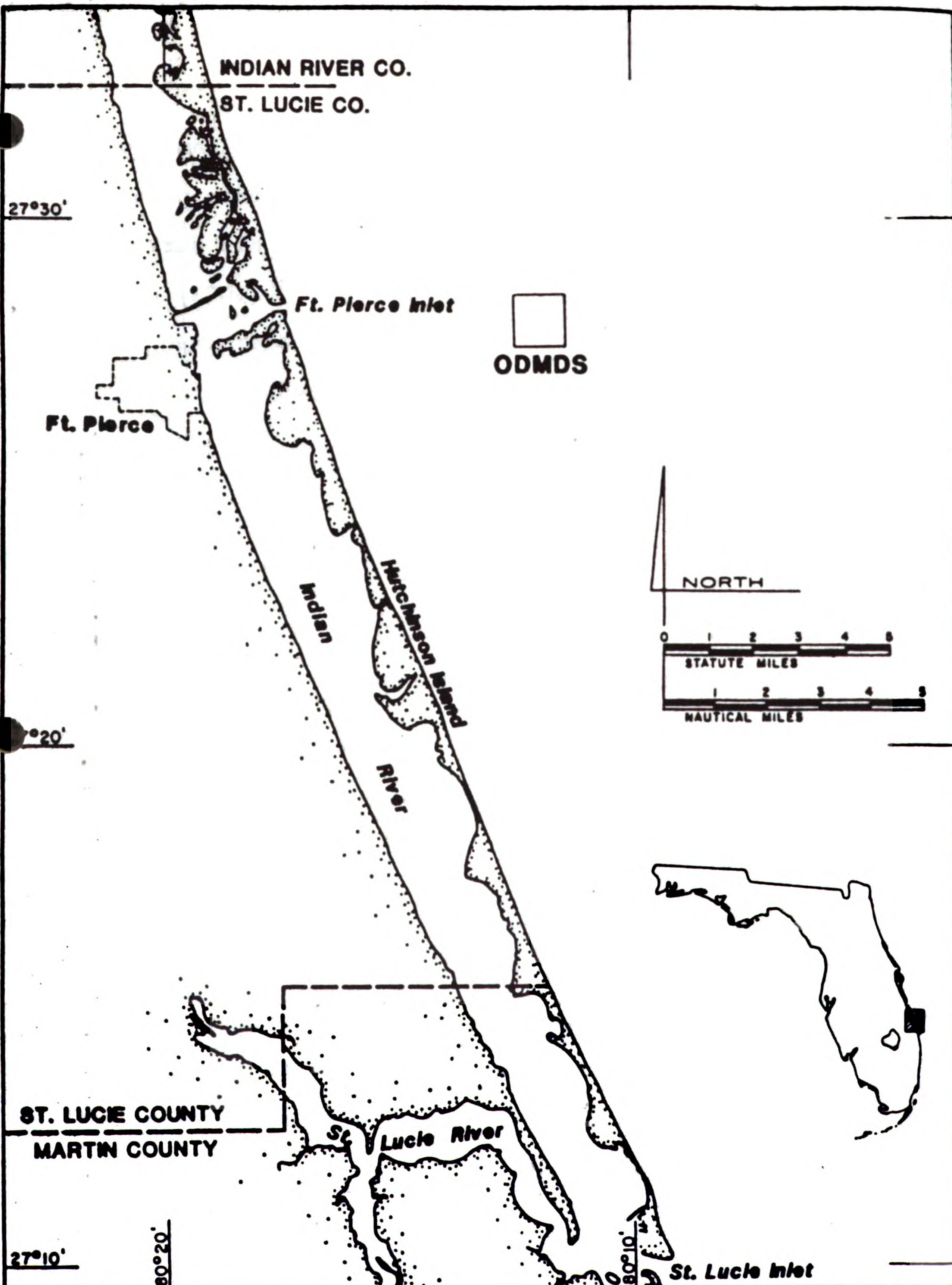

FIGURE A-1

GENERAL LOCATION MAP

Ocean Dredged Material Disposal Site Ft. Pierce, Florida

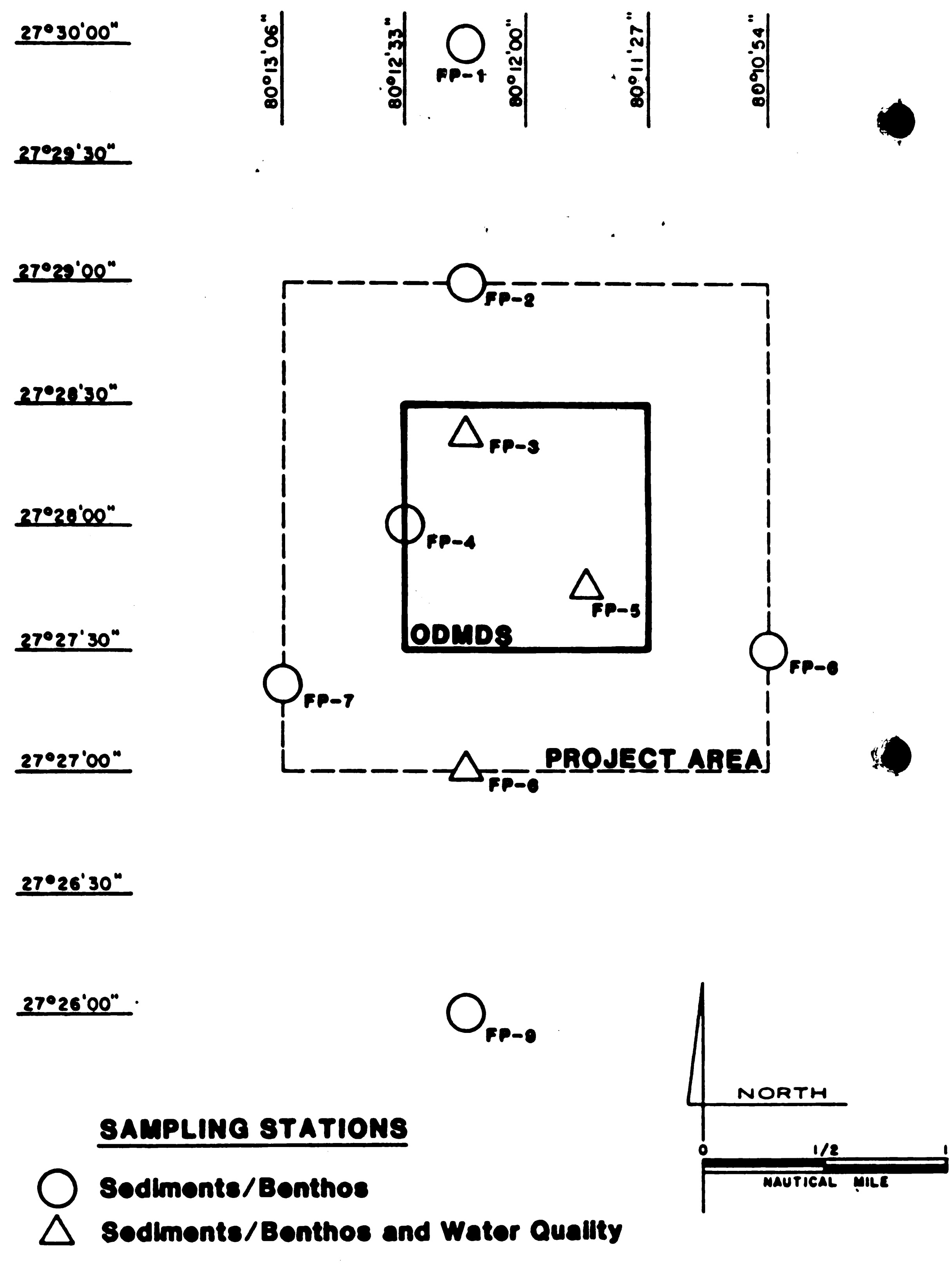

FIGURE A-2.

SAMPLING STATION LOCATIONS

Ocean Dredged Material Disposal Site Ft. Pierce, Florida

Table A-1. Station Locations and Types of Samples Collected from the Ft. Pierce Harbor ODMDS Study Area.

Station No.	Latitude (N)	Longitude (W)	Samples Collected
FP-1	27°30'00"	80°12'16.5"	Sediments Benthic Invertebrates Trawl
FP-2	27°29'00"	80°12'16.5"	Sediments Benthic Invertebrates
FP-3	27°28'22.5"	80°12'16.5"	Sediments Benthic Invertebrates Water Quality
FP-4	27°28'00"	80°12'33"	Sediments Benthic Invertebrates
FP-5	27°27'45"	80°11'43.5"	Sediments Benthic Invertebrates Trawl Water Quality
FP-6	27°27'30"	80°10'54"	Sediments Benthic Invertebrates
FP-7	27°27'22.5"	80°13'06"	Sediments Benthic Invertebrates
FP-8	27°27'00"	80°12'16.5"	Sediments Benthic Invertebrates Trawl Water Quality
FP-9	27°26'00"	80°12'16.5"	Sediments Benthic Invertebrates Trawl

A.1.2 Physical and Geological Characteristics

A.1.2.1 Bathymetry

A bathymetric survey was conducted along ten transects in the Fort Pierce Harbor ODMDS study area. Each of these transects was approximately two nautical miles in length and oriented in an east-west direction. Transects were established to run between 80°10'42.5" and 80°13'17.5" west longitude at the following latitudes.

Transect No.	Latitude (N)
FP-T1	27°30'07.5"
FP-T2	27°29'07.5"
FP-T3	27°28'37.5"
FP-T4	27°28'30"
FP-T5	27°28'15"
FP-T6	27°28'00"
FP-T7	27°27'45"
FP-T8	27°27'30"
FP-T9	27°27'00"
FP-T10	27°26'00"

FP-T1 and FP-T2 are located approximately 1.5 and 0.5 nautical miles north of the ODMDS, respectively. Transect FP-T1 passed near sampling Station FP-1 while FP-T2 crossed near Station FP-2. Transect FP-T3 ran just north of the northern boundary of the ODMDS. Transects FP-T9 and FP-T10 were established about 0.5 and 1.5 nautical miles south of the disposal site, respectively. Transect FP-T9 crossed sampling Station FP-8, and FP-T10 crossed Station FP-9. The remaining five transects traversed the ODMDS. Each of the ten transects extended approximately 0.5 nautical mile (0.9 km) beyond both the east and west boundaries of the ODMDS.

A.1.2.2 Granulometry

Sediment samples were collected from each of the nine sediment sampling stations with a ponar grab sampler. Subsamples of the relatively undisturbed grab samples were taken with 3 cm (i.d.) Plexiglass coring tubes for granulometric analyses. These tubes were pushed into the sediment, sealed top and bottom with rubber stoppers, and then removed. The top ten centimeters of each core was then extruded into a labeled plastic bottle and transported to the laboratory for analysis.

Grain size determinations generally followed the procedures outlined by Pequegnat et al. (1981) in U.S. Army Waterways Experiment Station Technical Report EL-81-1; Procedural Guide for Designation Surveys of Ocean Dredged Material Disposal Sites. Samples were first wet sieved through a 62 um sieve, using a 5 g/l sodium hexametaphosphate dispersant, to separate the sand-shell fraction from the silt-clay fraction. The sand-shell fraction then underwent grain size analysis by dry sieving, while pipette analysis was used to quantify the silt-clay fraction. A Tyler Sieve Shaker (Model R-X24) and nested 8-inch brass sieves with mesh sizes of 2.0, 1.0, 0.5, 0.25, 0.177, 0.12, and 0.06 mm were used to conduct the sieve analysis.

A.1.3 Chemical Characteristics

A.1.3.1 Water Quality

Grab samples for chemical analysis were collected from just below the surface and from approximately one meter off the bottom at each of three designated water quality sampling stations. Methods of preservation and analysis are summarized in Table A-2.

A.1.3.2 Sediment Chemistry

Sediment samples for chemical analysis were taken with a ponar grab sampler. Well-mixed composite samples were collected from each station for analysis. Upon collection, sediment samples were placed in labeled glass jars and kept on ice until delivered to the laboratory.

Two methods were used for the extraction of trace metals from sediment samples, as recommended by Pequegnat et al. (1981). Seven of the nine samples collected were treated by seawater elutriation and two by 0.1 N HCl partial extraction. Methods used for the chemical analysis of sediments are given in Table A-2.

Table A-2. Methods of Chemical Analysis of Water, Sediment, and Tissue Samples.

Parameter	Sample Type	Preservation	Analytical Methods
Cadmium	Water	Nitric Acid	Atomic Absorption Spectrophotometry/Graphite Furnace
	Sediment	Chilled	Atomic Absorption Spectrophotometry/Graphite Furnace
	Tissue	Chilled	Atomic Absorption Spectrophotometry/Graphite Furnace
Lead	Water	Nitric Acid	Atomic Absorption Spectrophotometry/Graphite Furnace
	Sediment	Chilled	Atomic Absorption Spectrophotometry/Graphite Furnace
	Tissue	Chilled	Atomic Absorption Spectrophotometry/Graphite Furnace
Mercury	Water	Nitric Acid	Atomic Absorption Spectrophotometry/Cold Vapor
	Sediment	Chilled	Atomic Absorption Spectrophotometry/Cold Vapor
	Tissue	Chilled	Atomic Absorption Spectrophotometry/Cold Vapor
Chlorinated Hydro- carbons (PCBs and Pesticides)	Water	Chilled	Gas Chromatography/Electron Capure Detector
	Sediment	Chilled	Gas Chromatography/Electron Capure Detector
	Tissue	Chilled	Gas Chromatography/Electron Capure Detector
HMW Hydrocarbons	Water	Chilled	Gas Chromatography/Flame Ionization Detector
	Sediment	Chilled	Gas Chromatography/Flame Ionization Detector
	Tissue	Chilled	Gas Chromatography/Flame Ionization Detector
Total Suspended Solids	Water	Chilled	Gravimetric
Total Organic Carbon	Sediment	Chilled	Wet Combustion/Infrared Detector
Oil and Grease	Sediment	Chilled	Soxhlet Extraction (hexane)
Turbidity	Water	In-situ	Nephelometry

NOTE 1. Analytical methods followed those outlined in Pequegnat (1981) U.S. Army Waterways Experiment Station,

Technical Report EL-81-1; Procedural Guide for Designation Surveys of Ocean Dredged Material Disposal Sites.

NOTE 2. PCBs = Polychlorinated Biphenyls.
HMW = High Molecular Weight.

A.1.4 Biological Characteristics

A.1.4.1 Benthic Macroinvertebrates

Benthic macroinvertebrates were sampled by ponar dredge at nine stations in the Fort Pierce Harbor ODMDS study area. The ponar dredge samples 0.0225 square meters of sediment surface. Five samples, representing 0.1125 square meters of bottom surface, were taken at each station.

Upon collection, samples were fixed in a ten percent solution of buffered Formalin to which a stain, rose bengal (200 mg/l), had been added. This stain concentrates in animal tissues and facilitates the effective recovery of organisms for analysis.

In the laboratory, samples were sieved through a 500 u mesh and re-preserved in a 70 percent solution of isopropyl alcohol. The sieved samples were then sorted under a dissecting microscope to recover all benthic organisms. At least 30 percent of all samples were cross-checked to ensure the efficiency of sample processing.

Following sorting, identifications and counts were made under a dissecting microscope. Representative specimens have been preserved in a reference collection.

A.1.4.2 Meiofauna

Two meiofauna samples were collected at each of the nine benthic sampling stations in the Ft. Pierce Harbor ODMDS study area. Meiofauna samples were taken by coring sediments collected by ponar dredge with a 3 cm (1.2 in) i.d. Plexiglass coring tube. The coring tube was then capped at both ends, removed from the sediment, and the top 20 cm (7.87 in) of material extruded into a labeled sample container. Meiofauna samples were preserved in a 5 percent solution of buffered Formalin to which a stain, rose bengal (200 mg/l), had been added.

In the laboratory, meiofaunal samples were first sieved through a 500 u mesh screen to remove representatives of the macrobenthos. The remaining material was passed through a 64 u sieve, and the portion retained sorted to remove meiofauna. All counts and identifications were made under a binocular dissecting microscope at a magnification of 25 X.

A.1.4.3 Macroepifauna

Macroepifauna were collected by trawl at four sites in the study area. Two 10 minute tows with a 10 ft. (3.1 m) trawl were made at each site. The wet weight biomass of each sample was determined immediately after collection with a Hanson (Model 600) spring scale.

Following biomass determination, organisms were counted and identified to the extent possible in the field. Those organisms which were selected for tissue analyses were removed at this time, identified, weighed, and placed on ice. All other organisms were preserved in a 10 percent Formalin solution. Upon return to the laboratory, taxonomic verifications were made and all samples were placed in storage.

A.1.4.4 Tissue Analyses

Tissues for analysis were taken from macroepifaunal organisms collected by trawl as described in Section A.1.4.3. Edible or soft tissues were removed from each of the specimens selected for analysis. These tissues were frozen and transported in a chilled state to the laboratory for analysis.

Tissue constituents analyzed and methods of analysis are given in Table A-2.

A.2 Results and Discussion

A.2.1 Physical and Geological Characteristics

A.2.1.1 Bathymetry

Depths at the Ft. Pierce ODMDS range from about 40 to 54 ft. (12.1 to 16.5 m). Little relief and no evidence of mounding was apparent from bathymetric profiles. A bathymetric map of the ODMDS vicinity is presented as Figure A-3. Depths are shallowest at the southwest corner of the disposal area and shoal rapidly beyond the site toward Capron Shoal. Depths are greatest at the northeast corner of the disposal site. Low relief mounding potentially associated with prior dumping was noted to the north of the ODMDS.

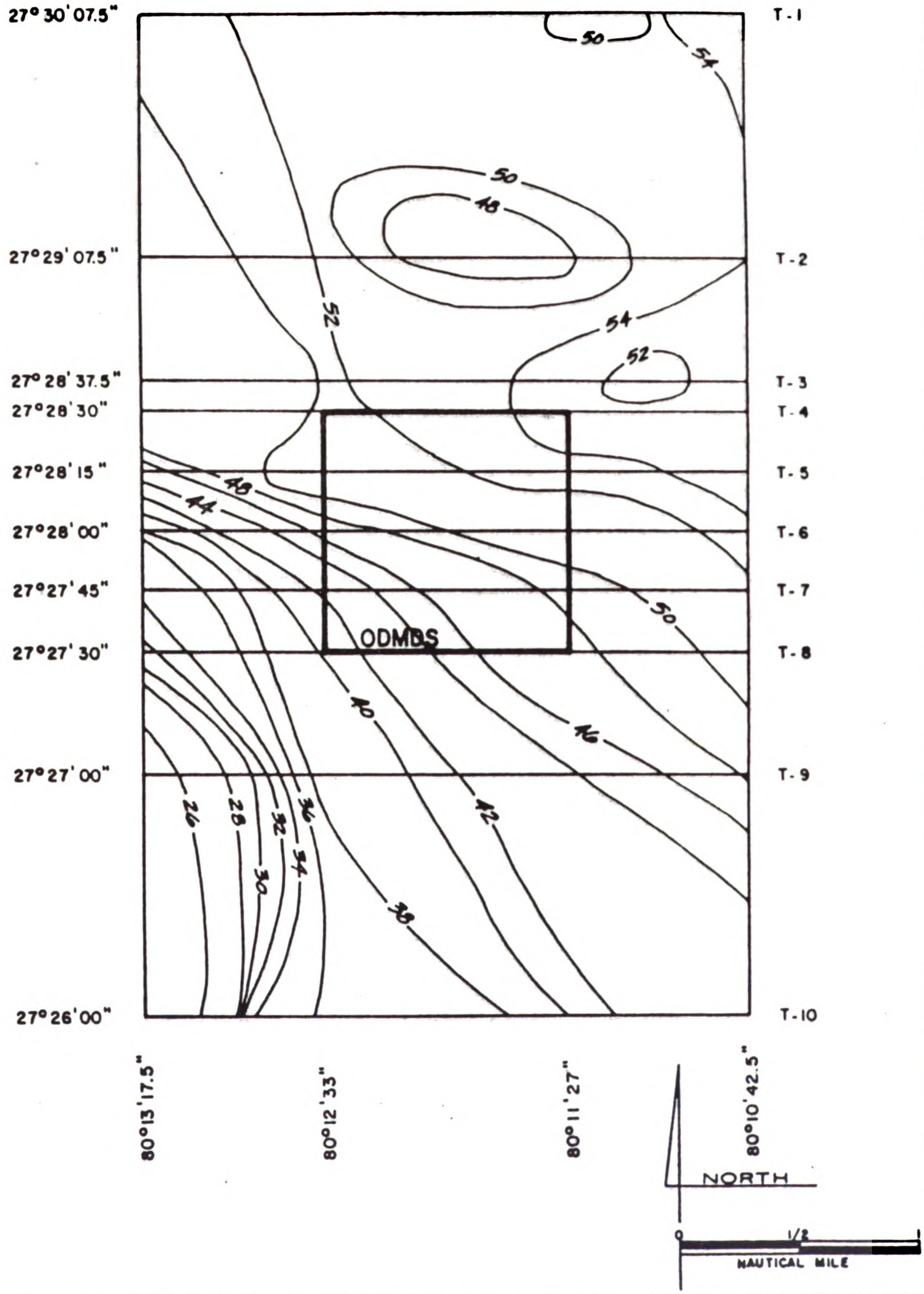

FIGURE A-3

BATHYMETRIC MAP

Ocean Dredged Material Disposal Site Ft. Pierce, Florida

A.2.1.2 Hydrography

Hydrographic profiles were made at each of the nine stations in the study area. Measurements of temperature, salinity, pH, and dissolved oxygen were taken at 3 ft (0.91 m) intervals. These profiles are presented in Table A-3.

Temperature

Temperatures measured during this survey ranged from 23.9 to 24.7°C. These temperatures are within the range previously reported for area waters. The U.S. Environmental Protection Agency (EPA, 1973) reports surface water temperatures for the vicinity ranging from a low of around 21°C in February to a high of about 29°C in July. Worth and Hollinger (1977) report an annual range of 16°C to 27°C for nearshore area waters.

No evidence of thermal stratification was noted during this December, 1985 survey. Variation between surface and bottom temperatures did not exceed 0.1°C. Throughout the year, variation in surface and bottom water temperatures in the ODMDS vicinity rarely exceeds 1°C (Worth and Hollinger, 1977).

Salinity

Salinities measured in the ODMDS vicinity in December, 1985 ranged between 36.2 and 36.4 parts per thousand (ppt). Similar salinities have previously been reported for area waters. EPA (1973) reports a mean salinity of 35.4 ppt for ocean waters off Ft. Pierce, and Worth and Hollinger (1977)

Table A-3. Temperature, Salinity, pH, and Dissolved Oxygen Profiles Taken at Stations in the Ft. Pierce Harbor ODMDS Vicinity; December 6, 1985.

Station	Time	Depth (ft.)	Temperature (°C)	Salinity (ppt)	pH	Dissolved Oxygen (ppm)	Dissolved Oxygen % Saturation
FP-1	1352	3	24.1	36.2	7.9	7.5	110
		6	24.1	36.2	7.9	7.4	109
		9	24.1	36.2	7.9	7.4	109
		12	24.2	36.2	7.9	7.4	109
		15	24.2	36.2	7.9	7.4	109
		18	24.2	36.2	7.9	7.4	109
		21	24.2	36.2	7.9	7.4	109
		24	24.2	36.2	7.9	7.4	109
		27	24.2	36.2	7.9	7.4	109
		30	24.2	36.2	7.9	7.4	109
		33	24.2	36.2	7.9	7.4	109
		36	24.2	36.2	7.9	7.5	110
		39	24.2	36.2	7.9	7.5	110
		42	24.2	36.2	7.9	7.5	110
		45	24.2	36.2	7.9	7.5	110
FP-2	1244	3	24.2	36.2	7.8	7.5	110
		6	24.2	36.3	7.9	7.4	109
		9	24.2	36.2	7.9	7.4	109
		12	24.2	36.2	7.9	7.4	109
		15	24.2	36.2	7.8	7.4	109
		18	24.2	36.2	7.8	7.4	109
		21	24.2	36.2	7.9	7.4	109
		24	24.2	36.2	7.9	7.4	109
		27	24.2	36.2	7.9	7.4	109
		30	24.2	36.2	7.9	7.4	109
		33	24.2	36.2	7.9	7.4	109
		36	24.2	36.2	7.9	7.4	109
		39	24.2	36.2	7.9	7.4	109
		42	24.2	36.2	7.9	7.4	109
		45	24.2	36.2	7.9	7.3	107
FP-3	1540	3	24.7	36.3	7.8	7.7	115
		6	24.7	36.3	7.8	7.6	113
		9	24.7	36.3	7.8	7.3	109
		12	24.7	36.3	7.8	7.4	110
		15	24.7	36.3	7.8	7.3	109
		18	24.7	36.3	7.8	7.4	110
		21	24.7	36.3	7.8	7.3	109
		24	24.7	36.3	7.8	7.3	109
		27	24.7	36.3	7.8	7.3	109
		30	24.7	36.3	7.8	7.3	109
		33	24.7	36.3	7.8	7.3	109
		36	24.7	36.3	7.8	7.3	109
		39	24.7	36.3	7.8	7.3	109
		42	24.7	36.3	7.8	7.3	109
		45	24.7	36.3	7.8	7.2	107

Table A-3. (Continued)

Station	Time	Depth (ft.)	Temperature (°C)	Salinity (ppt)	pH	Dissolved Oxygen (ppm)	Dissolved Oxygen % Saturation
FP-4	1122	3	24.0	36.4	7.8	7.6	111
		6	24.1	36.4	7.8	7.4	109
		9	24.1	36.4	7.8	7.4	109
		12	24.1	36.3	7.8	7.4	109
		15	24.1	36.3	7.8	7.4	109
		18	24.1	36.3	7.8	7.4	109
		21	24.1	36.3	7.8	7.4	109
		24	24.1	36.3	7.8	7.4	109
		27	24.1	36.3	7.8	7.4	109
		30	24.1	36.3	7.8	7.4	109
		33	24.1	36.3	7.8	7.4	109
		36	24.1	36.3	7.8	7.4	109
		39	24.1	36.3	7.8	7.4	109
		42	24.1	36.3	7.8	7.4	109
FP-5	1440	3	24.6	36.4	7.8	7.6	113
		6	24.6	36.4	7.8	7.3	109
		9	24.6	36.4	7.8	7.2	107
		12	24.6	36.4	7.8	7.5	112
		15	24.6	36.4	7.8	7.4	110
		18	24.6	36.4	7.8	7.3	109
		21	24.6	36.4	7.8	7.3	109
		24	24.6	36.4	7.8	7.4	110
		27	24.6	36.4	7.8	7.3	109
		30	24.6	36.4	7.8	7.3	109
		33	24.6	36.4	7.8	7.3	109
		36	24.6	36.4	7.8	7.3	109
		39	24.6	36.4	7.8	7.4	110
		42	24.6	36.4	7.8	7.4	110
		45	24.6	36.4	7.8	7.4	110
		48	24.6	36.4	7.8	7.4	110
FP-6	1457	3	24.1	36.3	7.9	7.7	113
		6	24.1	36.3	7.9	7.6	111
		9	24.2	36.3	7.9	7.5	110
		12	24.2	36.3	7.9	7.5	110
		15	24.2	36.3	7.9	7.5	110
		18	24.2	36.3	7.9	7.5	110
		21	24.2	36.3	7.9	7.5	110
		24	24.2	36.3	7.9	7.5	110
		27	24.2	36.2	7.9	7.5	110
		30	24.2	36.3	7.9	7.5	110
		33	24.2	36.2	7.9	7.5	110
		36	24.2	36.2	7.9	7.5	110
		39	24.2	36.2	7.9	7.5	110
		42	24.2	36.2	7.9	7.5	110
		45	24.2	36.2	7.9	7.5	110

Table A-3. (Continued)

Station	Time	Depth (ft.)	Temperature (°C)	Salinity (ppt)	pH	Dissolved Oxygen (ppm)	Dissolved Oxygen % Saturation
FP-7	1000	3	23.9	36.4	7.7	7.6	111
		6	23.9	36.4	7.7	7.3	107
		9	23.9	36.4	7.7	7.4	109
		12	24.0	36.4	7.7	7.4	109
		15	24.0	36.4	7.7	7.4	109
		18	24.0	36.4	7.7	7.4	109
		21	24.0	36.4	7.7	7.4	109
		24	24.0	36.4	7.8	7.4	109
		27	24.0	36.4	7.8	7.4	109
		30	24.0	36.4	7.8	7.4	109
		33	24.0	36.4	7.8	7.4	109
		36	24.0	36.4	7.8	7.4	109
		39	24.0	36.4	7.8	7.4	109
		42	24.0	36.3	7.8	7.4	109
		45	24.0	36.3	7.8	7.4	109
FP-8	1330	3	24.6	36.4	7.8	7.5	112
		6	24.6	36.4	7.8	7.3	109
		9	24.6	36.4	7.8	7.4	110
		12	24.6	36.4	7.8	7.3	109
		15	24.6	36.4	7.8	7.3	109
		18	24.6	36.4	7.8	7.3	109
		21	24.6	36.4	7.8	7.3	109
		24	24.6	36.4	7.8	7.3	109
		27	24.6	36.4	7.8	7.3	109
		30	24.6	36.4	7.8	7.3	109
		33	24.6	36.4	7.8	7.3	109
		36	24.6	36.4	7.8	7.4	112
		39	24.6	36.4	7.8	7.3	109
		42	24.6	36.4	7.8	7.3	109
FP-9	1555	3	24.0	36.3	7.9	7.5	110
		6	24.0	36.3	7.9	7.4	109
		9	24.0	36.3	7.9	7.4	109
		12	24.0	36.3	7.9	7.5	110
		15	24.1	36.3	7.9	7.5	110
		18	24.0	36.3	7.9	7.6	111
		21	24.0	36.2	7.9	7.5	110
		24	24.0	36.2	7.9	7.5	110
		27	24.0	36.2	7.9	7.5	110
		30	24.0	36.2	7.9	7.5	110
		33	24.0	36.2	7.9	7.5	110
		36	24.0	36.2	7.9	7.5	110
		39	24.0	36.2	7.9	7.6	111

report nearshore salinities off Hutchinson Island ranging from 33 to 38.5 ppt.

No evidence of salinity stratification was apparent and none is expected to occur in the disposal site vicinity. Little tendency for stratification was observed by EPA (1973) in studies of southeast Florida Shelf waters. Worth and Hollinger (1977) report maximum surface to bottom salinity differences in nearshore waters of about 3 ppt. Differences when they occur are generally temporary and associated with increased freshwater discharge.

pH

Values for pH ranged from 7.7 to 7.9 and were slightly lower than would generally be expected for well-mixed coastal waters. The pH of marine waters in equilibrium with the atmosphere ranges from about 8.1 to 8.3 (Sverdrup et al., 1942). Lower values in coastal waters are often associated with periods of high freshwater discharge.

Dissolved Oxygen

Dissolved oxygen (DO) concentrations measured in area waters on December 6, 1985 ranged from 7.2 to 7.7 ppm. Waters were consistently above saturation with respect to oxygen. Little variation in DO concentration with depth was observed, reflecting the well-mixed nature of waters in the Ft. Pierce ODMDS vicinity.

Solids (Suspended Solids and Turbidity)

Total suspended solids (TSS) concentrations were measured in near bottom waters collected from each station in the study area. Results of these analyses are presented in Table A-4. Suspended solids concentrations ranged from 5 to 24 mg/l.

Turbidity is defined as the optical property of a sample which causes light to be scattered and absorbed rather than transmitted in straight lines. Turbidity is commonly measured with a nephelometer, which measures scattered light, and is reported in NTUs (nephelometric turbidity units). Turbidity samples were collected from near the surface, at mid-depth, and from near the bottom at each station. Results of turbidity analyses are given in Table A-4. Turbidity values were low, ranging from 0.6 to 2.2 NTU, and were characteristic of Shelf waters. No zone of elevated turbidity was found, and no patterns in the distribution of values between stations or with depth were observed.

A.2.1.3 Granulometry

The grain size distributions of surficial sediments collected in the study area are presented in Table A-5. Mean grain sizes, modes, and inclusive standard deviations, calculated for the sediments collected from each station are given in Table A-6.

Surficial sediments in the Ft. Pierce ODMDS vicinity are primarily comprised of coarse to medium sands. Shell material

Table A-4. Total Suspended Solids Concentrations and Turbidity Levels at Stations in the Ft. Pierce Harbor ODMDS Vicinity.

Station	Position*	Depth (Ft.)	Total Suspended Solids (mg/l)	Turbidity (NTU)
FP-1	S	3	—	1.1
	M	21	—	1.2
	B	45	10	1.2
FP-2	S	3	—	1.4
	M	21	—	1.0
	B	45	24	1.1
FP-3	S	3	—	0.7
	M	21	—	0.6
	B	45	13	1.1
FP-4	S	3	—	1.1
	M	—	—	—
	B	42	8	0.9
FP-5	S	3	—	0.8
	M	27	—	0.7
	B	48	5	1.2
FP-6	S	3	—	0.9
	M	21	—	1.0
	B	45	9	1.1
FP-7	S	3	—	1.7
	M	—	—	—
	B	45	18	2.2
FP-8	S	3	—	0.7
	M	21	—	0.7
	B	42	7	0.4
FP-9	S	3	—	1.0
	M	21	—	0.9
	B	39	13	0.8

*S = Surface
M = Mid-Depth
B = Near Bottom

Table A-5. Grain Size Distribution of Sediments Collected from the Ft. Pierce Harbor ODMDS Vicinity.

Station	Percent Composition					
	Shell ($\leq$ -1 ø)	Coarse sands (-1 to 1 ø)	Medium sands (1 to 2 ø)	Fine sands (2 to 4 ø)	Silt (4 to 8 ø)	Clay ($\geq$ 8 ø)
FP-1	13	18	41	24	<1	3
FP-2	33	48	13	2	<1	4
FP-3	19	58	19	2	<1	2
FP-4	30	56	10	1	<1	3
FP-5	11	38	45	5	<1	<1
FP-6	19	61	16	3	<1	1
FP-7	15	42	28	8	<1	7
FP-8	30	42	22	3	<1	3
FP-9	24	61	10	1	<1	4

Table A-6. Granulometric Characteristics of Sediments Collected from the Ft. Pierce Harbor ODMDS Vicinity.

Station	Mean (phi, ∅)	Mode (phi, ∅)	Inclusive Standard Deviation (phi, ∅)
FP-1	1.0	1.0	1.4
FP-2	-0.3	-1.0	1.5
FP-3	0.2	1.0	1.2
FP-4	-0.3	1.0	1.1
FP-5	0.8	2.0	1.2
FP-6	0	1.0	1.0
FP-7	0.5	2.0	2.8
FP-8	0	-1.0	1.4
FP-9	-0.2	-1.0	1.0

was also a major constituent of the sediments. No differences were noted between stations located within the ODMDS and those in the surrounding area.

Inclusive graphic standard deviations were calculated as a measure of the uniformity or sorting of sediments. Values for this statistic generally range from 0.35 phi for well-sorted sediments to 4.00 phi for poorly sorted, non-uniform sediments (Pequegnat et al., 1981). Surficial sediments in the study area were moderately sorted, with inclusive standard deviation values ranging from 1.0 to 2.8.

The results of this survey agree well with those previously reported for the area. Meisburger and Duane (1971) found the surficial sediments off Ft. Pierce between the 40 and 60 foot depth contours to consist primarily of coarse, brown shell sand forming an irregular blanket deposit of varying thickness. Gallagher (1977) described the surficial sediments midway between the ODMDS and Hutchinson Island as being primarily coarse, clean, poorly sorted sands with a high shell content.

A.2.2 Chemical Characteristics

A.2.2.1 Water Quality

Water samples for chemical analysis were collected from just below the surface and approximately one meter off the bottom at Stations FP-3, FP-5, and FP-8. Stations FP-3 and FP-5 are within the Ft. Pierce Harbor ODMDS while Station FP-8 is located to the south (upstream) of the disposal site. Samples were analyzed for selected trace metals, pesticides, polychlorinated biphenyls (PCBs), and high molecular weight (HMW) hydrocarbons. None of these contaminants were detected in samples. Specific parameters measured in surface and near bottom waters, and analytical detection limits are given in Tables A-7 and A-8.

A.2.2.2 Sediment Chemistry

Sediments were collected from each station for chemical analysis. Constituents analyzed were trace metals, pesticides, polychlorinated biphenyls (PCBs), high molecular weight hydrocarbons, total organic carbon, and oil and grease. Metals were extracted from sediments collected from Stations FP-1, FP-2, FP-3, FP-5, FP-6, FP-7 and FP-9 by seawater elutriation. Weak acid extraction (0.1 N HCl) was used to extract metals from sediments collected from FP-4 and FP-8. Results of sediment chemistry analyses are presented in Table A-9.

Concentrations of metals in sediments were low. Levels of mercury and lead were below detection in all seawater elutriates. Cadmium was detected, at the detection limit (0.5 ug/l), at Station FP-7. Levels of mercury, cadmium, and lead were generally comparable in acid extracts of sediments from the disposal site (FP-4) and upstream station FP-8. Highest

Table A-7. Results of Chemical Analyses of Surface Waters Collected from the Fort Pierce Harbor ODMDS Study Area.

	Station		
Parameter	FP-3	FP-5	FP-8
Trace Metals			
Mercury, ug/l	<0.2	<0.2	<0.2
Cadmium, ug/l	<0.05	<0.05	<0.05
Lead, ug/l	<0.5	<0.5	<0.5
Pesticides			
Alpha - BHC, ug/l	<0.005	<0.005	<0.005
Gamma - BHC, ug/l	<0.006	<0.006	<0.006
Heptachlor, ug/l	<0.02	<0.02	<0.02
Beta - BHC, ug/l	<0.03	<0.03	<0.03
Aldrin,. ug/l	<0.009	<0.009	<0.009
Heptachlor Epoxide, ug/l	<0.02	<0.02	<0.02
4,4' - DDE, ug/l	<0.02	<0.02	<0.02
4,4' - DDD, ug/l	<0.05	<0.05	<0.05
4,4' - DDT, ug/l	<0.06	<0.06	<0.06
o,p' - DDD, ug/l	<0.1	<0.1	<0.1
o,p' - DDT, ug/l	<0.1	<0.1	<0.1
Chlordane, ug/l	<0.1	<0.1	<0.01
Dieldrin, ug/l	<0.03	<0.03	<0.03
Endrin, ug/l	<0.06	<0.06	<0.06
Total PCBs as Archlor 1254, ug/l	<0.4	<0.4	<0.4
High Molecular Weight Hydrocarbons			
Volume of sample extracted, ml	1500	1500	1500
Weight of extractables, ppm	<5.0	<5.0	<5.0
Aliphatics and aromatics, ppb	<0.5	<0.5	<0.5
Resolved hydrocarbons, ppb	<0.5	<0.5	<0.5
Unresolved hydrocarbons, ppb	<0.5	<0.5	<0.5
Sum of n-alkanes, ppb	<0.5	<0.5	<0.5
Sum of even n-alkanes, ppb	<0.5	<0.5	<0.5
Sum of odd n-alkanes, ppb	<0.5	<0.5	<0.5

Table A-8. Results of Chemical Analyses of Near Bottom Waters Collected from the Fort Pierce Harbor ODMDS Study Area.

Parameter	Station		
	FP-3	FP-5	FP-8
Trace Metals			
Mercury, ug/l	<0.2	<0.2	<0.2
Cadmium, ug/l	<0.05	<0.05	<0.05
Lead, ug/l	<0.5	<0.5	<0.5
Pesticides			
Alpha - BHC, ug/l	<0.005	<0.005	<0.005
Gamma - BHC, ug/l	<0.006	<0.006	<0.006
Heptachlor, ug/l	<0.02	<0.02	<0.02
Beta - BHC, ug/l	<0.03	<0.03	<0.03
Aldrin,. ug/l	<0.009	<0.009	<0.009
Heptachlor Epoxide, ug/l	<0.02	<0.02	<0.02
4,4' - DDE, ug/l	<0.02	<0.02	<0.02
4,4' - DDD, ug/l	<0.05	<0.05	<0.05
4,4' - DDT, ug/l	<0.06	<0.06	<0.06
o,p' - DDD, ug/l	<0.1	<0.1	<0.1
o,p' - DDT, ug/l	<0.1	<0.1	<0.1
Chlordane, ug/l	<0.1	<0.1	<0.01
Dieldrin, ug/l	<0.03	<0.03	<0.03
Endrin, ug/l	<0.06	<0.06	<0.0[illegible]
Total PCBs as Archlor 1254, ug/l	<0.4	<0.4	<0.4
High Molecular Weight Hydrocarbons			
Volume of sample extracted, ml	1500	1500	1500
Weight of extractables, ppm	<5.0	<5.0	<5.0
Aliphatics and aromatics, ppb	<0.5	<0.5	<0.5
Resolved hydrocarbons, ppb	<0.5	<0.5	<0.5
Unresolved hydrocarbons, ppb	<0.5	<0.5	<0.5
Sum of n-alkanes, ppb	<0.5	<0.5	<0.5
Sum of even n-alkanes, ppb	<0.5	<0.5	<0.5
Sum of odd n-alkanes, ppb	<0.5	<0.5	<0.5

Table A-9. Results of Chemical Analyses of Sediments Collected from the Fort Pierce Harbor ODMDS Vicinity.

PARAMETER	Station FP-1	FP-2	FP-3	FP-4	FP-5	FP-6	FP-7	FP-8	FP-9
Trace Metals									
Mercury (in seawater elutriate),* ug/l	<0.2	<0.2	<0.2	----	<0.2	<0.2	<0.2	----	<0.2
Cadmium (in seawater elutriate), ug/l	<0.05	<0.05	<0.05	----	<0.05	<0.05	0.05	----	<0.05
Lead (in seawater elutriate), ug/l	<0.5	<0.5	<0.5	----	<0.5	<0.5	<0.5	----	<0.5
Mercury (in acid leachate),** ug/g, dry	----	----	----	0.09	----	----	----	0.11	----
Cadmium (in acid leachate), ug/g, dry	----	----	----	0.073	----	----	----	0.042	----
Lead (in acid leachate), ug/g, dry	----	----	----	0.83	----	----	----	0.62	----
Pesticides									
Alpha-BHC, ug/kg	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02
Gamma-BHC, ug/kg	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02
Heptachlor, ug/kg	<0.03	<0.03	<0.03	<0.03	<0.03	<0.03	<0.03	<0.03	<0.03
Beta-BHC, ug/kg	<0.08	<0.08	<0.08	<0.08	<0.08	<0.08	<0.08	<0.08	<0.08
Aldrin, ug/kg	<0.03	<0.03	<0.03	<0.03	<0.03	<0.03	<0.03	<0.03	<0.03
Heptachlor Epoxide, ug/kg	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04
4,4'-DDE, ug/kg	<0.06	<0.06	<0.06	<0.06	<0.06	<0.06	<0.06	<0.06	<0.06
4,4'-DDD, ug/kg	<0.4	<0.4	<0.4	<0.4	<0.4	<0.4	<0.4	<0.4	<0.4
4,4'-DDT, ug/kg	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2
o,p'-DDD, ug/kg	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2
o,p'-DDT, ug/kg	<0.4	<0.4	<0.4	<0.4	<0.4	<0.4	<0.4	<0.4	<0.4
Chlordane, ug/kg	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5
Dieldrin, ug/kg	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2
Endrin, ug/kg	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5
Total PCBs as Archlor 1254, ug/kg	<0.8	1.1	<0.8	<0.8	<0.8	<0.8	1.1	<0.8	<0.8

Table A-9. (Continued)

PARAMETER	Station								
	FP-1	FP-2	FP-3	FP-4	FP-5	FP-6	FP-7	FP-8	FP-9
<u>High Molecular Weight Hydrocarbons</u>									
Wet weight of sample extracted, g	250	250	250	250	250	250	250	250	250
Dry weight of sample extracted, g	173	183	180	183	190	177	168	173	198
Percent dry weight of wet weight	69	73	72	73	76	71	67	69	79
Weight of extractables, ppm, dry	630	27	49	52	210	57	190	170	49
Aliphatics and aromatics, ppm, dry	0.07	0.12	0.32	0.23	0.21	0.12	0.09	0.27	0.12
Resolved hydrocarbons, ppm, dry	0.15	0.32	0.42	0.27	0.35	0.15	0.17	0.35	0.21
Unresolved hydrocarbons, ppm, dry	0.12	0.10	0.07	0.17	0.12	0.03	0.05	0.09	0.07
Sum of n-alkanes, ppm, dry	0.02	0.07	0.12	0.07	0.14	0.03	0.06	0.09	0.04
Sum of even n-alkanes, ppm, dry	0.01	0.05	0.10	0.07	0.09	0.02	0.02	0.08	0.02
Sum of odd n-alkanes, ppm, dry	0.01	0.02	0.02	0.01	0.05	0.01	0.04	0.01	0.02
Unresolved hydrocarbons/resolved hydrocarbons	0.80	0.31	0.17	0.63	0.34	0.20	0.29	0.26	0.33
Odd n-alkanes/even n-alkanes	1.0	0.40	0.20	N/A	0.55	0.50	2.0	0.13	1.0
Phytane/n-C18	N/A***	N/A	0.42	0.37	N/A	N/A	N/A	0.42	N/A
Pristane/n-C17	N/A	0.31	0.12	N/A	N/A	N/A	N/A	N/A	N/A
<u>Total organic carbon</u>, mg/g	3.7	5.5	7.6	4.2	6.3	6.7	5.0	6.3	6.1
<u>Oil and grease</u>, ug/g	22	14	26	31	140	27	110	140	29

*Seawater elutriation conducted in accordance with Environmental Protection Agency/Corps of Engineers Technical Report EPA/CE-81-1; Sediment:water ratio of 1:4 (vol/vol).

**Acid extraction with 0.1 N HCl in accordance with Pequegnat et al. (1981); Corps of Engineers Technical Report EL-81-1.

***N/A = Cannot be calculated from available data.

concentrations of cadmium and lead were measured in the acid extract of FP-4 sediment, while higher mercury concentrations were measured in the extract of FP-8 sediment.

No chlorinated hydrocarbon pesticides or pesticide derivatives were detected in study area sediments. Polychlorinated biphenyls were detected at low levels in sediments from Stations FP-2 and FP-7, both located outside ODMDS boundaries.

Sediment concentrations of HMW hydrocarbons exhibited no consistent patterns of distribution. Highest total HMW hydrocarbon concentrations were found at FP-1, located upstream of the disposal site. Component HMW hydrocarbon fractions measured were generally higher in disposal site sediments than in sediments collected from the surrounding area.

Total organic carbon concentrations were low, ranging from 3.7 to 7.6 mg/g, and exhibited no definitive spatial trends. The highest TOC concentration was found at Station FP-3, within the ODMDS.

Oil and grease concentrations varied from 14 to 140 ug/g. Highest concentrations were found at Stations FP-5 in the ODMDS, and at Stations FP-7 and FP-8, located upstream (south) of the disposal site. The concentration of oil and grease in area sediments does not appear to be related to prior disposal site utilization.

A.2.3 Biological Characteristics

The biological communities included in this investigation were benthic macroinvertebrates, benthic meiofauna, and epibenthic fish and invertebrates.

A.2.3.1 Benthic Macroinvertebrates

A total of 122 benthic macroinvertebrate taxa were represented in samples collected from the Ft. Pierce Harbor ODMDS vicinity. A listing of the benthic macroinvertebrate taxa identified in this program is given in Appendix B, Table B-1. The composition, abundance, and diversity of invertebrates collected in each sample taken from the nine stations in the study area are presented in Appendix B, Tables B-2 through B-10.

The mean abundance, overall diversity, and number of taxa present in samples collected from each station are presented in Table A-10. Average densities ranged from 620 organisms/m^2 at FP-1, located about 1.5 nmi (2.8 km) north of the ODMDS, to 1,886 organisms/m^2 at Stations FP-2 and FP-9, located 0.5 nmi (0.93 km) north and 1.5 nmi (2.8 km) south of the disposal area, respectively. The mean density of benthic macroinvertebrates, averaged over all stations in the study area, was 1,073 organisms/m^2.

Shannon-Weaver diversities, calculated for all the organisms collected from each station, ranged from 3.49 to 4.50. Values

Table A-10. Mean Abundance and Diversity of Benthic Macroinvertebrates Collected from Stations in the Ft. Pierce Harbor ODMDS Vicinity.

Station	Abundance (Organisms/m^2)*	Number of Taxa**	Shannon-Weaver Diversity**
FP-1	620 ± 142	25	3.85
FP-2	1886 ± 1526	52	4.54
FP-3	672 ± 690	21	3.49
FP-4	1025 ± 826	36	3.85
FP-5	741 ± 555	25	3.70
FP-6	1137 ± 1063	33	3.75
FP-7	929 ± 810	39	4.50
FP-8	758 ± 332	25	3.70
FP-9	1886 ± 2586	43	4.30

*Value given is the mean ± one standard deviation of the five samples taken at each station.

**Calculated based on data composited from the five samples taken at each station.

in this range are often considered characteristic of stable environments.

No distinct spatial patterns were apparent in the distribution of macroinfaunal densities or diversities. The overall abundance and diversity of macroinvertebrates was slightly, though not consistently, lower within than outside the ODMDS.

The composition of the benthic macroinfaunal community, by major taxonomic group, is given in Table A-11. Polychaete worms were the most abundant group at all stations and accounted for 51 percent of all organisms collected from the study area. Polychaete numbers and the contribution of this group to total macroinvertebrate abundance were highest at Stations FP-2 and FP-9, located outside ODMDS boundaries. Polychaete abundance and percent composition was lowest at Station FP-3, located within the ODMDS.

In addition to polychaetes, several other groups are characteristic of the ODMDS vicinity. Nematodes were relatively abundant at all stations and accounted for 13 percent of the macroinfaunal community. Other major groups comprising the areawide benthic macroinvertebrate assemblage included turbellarians (7 percent), crustaceans (6 percent), molluscs (6 percent), oligochaetes (5 percent), and echinoderms (4 percent).

The most abundant benthic macroinfaunal taxa, ranked for each station in the study area, are listed in Table A-12. The

Table A-11. Benthic Macroinvertebrate Community Composition by Major Group.

	Percent Composition							
Station	Polychaetes	Nematodes	Turbellarians	Crustaceans	Molluscs	Oligochaetes	Echinoderms	Others
FP-1	46	17	4	3	4	--	3	23
FP-2	59	10	4	3	8	5	5	6
FP-3	31	19	5	1	19	19	--	6
FP-4	53	4	1	30	4	1	1	6
FP-5	56	13	13	2	--	--	11	5
FP-6	53	24	11	2	5	1	3	1
FP-7	50	7	9	9	3	7	7	8
FP-8	49	16	15	1	8	1	2	8
FP-9	63	11	4	3	<1	7	2	10
Average	51	13	7	6	6	5	4	8

NOTE: -- indicates group not present.

Table A-12. Benthic Macroinvertebrate Taxa of the Ft. Pierce Harbor ODMDS Vicinity Ranked in Order of Abundance.

	Taxon* Rank				
Station	1	2	3	4	5
FP-1	Syllidae	Nematoda	Hydrozoa	Goniadidae	Eunicidae
FP-2	Syllidae	Nematoda	Goniadidae	Oligochaeta	Polyplacophora**
FP-3	Nematoda	Oligochaeta**	Polyplacophora	Syllidae	Chrysopetalidae Turbellaria
FP-4	Sabellidae	Corophiidae	Syllidae	Dorovillidae	Nematoda
FP-5	Syllidae	Dorovillidae	Nematoda	Turbellaria**	Ophiuroidea
FP-6	Syllidae	Nematoda	Goniadidae	Turbellaria**	Glyceridae
FP-7	Syllidae	Turbellaria	Phyllodocidae	Nematoda	Oligochaeta**
FP-8	Syllidae	Nematoda	Turbellaria	Goniadidae**	Crepidulidae Nephytidae Cephalochordata
FP-9	Syllidae	Nematoda	Eunicidae	Oligochaeta	Polyplacophora
Overall	Syllidae	Nematoda	Goniadidae	Turbellaria	Oligochaeta

*Ranked by taxonomic family or by lowest practical taxonomic level.
**Taxon was present in same abundance (and has same actual rank) as previously ranked species.

polychaete family Syllidae was the most abundant taxa at all stations except FP-3 and FP-4. This family accounted for 25 percent of the macroinvertebrates collected from the disposal site vicinity. Other polychaete families characteristic of the area were Goniadidae, Dorovillidae, and Eunicidae. Nematodes, turbellarians, and oligochaetes were also relatively important throughout the study area.

A trophic classification of the most abundant macroinfaunal taxa of the study area is presented in Table A-13. Carnivorous taxa, including the polychaete families Syllidae, Gonadidae, Eunicidae, and Dorovillidae, and turbellarians and hydrozoans, were dominant at all stations except FP-3 and FP-4.

Deposit feeding taxa, including nematodes, oligochaetes, and polyplacophoran molluscs, were dominant at FP-3. Such taxa typically colonize organic sediments. While the organic content of area sediments sampled was found to be relatively low overall, highest concentration of total organic carbon were measured in sediments from FP-3. Increased organic carbon concentrations and associated faunal communities may reflect the prior disposal and subsequent colonization of inshore or nearshore materials which typically contain higher organic fractions than coastal sediments.

At Station FP-4, suspension feeders of the polychaete family Sabellidae and the crustacean amphipod family Corophiidae were dominant. Suspension feeders filter their food from overlying

Table A-13. Trophic Classification of Major Benthic Macroinvertebrate Taxa Collected from the Ft. Pierce Harbor ODMDS Vicinity.

Phylum	Class/Order	Family	Trophic Guild	Trophic Type
Annelida	Polychaeta	Chrysopetalidae	CMT	C
Annelida	Polychaeta	Dorovillidae	CMJ	C
Annelida	Polychaeta	Eunicidae	CMJ	C
Annelida	Polychaeta	Glyceridae	CMJ/BMJ	C/NSDF
Annelida	Polychaeta	Goniadidae	CMJ	C
Annelida	Polychaeta	Nephtyidae	CMJ	C
Annelida	Polychaeta	Phyllodocidae	CMS	C
Annelida	Polychaeta	Sabellidae	FST	SF
Annelida	Polychaeta	Syllidae	CMJ	C
Annelida	Oligochaeta	---	BMX	NSDF
Arthropoda	Amphipoda	Corophiidae	SDX	SF
Aschelminthes	Nematoda	---	SMX	NSDF
Chordata	Cephalochordata	Branchiostomidae	FMX	SF
Cnidaria	Hydrozoa	---	CST	C
Echinodermata	Ophiuroidea	---	SMJ	NSDF/C
Mollusca	Gastropoda	Crepidulidae	SMX	NSDF
Mollusca	Polyplacophora	---	SMX	NSDF
Platyhelminthes	Turbellaria	---	CMX	C

Trophic Guild Codes:
Feeding Preference: S - Surface deposit; B - Subsurface deposit; C - Carnivore; F - Filter feeder
Mobility: M - Motile; D - Discreetly motile; S - Sessile;
Feeding Structures: J - Jaws; T - Tentacles; X - Miscellaneous.

Trophic Type Codes: C - Carnivore; O - Omnivore; SF - Suspension feeder;
SDF - Selective deposit feeder;
NSDF - Non-selective deposit feeder.

or interstitial waters. Sediments at this station were relatively coarse with a low organic content. Sediment character and faunal composition do not appear to be related to disposal site utilization.

Three similarity indices were used to aid in the classification and evaluation of the benthic macroinfauna collected at stations in the Ft. Pierce Harbor ODMDS vicinity. Indices used were the Morisita index, Bray-Curtis index, and a simple matching index. The Morisita and Bray-Curtis indices are quantitative and take into account both the occurrence and the abundance of organisms. The simple matching index is qualitative and is based solely on the presence of common species in samples compared.

Cluster analyses were based on the above determinations of similarity. Results of cluster analyses based on the Morisita index, Bray-Curtis index, and simple matching are presented in Figures A-4, A-5, and A-6, respectively. Analyses based on each of these indices paired Stations FP-1 and FP-3. Each of these indices also identified Station FP-4 as an outlier; relatively different from the other stations in the area in terms of macroinfaunal composition. Other clustering relationships were more subject to variation based on the clustering technique employed.

Both the Morisita and the Bray-Curtis index paired Stations FP-6 and FP-7. The Bray-Curtis also included Station FP-5 in this cluster. Both of these quantitative indices also paired

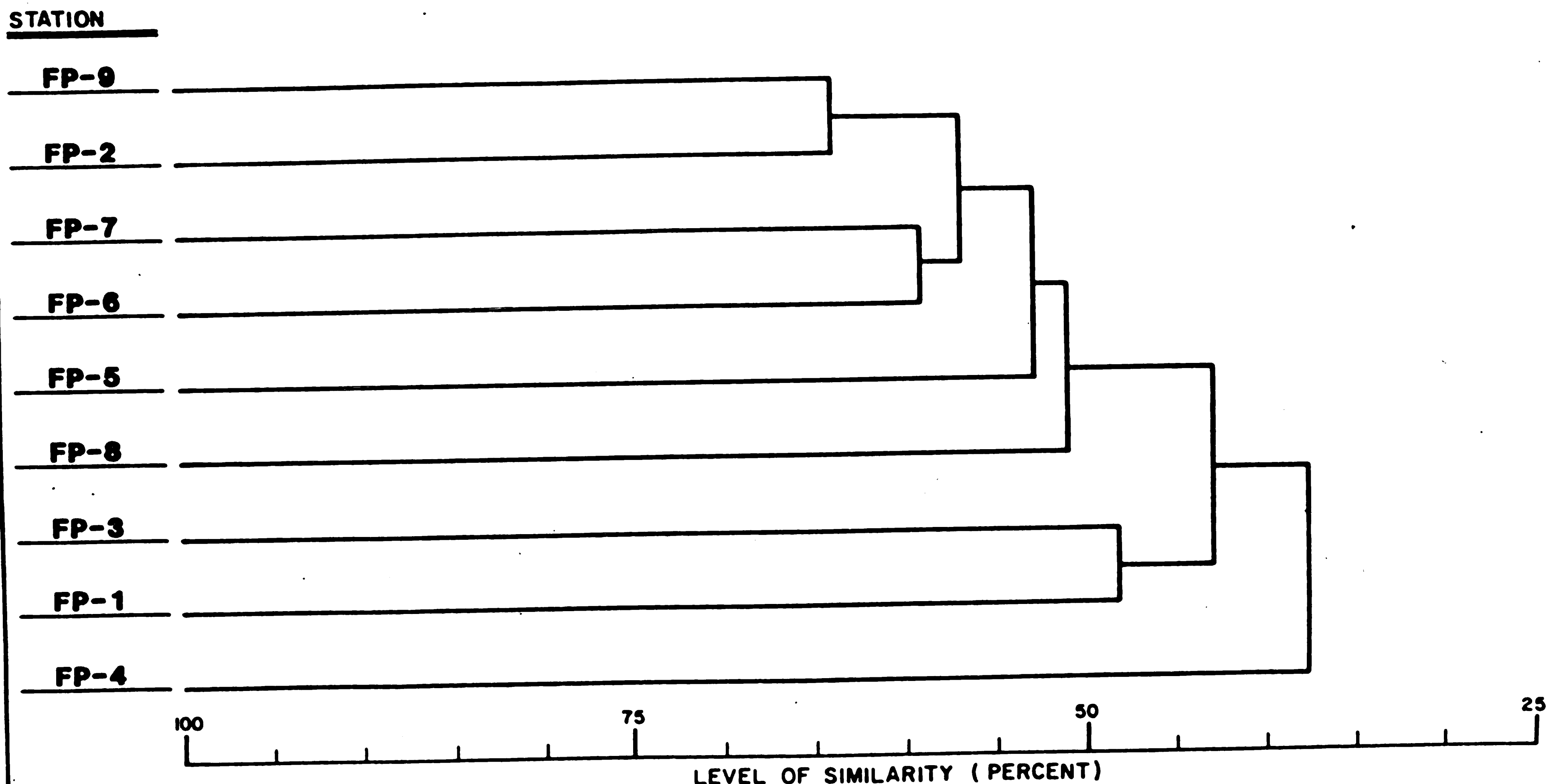

FIGURE A-4

CLUSTER DENDOGRAM SHOWING STATION ASSOCIATIONS BASED ON BENTHIC MACROINVERTEBRATE SIMILARITY AS DETERMINED USING THE MORISITA INDEX

Ocean Dredged Material Disposal Site Ft. Pierce, Florida

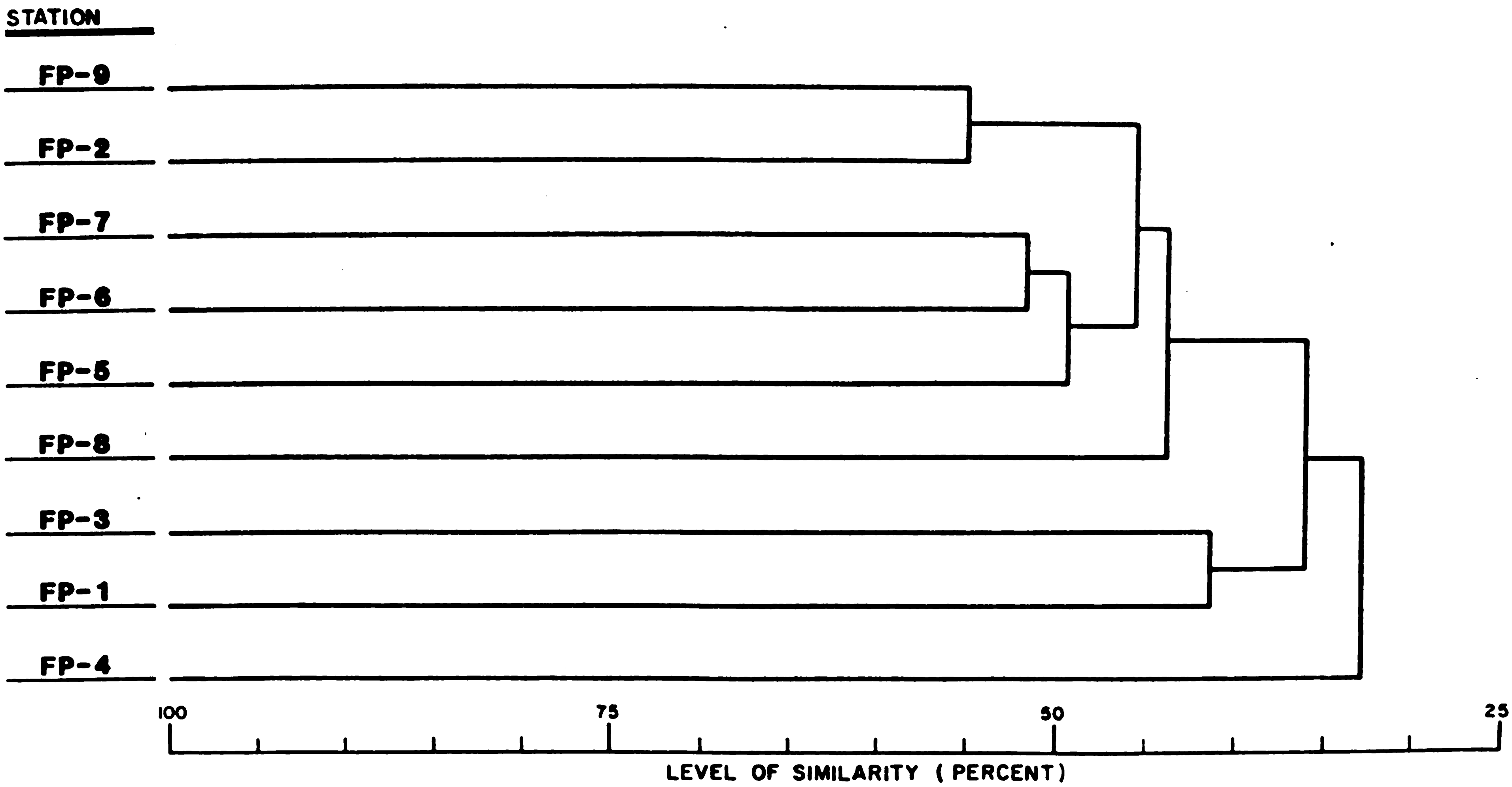

FIGURE A-5

CLUSTER DENDOGRAM SHOWING STATION ASSOCIATIONS BASED ON BENTHIC MACROINVERTEBRATE SIMILARITY AS DETERMINED USING THE BRAY-CURTIS INDEX

Ocean Dredged Material Disposal Site Ft. Pierce, Florida

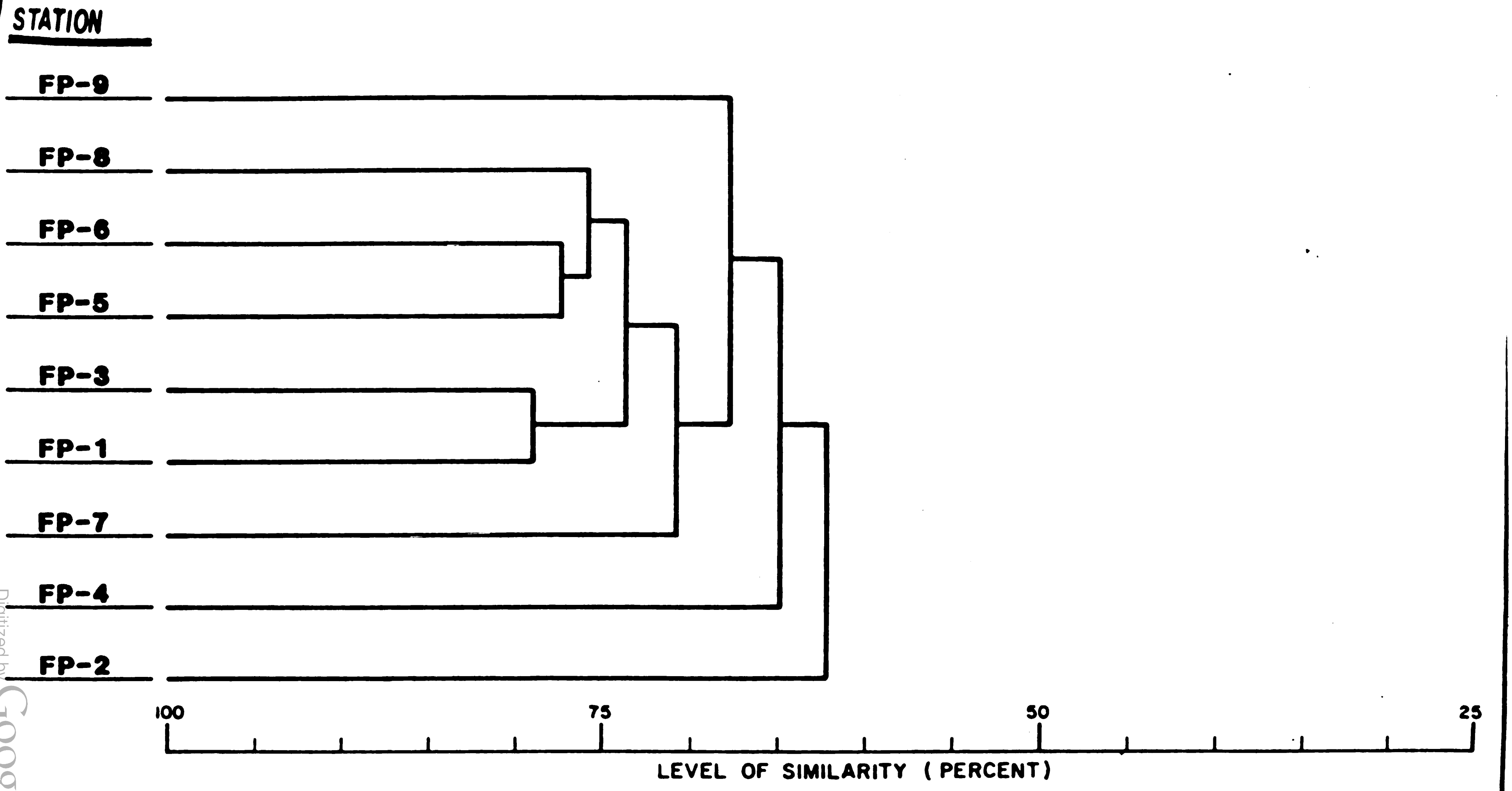

FIGURE A-6

CLUSTER DENDOGRAM SHOWING STATION ASSOCIATIONS BASED ON BENTHIC MACROINVERTEBRATE SIMILARITY AS DETERMINED BY SIMPLE MATCHING (PRESENCE/ABSENCE)

Ocean Dredged Material Disposal Site Ft. Pierce, Florida

Stations FP-2 and FP-9 and associated this cluster, at a relatively low similarity level, with the clusters including FP-6 and FP-7.

The simple matching index resulted in only two clusters. In addition to the pairing of FP-1 and FP-3, simple matching clustered Stations FP-5, FP-6, and FP-9. These two groups of stations are more similar to each other than to other stations in the area in terms of faunal presence or absence.

Cluster analyses did not reveal consistent differences between stations located within the disposal site and those located outside ODMDS boundaries. Benthic communities at Stations FP-3 and FP-5, located within the disposal area, were similar to communities found at stations located outside the ODMDS. Station FP-4, on the disposal area's western boundary, was an outlier. The unique faunal community at FP-4 may reflect the relatively coarse nature of sediments at this site.

Based on the results of this survey of benthic infaunal communities in the Ft. Pierce Harbor ODMDS vicinity, the following observations can be made.

1. Polychaete worms dominated the benthic infauna numerically.

2. In terms of abundance, number of taxa, and diversity, consistent differences between stations located within the ODMDS and those outside the ODMDS were not observed. Potential effects of

disposal on benthic community trophic structure were noted at Station FP-3.

3. Cluster analyses based on several similarity indices do not reveal differences between benthic communities at stations located within the disposal site and those in surrounding areas. Faunal differences observed are more likely related to substrate character or other undetermined environmental variables.

A.2.3.2 Meiofauna

The composition, abundance and diversity of meiofauna collected from the study area is given in Table A-14. Nematodes and harpacticoid copepods were the most abundant taxa and together accounted for 53 percent of the meiofaunal community. Polychaete larvae and cyclopoid copopods were also abundant. Other common though less abundant taxa included crustacean nauplii, turbellarians, and members of the phylum Gastrotricha.

No consistent trends in meiofaunal composition, abundance, or diversity were noted. The meiofaunal community within the ODMDS appears to be similar to that in the surrounding area.

The nematode-to-copepod or nematode-to-harpacticoid copepod ratio has been proposed as an index to detect differences in sediment type (Raffaelli and Mason, 1981 in Shiells and Anderson, 1985). In theory, as the organic content of

Table A-14. Meiofauna Collected from Stations in the Fort Pierce Harbor ODMDS Vicinity.

TAXA Phylum Class Subclass Order	FP-1 A	FP-1 B	FP-2 A	FP-2 B	FP-3 A	FP-3 B	FP-4 A	FP-4 B	FP-5 A	FP-5 B	FP-6 A	FP-6 B	FP-7 A	FP-7 B	FP-8 A	FP-8 B	FP-9 A	FP-9 B	Mean Taxa Abundance (± sd)**
	Station/Replicate/Abundance*																		
Coelenterata				1	1														<1
Platyhelminthes																			
Turbellaria	3	4	7	8	7	9	57	37	13	5	13	18	22	27	11	26	11	7	16 ± 14
Aschelminthes																			
Nematoda	35	82	68	44	96	91	146	177	109	108	45	47	163	149	128	119	54	111	98 ± 44
Gastrotricha	12	13	9	9	32	44	17	21	44	38	9	12	24	32	26	24	1	2	21 ±13
Priapulida							1												
Kinorhyncha		2	3	2	3	3	2	1			2	1	1	1	1	1			<1
Bryozoa						2	1												<1
Annelida																			
Polychaeta																			
(larvae)	58	43	29	32	30	25	47	34	45	35	41	34	83	82	37	28	55	29	43 ± 17
Tardigrada		2	1	1		1	1	2	3	4	1	2	5	1	3	8	23	32	5 ± 9
Arthropoda																			
Crustacea																			
(nauplii)	7	34	24	17	25	16	18	38	30	25	12	23	39	50	13	16	18	32	24 ± 11
Copepoda																			
Harpacticoida	61	81	73	51	40	55	154	175	49	47	13	43	143	155	62	86	56	58	78 ± 47
Cyclopoida	58	88	66	40	35	48	43	15	24	19	51	42	104	56	20	11	8	4	41 ± 28
Arachida																			
Acarina	2	6	1		2	3	4	4	1	2	2	5	16	8	3	2	3	7	4 ± 4
Echinodermata																			
Ophiuroida	3	4	2	3							5								1 ± 2
Total Sample Abundance	239	359	283	206	271	297	491	504	318	283	194	227	600	561	304	319	227	282	
Mean Station Abundance	299		245		284		498		301		211		581		312		255		
Mean Overall Abundance (± sd)																			331 123
Shannon-Weaver Diversity	2.63		2.66		2.69		2.45		2.59		2.86		2.67		2.49		2.55		

*Abundance given as organisms per sample. Each sample represents approximately 9.5 cm^2 of sediment surface area.

**Mean abundance plus or minus one standard deviation.

sediments increases, deposit-feeding nematodes increase and/or copepods decrease, resulting in a higher nematode:copepod ratio. The usefulness of this index, given the temporal and spatial variability of meiofaunal populations, has recently been questioned by a number of authors (Gee, et al., 1985; Shiells and Anderson, 1985).

Values for the nematode:copepod ranged from 0.41 to 1.56 while values for the nematode:harpacticoid ratio ranged between 0.82 and 2.26. Nematode:copepod and nematode:harpacticoid ratios for each station in the study area are given in Table A-15. Nematode:copepod ratios were variable and exhibited no trends. Nematode:harpacticoid ratios were highest at Stations FP-3 and FP-5, within the ODMDS. The significance of this finding or the potential utility of this ratio for future site monitoring cannot be determined from the number of samples collected. Neither ratio was related to grain size or concentrations of total organic carbon measured in area sediments.

A.2.3.3 Macroepifauna

Fish

Table A-16 lists the fish and invertebrates collected in replicate trawls at Stations FP-1, FP-5, FP-8, and FP-9. Macroepifauna were not abundant. Only 16 fish, representing 9 species were collected. Species collected were lane snapper (Lutjanus synagris), sand perch (Diplectrum formosum), lizardfish (Synodus foetens), bay whiff (Citharicthys spilopterus),

Table A-15. Nematode:Copepod and Nematode:Harpactico Ratios Calculated for Meiofauna Collected from the Ft. Pierce Harbor ODMDS.

Station	Nematodes (No./Sample)	Total Copepods (No./Sample)	Harpacticoid Copepods (No./Sample)	Nematode:Copepod Ratio	Nematode:Harpacticoid Ratio
FP-1	117	288	142	0.41	0.82
FP-2	112	230	124	0.49	0.90
FP-3	187	178	95	1.05	1.97
FP-4	323	387	329	0.83	0.98
FP-5	217	139	96	1.56	2.26
FP-6	92	149	56	0.62	1.64
FP-7	312	458	298	0.68	1.05
FP-8	247	179	148	1.38	1.67
FP-9	165	124	114	1.33	1.45

Table A-16. Fish and Invertebrates Collected by Trawl from the Ft. Pierce Harbor ODMDS Vicinity.

Station	Replicate	Scientific Name	Common Name	Number	Species Weight (wet, g)	Sample Biomass (wet, g)
FP-1	A	Invertebrates				
		Echinaster sp.	Starfish	1	12.8	
		Luidia clathrata	Starfish	2	47.5	
		Ophiuroidea	Brittle star	1	0.4	
						60.7
	B	Fish				
		Prionotus scitulus	Leopard sea robin	1	55.7	55.7
FP-5	A	Fish				
		Citharicthys spilopterus	Bay whiff	1	169.0	
		Haemulon striatum	Striped grunt	1	107.5	
		Lutjanus synagris	Lane snapper	4	324.3	
						600.8
	B	Fish				
		Monacanthus hispidus	Planehead file-fish	1	29.8	
		Invertebrates				
		Lytechinus variegatus	Sea urchin	1	12.7	
						42.5
FP-8	A	Fish				
		Arius felis	Sea catfish	1	39.8	
		Invertebrates				
		Lolliguncula brevis	Squid	1	5.5	
		Lytechinus variegatus	Sea urchin	8	36.0	
						81.3

Table A-16. (Continued)

Station	Replicate	Scientific Name	Common Name	Number	Species Weight (wet, g)	Sample Biomass (wet, g)
FP-8	B	Fish				
		Chilomycterus schoepfi	Striped burrfish	1	240.0	
		Diplectrum formosum	Sand perch	2	175.0	
						415.0
FP-9	A	Fish				
		Diplectrum formosum	Sand perch	1	66.0	
		Synodus foetens	Lizardfish	1	164.5	
		Invertebrates				
		Lytechinus variegatus	Sea urchin	5	33.5	
						264.0
	B	Fish				
		Diplectrum formosum	Sand perch	1	116.8	
		Synodus foetens	Lizardfish	1	242.0	
		Invertebrates				
		Lytechinus variegatus	Sea urchin	3	10.3	
		Ophiuroidea	Brittle star	1	0.2	
						369.3

striped grunt (Haemulon striatum), leopard sea robin (Prionotus scitulus), sea catfish (Arius felis), striped burrfish (Chilomycterus schoepfi), and planehead filefish (Monacanthus hispidus).

Futch and Dwinell (1977) also report poor returns from trawl sampling on the shallow Shelf off Ft. Pierce. Benthic fish listed by these authors as characteristic of the sandy offshore environment and common to the December, 1985 survey were lizardfish, leopard sea robin, and sea catfish. Other fish frequently represented in collections from this environment were spotted flounder (Bothus robinsi), spotted whiff (Citharicthys macrops), dusky flounder (Syacium papillosum), and rock sea bass (Centropristis philadelphica). Reef fish were also common in, but not endemic to, the sandy offshore environ.

Invertebrates

Few invertebrates were collected by trawl from the Ft. Pierce Harbor ODMDS. With the exception of one pelagic specimen, a squid, all invertebrates collected were echinoderms. The sea urchin, Lytechinus variegatus was the most common species collected. Other invertebrates represented in samples were the starfish Echinaster sp. and Luidia clathrata and ophiuroid brittle stars.

In a previous study of the epibenthos of the shallow Shelf between the ODMDS and Hutchinson Island, Camp et al. (1977) found several crustacean species to be characteristic of the offshore sand environment. These included two crabs, *Portunus gibbesii* and *P. spinimanus*, and the shrimp, *Trachypenaeus constrictus*.

A.2.3.4 Tissue Analyses

Levels of trace metals, pesticides, polychlorinated biphenyls (PCBs), and high molecular weight (HMW) hydrocarbons were measured in a variety of organisms collected by trawl from the Ft. Pierce ODMDS vicinity. The results of these analyses are presented in Table A-17.

Lead, chlorinated hydrocarbon pesticides, and pecticide derivatives were not detected in any of the tissues analyzed. In general, concentrations of mercury, cadmium, PCBs, and HMW hydrocarbons, were comparable in tissues collected from outside the ODMDS and within the ODMDS. No indications of unusual contaminant accumulation were noted.

Tissue data obtained serve primarily as an aid to establishing a baseline for this area. Poor trawl returns did not allow for between station comparisons of constituent concentrations between representatives of individual species collected from both inside and outside the ODMDS.

Table A-17. Results of Tissue Analyses of Fish and Invertebrate Species Collected from the Fort Pierce Harbor ODMDS Vicinity.

PARAMETER*	Station	FP-1	FP-5	FP-5	FP-8	FP-8	FP-9	FP-9
	Scientific Name	*Prionotus scitulus*	*Lutjanus synagris*	*Citharichthys spilopterus*	*Diplectrum formosum*	*Lolliguncula brevis*	*Diplectrum formosum*	*Synodus foetens*
	Common Name	(Leopard sea robin)	(Lane snapper)	(Bay whiff)	(Sand perch)	(Squid)	(Sand perch)	(Lizardfish)
Trace Metals								
Mercury ug/g		0.04	0.04	0.07	0.03	0.09	0.07	0.04
Cadmium ug/g		0.008	0.021	0.012	0.007	0.007	0.012	0.008
Lead ug/g		<0.03	<0.03	<0.03	<0.03	<0.03	<0.03	<0.03
Pesticides								
Alpha-BHC, ug/kg		<0.07	<0.07	<0.07	<0.07	<0.07	<0.07	<0.07
Gamma-BHC, ug/kg		<0.09	<0.09	<0.09	<0.09	<0.09	<0.09	<0.09
Heptachlor, ug/kg		<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2
Beta-BHC, ug/kg		<0.3	<0.3	<0.3	<0.3	<0.3	<0.3	<0.3
Aldrin, ug/kg		<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
Heptachlor Epoxide, ug/kg		<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2
4,4'-DDE, ug/kg		<0.3	<0.3	<0.3	<0.3	<0.3	<0.3	<0.3
4,4'-DDD, ug/kg		<0.4	<0.4	<0.4	<0.4	<0.4	<0.4	<0.4
4,4'-DDT, ug/kg		<0.4	<0.4	<0.4	<0.4	<0.4	<0.4	<0.4
o,p'-DDD, ug/kg		<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10
o,p'-DDT, ug/kg		<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10
Chlordane, ug/kg		<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10
Dieldrin, ug/kg		<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2
Endrin, ug/kg		<0.4	<0.4	<0.4	<0.4	<0.4	<0.4	<0.4
Total PCBs as Archlor 1254**, mg/kg		<0.006	0.025	<0.006	<0.006	<0.006	0.006	0.013
High Molecular Weight Hydrocarbons								
Weight of sample extracted, g		100	100	100	100	100	100	100
Weight of extractables, ppm		980	1100	2800	1600	680	860	4600
Aliphatics and aromatics, ppm		0.08	0.09	0.07	0.09	0.09	0.09	0.25

Table A-1[illegible] (Continued)

PARAMETER*	FP-1	FP-5	FP-5	FP-8	FP-8	FP-9	FP-9
Scientific Name	*Prionotus scitulus*	*Lutjanus synagris*	*Citharichthys spilopterus*	*Diplectrum formosum*	*Lolliguncula brevis*	*Diplectrum formosum*	*Synodus foetens*
Common Name	(Leopard sea robin)	(Lane snapper)	(Bay whiff)	(Sand perch)	(Squid)	(Sand perch)	(Lizardfish)
High Molecular Weight Hydrocarbons (Cont)							
Resolved hydrocarbons, ppm	0.11	0.13	0.12	0.09	0.10	0.15	0.33
Unresolved hydrocarbons, ppm	0.04	0.05	0.08	0.10	0.04	0.05	0.22
Sum of n-alkanes, ppm	0.01	0.03	0.04	0.02	0.02	0.02	0.08
Sum of even n-alkanes, ppm	0.01	0.02	0.03	0.02	0.02	0.02	0.05
Sum of odd n-alkanes, ppm	<0.01	0.01	0.01	<0.01	<0.01	<0.01	0.03
Unresolved hydrocarbons/ resolved hydrocarbons	0.36	0.38	0.66	1.1	0.40	0.33	0.67
Odd n-alkanes/even n-alkanes	N/A***	0.05	0.33	N/A	N/A	N/A	0.60

*All values expressed on a wet weight basis.

**PCBs = Polychlorinated biphenyls

***Ratio cannot be calculated (one parameter not detected).

APPENDIX B

Benthic Macroinfauna Collected from the Ft. Pierce Harbor ODMDS Vicinity, December, 1985

Table B-1. Benthic Macroinvertebrates Collected from Statio[n]
in the Ft. Pierce Harbor ODMDS Vicinity.

Phylum / Class/Order / Family / Genus Species
Porifera
Cnidaria
Anthozoa
Hydrozoa
Hydrozoa A
Hydrozoa B
Hydrozoa C
Hydrozoa spp.
Platyhelminthes
Turbellaria
Rhynchocoela
Nemertea
Aschelminthes
Nematoda
Annelida
Polychaeta
Arabellidae
Arabella sp.
Capitellidae
Mastiobranchus sp.
Mediomastus sp.
Chrysopetalidae
Bhwania heteroseta
Psammolyce ctenidophora
Cirratulidae
Cirriformia sp.
Dorvilleidae
Schistomeringos pectinata
Schistomeringos rudolfi
Eunicidae
Eunice antennata
Eunice sp.
Flabelligeridae
Glyceridae
Hemipodus roseus
Goniadidae
Goniadides carolinae
Hesionidae
Podarke obscura
Lumbrineridae
Lumbrineriopsis paradoxa

Table B-1. (Continued)

Phylum / Class/Order / Family / Genus Species
Maldanidae
Axiothella sp. A
Petaloproctus sp.
Nereidae
Nephtyidae
Nephtys picta
Nephtys squamosa
Opheliidae
Ophelina sp.
Orbininidae
Leitoscoloplos robustus
Oweniidae
Owenia sp.
Phyllodocidae
Eteone lactea
Phyllodoce castanaea
Phyllodoce sp.
Pisionidae
Pisione remota
Polynoidae
Sabellidae
Sabellaria floridensis
Serpulidae
Spionidae
Aonides mayaguezensis
Paraprionospio pinnata
Prionospio sp.
Prionospio heterobranchia
Scolelepis squamata
Syllidae
Brania sp.
Exogone sp.
Trypanosyllis sp.
Terebellidae
Loimia medusa
Polycirrus plumosus
Oligochaeta
Mollusca
Gastropoda
Columbellidae
Anachis obesa
Anachis semiplicata

Table B-1. (Continued)

Phylum Class/Order Family Genus Species
Crepidulidae
Calyptraea centralis
Cyclostrematidae
Arene tricarinata
Mellanellidae
Pyramidellidae
Turbonilla protracta
Trochidae
Caecum sp.
Synaptoecochlea picta
Polyplacophora
Chaetopleuridae
Chaetopleura apiculata
Bivalvia
Crassinellidae
Crassinella lunulata
Veneridae
Chione grus
Chione sp.
Gouldina cerina
Scaphopoda
Dentalium sp.
Bryozoa
Ectoprocta sp.
Arthropoda
Amphipoda
Trichophoxus sp.
Ampithoidae
Cymadusa compta
Bateidae
Batea catharinensis
Caprellidae
Corophiidae
Cerapus tubularis
Cerapus sp.
Haustoriidae
Acanthohaustorius sp.
Melitidae
Melita c.f. *dentata*
Stenothoidae
Stenothoe sp.
Branchiopoda
Copepoda

Table B-1. (Continued)

Phylum / Class/Order / Family / Genus Species
Harpacticoida
Cumacea
Decapoda
Decapod zoea
Majidae
Paguridae
Processidae
Processa sp.
Isopoda
Anthuridae
Xenathura brevitelson
Ostracoda
Sipuncula
Sipunculida
Aspidosophonidae
Aspidosiphon albus
Aspidosiphon gosnoldi
Aspidosiphon sp.
Sipunculidae
Echinodermata
Echinoidea
Ophiuroidea
Amphiuridae
Amphiodia pulchella
Amphiodia sp.
Ophiolepididae
Ophiolepis sp.
Ophiothricidae
Ophiothrix angulata
Chaetognatha
Cephalochordata
Branchiostoma sp.

Table B-2. Abundance of Macroinfauna Collected at Station FP-1.

Phylum Class/Order Family Genus Species	Replicate/(Organisms/m^2)					Mean Abun (Organism
	1	2	3	4	5	
Cnidaria						
Hydrozoa						
Hydrozoa B	474					95
Platyhelminthes						
Turbellaria		43		43	43	26
Rhynchocoela		43		43		17
Aschelminthes						
Nematoda		86	172		259	103
Annelida						
Polychaeta						
Eunicidae						
Eunice sp.		43			43	17
Goniadidae		129	86			43
Maldanidae						
Petaloproctus sp.		43				9
Nephtyidae						
Nephtys squamosa				43		9
Orbiniidae			43			9
Serpulidae		43				9
Spionidae						
Prionospio sp.	43			43		17
Syllidae	86	43	129	86	216	112
Exogone sp.	86		43	43		34
Trypanosyllis sp.			86			17
Terebellidae						
Loimia medusa	43					9
Mollusca						
Polyplacophora					43	9
Chaetopleuridae		43				9
Chaetopleura apiculata			43			9
Bryozoa		P				P
Arthropoda						
Copepoda					43	9
Amphipoda						
Ampithoidae		43				9
Sipuncula						
Sipunculida						
Aspidosophonidae						
Aspidosiphon albus	43	43				17
Echinodermata						
Ophiuroidea				43		9
Ophiotricidae						
Ophiothrix angulata				43		9

Table B-2. (Continued)

Phylum Class/Order Family Genus Species	Replicate/(Organisms/m²) 1	2	3	4	5	Mean Abundance (Organisms/m²)
Cephalochordata						
Branchiostoma sp.		43	43			17
Totals	775	645	645	387	647	620
Number of Species	6	13	8	8	6	25
Shannon-Weaver Diversity	1.83	3.46	2.79	2.95	2.10	3.85

Table B-3. Abundance of Macroinfauna Collected at Station FP-2.

Phylum Class/Order Family Genus Species	Replicate/(Organisms/m^2) 1	2	3	4	5	Mean Abund (Organisms
Cnidaria						
Hydrozoa						
Hydrozoa A				43	86	26
Platyhelminthes		86				17
Turbellaria	86	43	216		43	78
Rhynchocoela						
Nemertea	43			43	43	26
Aschelminthes						
Nematoda	259	86	388	216		190
Annelida						
Polychaeta						
Chrysopetalidae						
Ehwania heteroseta	43	43				17
Psammolyce ctenidophora			43			9
Cirratulidae						
Cirriformia sp.		43				9
Dorvilleidae		43	43		43	26
Schistomeringos pectinata		43		43		17
Schistomeringos rudolfi		86				17
Eunicidae			43			9
Eunice antennata	86	172	517	43		164
Eunice sp.		43				9
Glylceridae			86			17
Hemipodus roseus	129					26
Goniadidae				86	43	26
Goniadides carolinae		129				26
Hesionidae				172		34
Maldanidae	43		43			17
Nephtyidae						
Nephtys squamosa			43	43		17
Phyllodocidae						
Phyllodoce castanoea			129			26
Pisionidae						
Pisione remota			43			9
Sabellidae			43			9
Spionidae					43	9
Aonides mayaquezensis					43	9
Paraprionospio pinnata				43		9
Prionospio sp.		43				9
Syllidae		345	302			129
Exogone sp.	43	302	1466	172		397
Trypanosyllis sp.	86		172			52
Oligochaeta			172	43	259	95

Table B-3. (Continued)

Phylum Class/Order Family Genus Species	Replicate/(Organisms/m²) 1	2	3	4	5	Mean Abundance (Organisms/m²)
Mollusca						
Gastropoda						
Crepidulidae						
Calyptraea centralis					86	17
Cyclostrematidae						
Arene tricarinata			43			9
Mellanellidae						
Mellanella sp.					43	9
Polyplacophora		43				9
Chaetopleuridae						
Chaetopleura apiculata		86	216		172	95
Bivalvia						
Veneridae						
Chione grus				43		9
Gouldina cerina				43		9
Scaphopoda						
Dentalium sp.				43		9
Bryozoa					P	P
Arthropoda						
Copepoda			43			9
Harpacticoid			43			9
Isopoda			43			9
Amphipoda						
Ampithoidae			43	43		17
Melitidae		43				9
Sipuncula						
Aspidosophonidae						
Aspidosiphon gosnoldi		86	43			26
Aspidosiphon sp.		86		86		34
Echinodermata						
Ophiuroidea	43		86	43		34
Amphiuridae						
Amphiodia pulchella					43	9
Echinoidea			216			43
Totals	904	1894	4482	1464	688	1886
Number of Species	11	18	26	17	12	52
Shannon-Weaver Diversity	3.14	3.77	3.64	3.70	3.25	4.54

Table B-4. Abundance of Macroinfauna Collected at Station FP-3.

Phylum Class/Order Family Genus Species	Replicate/(Organisms/m²)					Mean Abun (Organisms
	1	2	3	4	5	
Cnidaria						
Hydrozoa						
Hydrozoa B				43		9
Anthozoa		43			43	17
Platyhelminthes						
Turbellaria			129		43	34
Aschelminthes						
Nematoda	43	302	259	43		129
Annelida						
Polychaeta						
Capitellidae						
Mediomastus sp.		43				9
Chrysopetalidae						
Ehwania heteroseta		43	43	86		34
Cirratulidae						
Cirriformia	43					9
Goniadidae		86				17
Maldanidae						
Petaloproctus sp.			43			9
Nephtyidae						
Nephtys picta			43	43		17
Oweniidae						
Owenia sp.	86					17
Phyllodocidae						
Eteone lactea			43			9
Spionidae				43		9
Syllidae	43	43	172	129		77
Oligochaeta	43	43	560			129
Mollusca						
Gastropoda						
Crepidulidae						
Calyptraea centralis				43		9
Polyplacophora	86		474			112
Chaetopleuridae					43	9

Table B-4. (Continued)

Phylum Class/Order Family Genus Species	Replicate/(Organisms/m²) 1	2	3	4	5	Mean Abundance (Organisms/m²)
Bryozoa		P	P	P	P	P
Arthropoda						
Cumacea	43					9
Cephalochordata						
Branchiostoma sp.				43		9
Totals	387	301	1852	689	129	672
Number of Species	8	7	11	9	4	21
Shannon-Weaver Diversity	2.73	2.52	2.67	2.61	1.58	3.49

Table B-5. Abundance of Macroinfauna Collected at Station FP-4.

Phylum Class/Order Family Genus Species	Replicate/(Organisms/m^2) 1	2	3	4	5	Mean Abund. (Organisms/
Cnidaria						
Anthozoa					43	9
Hydrozoa						
Hydrozoa B	43					9
Platyhelminthes						
Turbellaria			43			9
Rhynchocoela						
Nemertea	43				86	26
Aschelminthes						
Nematoda	43		86		86	43
Annelida						
Polychaeta						
Dorvilleidae	216			86		60
Eunicidae					43	9
Glyceridae						
Hemipodus roseus	43					9
Goniadidae					129	26
Nephtyidae						
Nephtys picta		43				9
Opheliidae						
Ophelina sp.	43					9
Sabellidae						
Sabellaria floridensis		1422				284
Spionidae						
Prionospio sp.	43				129	34
Syllidae	259			43	86	78
Terebellidae	43				86	26
Oligochaeta						
Mollusca						
Gastropoda						
Columbellidae						
Anachis semiplicata			43			9
Crepidulidae						
Calyptraea centralis					43	9
Cyclostrematidae						
Arene tricarinata			43			9
Trochidae						
Synaptoecochlea picta					43	9
Bivalvia						
Crassinellidae						
Crassinella lunulata			43			9

Table B-5. (Continued)

Phylum Class/Order Family Genus Species	Replicate/(Organisms/m^2) 1	 2	 3	 4	 5	Mean Abundance (Organisms/m^2)
Bryozoa						
Ectoprocta				43		9
Arthropoda						
Branchiopoda		43				9
Isopoda						
Anthuridae	43					9
Amphipoda						
Ampithoidae					43	9
Cymadusa compta					43	9
Caprellidae	86					17
Corophiidae						
Cerapus tubularis	991					198
Melitidae						
Melita c.f. dentata					43	9
Stenothoidae	43					9
Stenothoe sp.	86					17
Decapoda						
Decapod zoea					86	17
Pagueidae		43				9
Echinodermata						
Ophiuroidea						
Amphiuridae						
Amphiodia pulchella		43				9
Cephalochordata						
Branchiostoma sp.	43					9
Totals	2068	1594	258	172	1032	1025
Number of Species	15	5	5	4	15	36
Shannon-Weaver Diversity	2.77	0.71	2.25	1.50	3.77	3.85

Table B-6. Abundance of Macroinfauna Collected at Station FP-5.

Phylum Class/Order Family Genus Species	Replicate/(Organisms/m^2)					Mean Abundance (Organisms/m^2)
	1	2	3	4	5	
Cnidaria						
Hydrozoa						
Hydrozoa C				43		9
Platyhelminthes						
Turbellaria	43	388	43			95
Aschelminthes						
Nematoda	216	86		172		95
Annelida						
Polychaeta						
Chrysopetalidae						
Bhwania heteroseta					43	9
Dorvilleidae	43			345		78
Schistomeringos pectinata	345					69
Eunicidae						
Eunice antennata				43		9
Glyceridae	43					9
Goniadidae	86			43	43	34
Lumbrineridae						
Lumbrineriopsis paradoxa					43	9
Phyllodocidae				43		9
Syllidae	388			431		[illegible]4
Brania sp.		43				9
Exogone sp.				43		9
Trypanosyllis sp.	43					9
Arthropoda						
Amphipoda						
Melitidae						
Melita c.f. dentata					43	9
Decapoda						
Majidae				43		9
Sipuncula						
Aspidosophonidae						
Aspidosiphon albus	43				43	17
Aspidosiphon gosnoldi				43		9
Echinodermata						
Ophiuroidea		86		43		26
Amphiuridae		43				9
Amphiodia pulchella		86				17

Table B-6. (Continued)

Phylum Class/Order Family Genus Species	Replicate/(Organisms/m²) 1	2	3	4	5	Mean Abundance (Organisms/m²)
Echinoidea		86			43	26
Cephalochordata						
Branchiostoma sp.	43					9
Totals	1293	818	86	1249	258	741
Number of Species	10	7	2	11	6	25
Shannon-Weaver Diversity	2.70	2.32	1.00	2.61	2.58	3.70

Table B-7. Abundance of Macroinfauna Collected at Station FP-6.

Phylum Class/Order Family Genus Species	Replicate/(Organisms/m²) 1	2	3	4	5	Mean Abundance (Organisms/m²)
Cnidaria						
Anthozoa						
Hydrozoa						
Hydrozoa A			43			9
Platyhelminthes						
Turbellaria	259	43	43	129	129	121
Aschelminthes						
Nematoda	1078		43		259	276
Annelida						
Polychaeta						
Capitellidae						
Mastiobranchus sp.	41					9
Chrysopetalidae						
Ehwania heteroseta					86	17
Dorvilleidae	86		43		43	34
Eunicidae						
Eunice antennata			43			9
Flabelligeridae					86	17
Glylceridae	172					34
Hemipodus roseus				43		9
Goniadidae					345	69
Goniadides carolinae	216		43	43		60
Nephtyidae						
Nephtys picta	43					9
Orbininidae						
Leitoscoloplos robustus					43	9
Spionidae					43	9
Syllidae	647	43	129	43	216	216
Exogone sp.		43		172	129	69
Trypanosyllis sp.					129	26
Terebellidae	43					9
Oligochaeta	86					17
Mollusca						
Gastropoda						
Caecum sp.					43	9
Columbellidae						
Anachis obesa					43	9
Pyramidellidae						
Turbonilla protracta				43		9
Polyplacophora						

Table B-7. (Continued)

Phylum Class/Order Family Genus Species	Replicate/(Organisms/m^2) 1	2	3	4	5	Mean Abundance (Organisms/m^2)
Chaetopleuridae						
Chaetopleura apiculata			43	43	43	26
Bryozoa				P		P
Arthropoda						
Amphipoda						
Bateidae						
Batea catharinensis			43			9
Decapoda						
Processidae						
Processa sp.			43			9
Sipuncula						
Aspidosophonidae						
Aspidosiphon albus	43					9
Echinodermata						
Ophiruoidea						
Amphiuridae						
Amphiodia pulchella			43		43	17
Ophiolepis sp.					43	9
Echinoidea				43		9
Totals	2716	129	559	559	1723	1137
Number of Species	11	3	13	9	16	33
Shannon-Weaver Diversity	2.58	1.58	3.33	2.72	3.59	3.75

Table B-8. Abundance of Macroinfauna Collected at Station FP-7.

Phylum / Class/Order / Family / Genus Species	Replicate/(Organisms/m^2) 1	2	3	4	5	Mean Abundance (Organisms/m^2)
Cnidaria						
Hydrozoa						
Hydrozoa A			43			9
Platyhelminthes						
Turbellaria		388	43			86
Rhynchocoela		43				9
Nemertea						
Aschelminthes						
Nematoda		259	43		43	69
Annelida						
Polychaeta						
Chrysopetalidae						
Bhwania heteroseta		43				9
Dorvilleidae	43	86		43		34
Eunicidae						
Eunice antennata		43				9
Glylceridae	43	43				17
Hemipodus roseus		43				9
Goniadidae	43	43	43			26
Goniadides carolinae					86	17
Maldanidae						
Axiothella sp. A	43					9
Petaloproctus sp.				43		9
Nephtyidae						
Nephtys picta					43	9
Phyllodocidae		129				26
Phyllodoce castanaea		43				9
Phyllodoce sp.	86	129				43
Spionidae						
Prionospio heterobranchia		43				9
Prionospio sp.		43				9
Syllidae		603	129	172	86	198
Exogone sp.					43	9
Terebellidae	43	43				17
Oligochaeta		172	43	129		69
Mollusca						
Gastropoda						
Crepidulidae						
Calyptraea centralis		43				9
Mellanellidae	43					9

Table B-8. (Continued)

Phylum Class/Order Family Genus Species	Replicate/(Organisms/m²) 1	2	3	4	5	Mean Abundance (Organisms/m²)
Polyplacophora						
Chaetopleuridae						
Chaetopleura apiculata					43	9
Arthropoda						
Isopoda						
Anthuridae						
Xenathura brevitelson	43	43				17
Amphipoda						
Trichophoxus			43			9
Corophiidae						
Cerapus sp.	129					26
Haustoriidae			43			9
Acanthohaustorius sp.			43			9
Melitidae						
Melita c.f. dentata					43	9
Sipuncula						
Sipunculida						
Sipunculidae		43				9
Aspidosophonidae						
Aspidosiphon albus				43	43	17
Echinodermata						
Ophiuroidea				172		34
Amphiruidae						
Amphiodia sp.		43	43			17
Echinoidea				86		17
Cephalochordata						
Branchiostoma sp.				43	43	17
Totals	516	2368	516	731	516	929
Number of Species	9	21	10	8	10	39
Shannon-Weaver Diversity	3.02	3.66	3.19	2.75	3.25	4.50

Table B-9. Abundance of Macroinfauna Collected at Station FP-8.

Phylum / Class/Order / Family / Genus Species	Replicate (Organisms/m^2) 1	2	3	4	5	Mean Abundance (Organisms/m^2)
Cnidaria						
Hydrozoa						
Hydrozoa A		43				9
Platyhelminthes						
Turbellaria				259	302	112
Rhynchocoela						
Nemertea		86				17
Aschelminthes						
Nematoda	86	172		345		121
Annelida						
Polychaeta						
Arabellidae						
Arabella sp.			43			9
Capitellidae			43			9
Glylceridae			43			9
Hemipodus roseus			43			9
Goniadidae						
Goniadides carolinae	345		43	172		112
Maldanidae				43		9
Nephtyidae						
Nephtys picta	43	86			43	34
Phyllodocidae	43					9
Spionidae						
Scolelepis squamata					43	9
Syllidae	302		129	129	86	129
Exogone sp.	43				43	17
Terebellidae						
Loimia medusa				43		9
Polycirrus plumosus		43				9
Oligochaeta				43		9
Mollusca						
Gastropoda						
Crepidulidae						
Calyptraea centralis				43	129	34
Polyplacophora						
Chaetopleuridae						
Chaetopleura apiculata	43				86	26
Bryozoa		P	P		P	P
Arthropoda						
Copepoda			43			9

Table B-9. (Continued)

Phylum Class/Order Family Genus Species	Replicate/(Organisms/m²) 1	2	3	4	5	Mean Abundance (Organisms/m²)
Echinodermata						
Ophiuroidea						
Amphiuridae						
Amphiodia pulchella				43		9
Echinoidea					43	9
Cephalochordata						
Branchiostoma sp.			43	86	43	34
Totals	905	430	430	1206	818	758
Number of Species	7	6	9	10	10	25
Shannon-Weaver Diversity	2.22	2.12	2.85	2.87	2.75	3.70

Table B-10. Abundance of Macroinfauna Collected at Station FP-9.

Phylum / Class/Order / Family / Genus Species	Replicate/(Organisms/m^2) 1	2	3	4	5	Mean Abundance (Organisms/m^2)
Cnidaria						
Hydrozoa						
Hydrozoa A			43			9
Hydrozoa B			43			9
Platyhelminthes						
Turbellaria	86	43	86	86	43	69
Rhynchocoela						
Nemertea	43	86	43		216	78
Aschelminthes						
Nematoda	259	86		172	517	207
Annelida						
Polychaeta						
Capitellidae						
Mastiobranchus sp.				86		17
Mediomastus sp.					43	9
Cirratulidae						
Cirriformia					43	9
Dorvilleidae				43	86	26
Eunicidae						
Eunice antennata		129			603	146
Eunice sp.					129	26
Glylceridae					43	9
Hemipodus roseus					86	17
Goniadidae		43	86	129		52
Goniadides carolinae					43	9
Hesionidae						
Podarke obscura					43	9
Lumbrineridae					43	9
Maldanidae		43				9
Petaloproctus sp.					43	9
Nereidae					43	9
Nephtyidae						
Nephtys squamosa				43		9
Phyllodocidae					172	34
Polynoidae					172	34
Spionidae						
Aonides mayaguezensis					43	9
Prionospio sp.					172	34
Syllidae	259		172	129	1509	414
Brania sp.					431	86
Exogone sp.		43			474	103
Trypanosyllis sp.					431	86

Table B-10. (Continued)

Phylum Class/Order Family Genus Species	Replicate/(Organisms/m^2) 1	2	3	4	5	Mean Abundance (Organisms/m^2)
Terebellidae					86	17
Oligochaeta	86	129		172	302	138
Mollusca						
Polyplacophora					172	34
Chaetopleuridae						
Chaetopleura apiculata	43				216	52
Mollusca						
Bivalvia						
Veneridae						
Chione sp.					43	9
Arthropoda						
Copepoda						
Harpacticoid					86	17
Ostracoda					43	9
Amphipoda						
Ampithoidae						
Amphipoda					43	9
Decapoda						
Processidae						
Decapod zoea	43					9
Processa sp.			43			9
Echinodermata						
Ophiuroidea		43			43	17
Amphiuridae		43				9
Echinoidea					43	9
Chaetognatha	43					9
Totals	862	688	516	860	6505	1886
Number of Species	8	10	7	8	33	43
Shannon-Weaver Diversity	2.57	3.16	2.58	2.85	4.14	4.30

APPENDIX C

EVALUATION OF THE DISPERSION CHARACTERISTICS

OF THE MIAMI AND FORT PIERCE

DREDGED MATERIAL DISPOSAL SITES

by

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and

Abhimanyu Swain

Coastal Engineering Research Center

April 1989

Final Report

Prepared for
US Army Engineer District, Jacksonville
Jacksonville, Florida 32232-0019

PREFACE

This report describes a comprehensive approach for evaluating the environmental suitability of proposed open water disposal sites for dredged material. Two proposed Florida disposal sites are evaluated in this investigation, one off the coast of Miami and one off the coast of Fort Pierce. The purpose of the evaluation is to determine whether either site poses a contamination threat to sensitive nearshore coral reefs. Two criteria are necessary of a site if it is to be approved as environmentally acceptable. The first is concerned with the immediate effects of the disposal operation, material from the descending plume of sediments can not contaminate areas outside the designated disposal site. This short-term phase analysis represents several minutes to several hours following the initial release of material from the dredge. The second phase of investigation determines whether material deposited within the disposal site can be eroded and subsequently transported out of the site by either local current fields or by storm conditions. This long-term phase examines mound stability for periods of time up to one year following the disposal operation.

A two-phase numerical modeling methodology was selected for this investigation. The approach utilizes the Disposal From an Instantaneous Dump (DIFID) model for calculating the short-term fate and a coupled hydrodynamic/ sediment transport model for computing the long-term fate of the disposed material. The project was authorized and funded by the US Army Engineer District, Jacksonville (SAJ), under the project management of Mr. Ronald Tapp and Ms. Elizabeth Rhodes and under the general direction of Mr. A. J. Salem.

Much of the prototype data required for numerical model input were provided by or extracted from research publications of Dr. T. N. Lee, School of Marine and Atmospheric Science, Division of Meteorology and Physical Oceanography, University of Miami, Florida. Supplementary velocity measurement data were also obtained from other sources. The study was conducted at the US Army Engineer Waterways Experiment Station's (WES) Coastal Engineering Research Center (CERC). The numerical investigation was completed, and this report prepared by Drs. Norman W. Scheffner and A. Swain.

Providing general supervision were Dr. James R. Houston and Mr. Charles C. Calhoun, Jr., Chief and Assistant Chief, respectively, CERC; direct supervision

the project was provided by Mr. H. L. Butler, Chief of the Research Division, and Mr. Bruce A. Ebersole, Chief of the Coastal Processes Branch of the Research Division. Commander and Director of WES during the course of this study and the preparation and publication of this report was COL Dwayne G. Lee, CE. Technical Director was Dr. Robert. W. Whalin.

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EVALUATION OF THE DISPERSION CHARACTERISTICS OF THE MIAMI AND FORT PIERCE DREDGED MATERIAL DISPOSAL SITES

INTRODUCTION

Background and Objective

1. Dredging of estuaries, bays, harbors, and coastal inlets in the United States is often required in order to maintain minimum navigation depths. The selection of an environmentally acceptable disposal site for this dredged material requires some means of predicting the effects of the disposal operation on the coastal and inland water environment. One means of prediction is the utilization of numerical models capable of simulating the short- and long-term diffusion and transport of dredged material from the disposal site.

2. The Corps of Engineers have become increasingly active in the area of maintenance dredging of harbor channels and coastal inlets. The designation of acceptable disposal sites for this material is, however, becoming increasingly difficult. Open water disposal sites are often selected as a means of minimizing any adverse effects resulting from the disposal of material in the vicinity of the dredging operation. This approach is acceptable if the designated site is far enough removed from any environmentally sensitive area that material at the site will remain at the site and not represent a possible source of contamination.

3. The Planning Division, US Army Engineer District, Jacksonville (SAJ), is preparing an Environmental Impact Statement (EIS) for submission to the US Environmental Protection Agency (EPA). The purpose of the EIS is to evaluate the environmental impact of dredged material disposed at the proposed Ocean Dredged Material Disposal Sites (ODMDS) offshore of Miami and Fort Pierce, Florida. The location and bathymetries of these sites are shown in Figures 1.1 and 1.2.

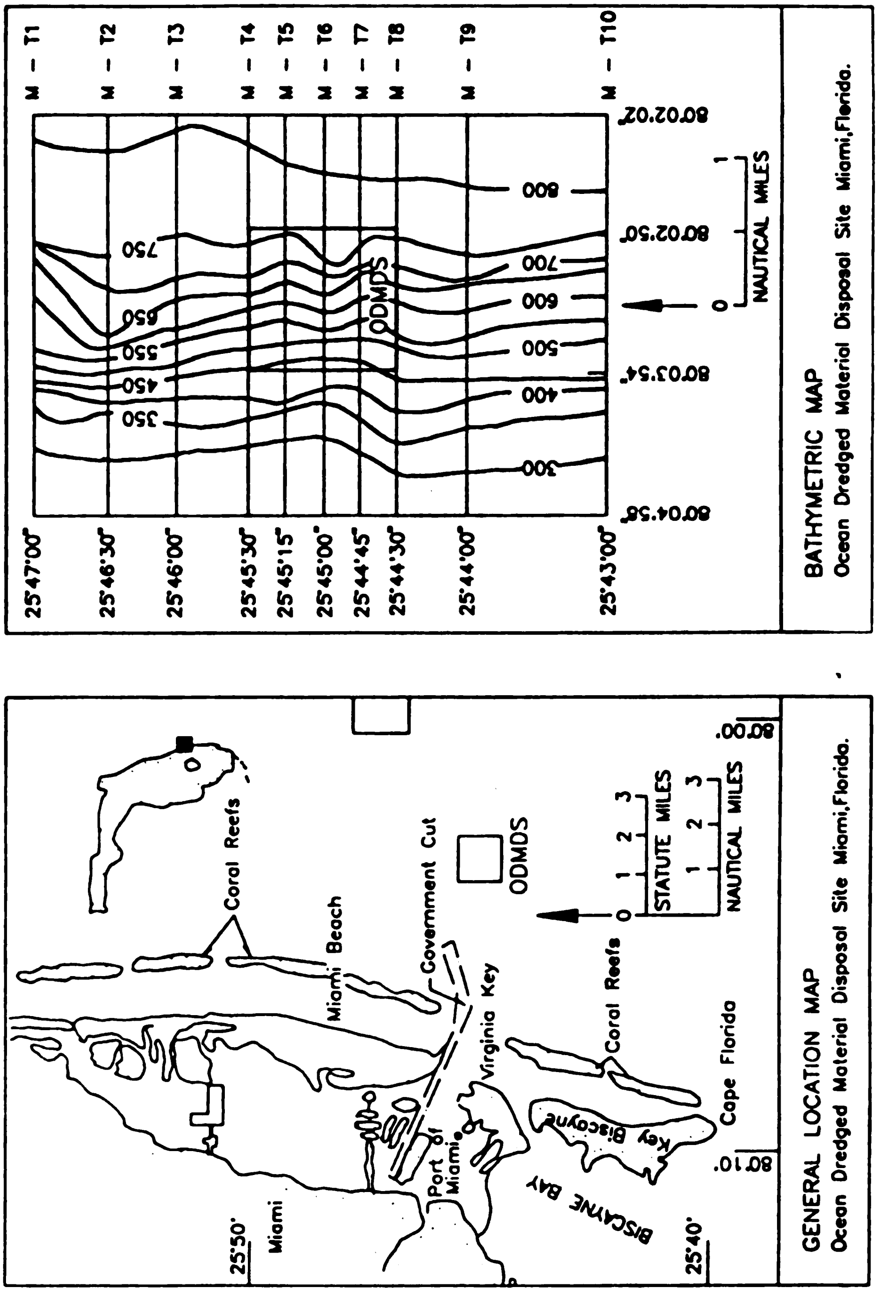
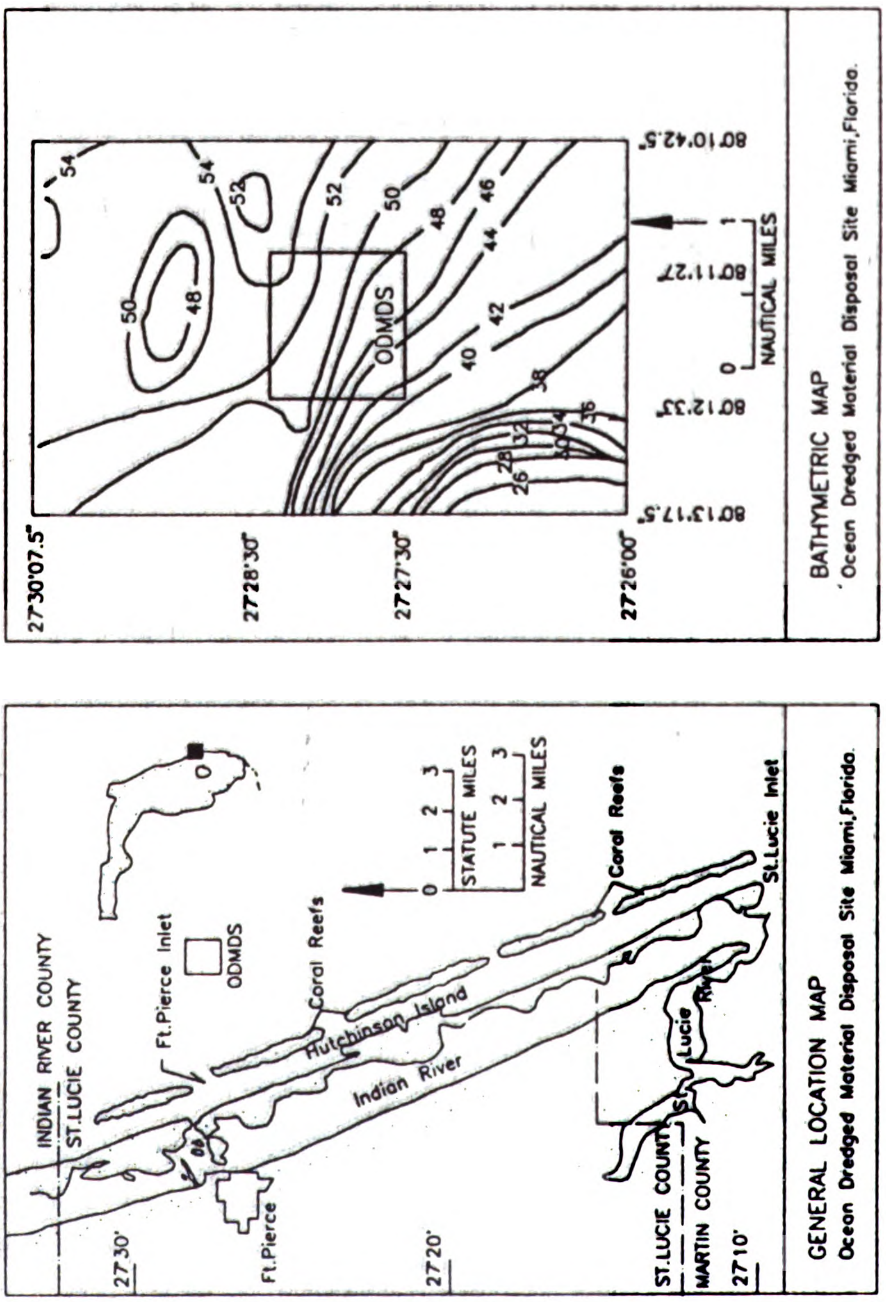


Figure 1.1. Location of ODMDS, bathymetry map, and coral reefs for the Miami Site



Figures 1.2. Location of ODMDS, bathymetry map, and coral reefs for the Fort Pierce site

4. The EPA has expressed a concern regarding the fate of the disposed materials at both proposed ODMDS. It is feared that discharged sediments from either disposal site may be carried by the Gulf Stream and its spin-off eddies onto sensitive shore-parallel coral reefs located approximately 1 mile offshore of the barrier islands. In addition to sediment transported by eddies and ambient currents, the possibility of resuspension and subsequent transport of material from the disposal site during storm events is also an expressed concern.

5. The SAJ requested the US Army Engineer Waterways Experiment Station's (WES) Coastal Engineering Research Center (CERC) to perform a technical study of the Gulf Stream, the spin-off eddies, and other relevant environmental forces, with respect to the potentials for reef contamination by dredged material originating from either proposed ODMDS. The CERC was first requested to study the acceptability of the proposed sites offshore of Miami and Fort Pierce. If these sites are not found to be environmentally acceptable, the first acceptable offshore location which does not pose a contamination threat to the reefs should be identified.

6. A preliminary technical review was performed by the CERC (MFR, 9 February 1988) of the available literature provided by SAJ (Memorandum, 4 December 1987). The review concluded that a detailed disposal site evaluation should be performed in order to determine whether velocities in the Gulf Stream and its spin-off eddies are sufficient in magnitude to transport disposed material from the proposed ODMDS onto the coral reefs.

7. The study reported here uses a numerical modeling approach for estimating both short-term and long-term fate of dredged material disposed at a proposed ODMDS. The modeling of the short-term dumping operation is performed by the Disposal From an Instantaneous Dump (DIFID) model (Johnson et al. 1988). Long-term simulations, using a newly developed coupled hydrodynamic/sediment transport model (Scheffner 1988), use depth averaged velocity fields to determine whether non-storm related currents are capable of transporting sediments outside of the designated ODMDS over long periods of time following the initial deposition. The effects of storm erosion are separately examined with the model by simulating the passage of a storm surge over the site.

Scope of Report

8. The purpose of this study is to evaluate the dispersion characteristics of the proposed disposal sites offshore of Miami and Fort Pierce. These two sites were selected as representative of the two primary environments found off the east coast of Florida. The first is typified by the proposed Miami site at which the bathymetry is complex, the water is deep (greater than 500 ft), and the site is directly influenced by the Gulf Stream and its spin-off eddies. Due to the close proximity of the Gulf Stream to the disposal site, it is feared that disposed sediments may be carried onto the coral reefs by spin-off eddies shed by the Gulf Stream.

9. In contrast to the Miami site, the Fort Pierce disposal site is removed from the direct effects of the Gulf Stream, is situated on a broad, gently sloping shelf, and is located in shallow water (less than 75 ft). This ODMDS has a small cross-sectional area of flow compared to that of the Miami site. A comparison of the site characteristics of both the Miami and Fort Pierce ODMDS is given in Table 1.1.

10. This investigation will classify each of the proposed disposal sites as either dispersive of non-dispersive according to whether the local current fields are capable of transporting material from the disposal site onto the reef area. This approach requires documenting the local velocities at each site in order to identify a reef-directed component which may be attributed to the Gulf Stream. This component will be used to compute a sediment transport rate and direction for use in evaluating the possibility of disposal site related reef contamination. The following section represents the result of an extensive literature review which begins with a description of the Gulf Stream and its major characteristics. This portion of the review is included to verify that shoreward directed spinoff eddies do exist and should be investigated as a possible source of sediment transport. This background documentation will be followed by a quantification of velocity magnitudes and directions which are shown to be representative of each site. These velocities will then be used as model input for the short- and long-term stability analyses of Parts II and III.

Table 1.1

Disposal Site Characteristics for Miami and Fort Pierce

Characteristics	Miami	Fort Pierce
Water depth	Greater than 500 ft	Less than 75 ft
Bottom slope	Steep (0.02-0.05)	Mild (0.001-0.002)
Topography	Complex (nonlinear)	Simple (linear)
Terrace	Miami Terrace confined to a 2 mile offshore zone	No terrace zone
Flow cross-section of ODMDS	About 3,168,000 sq ft	About 294,000 sq ft
Continental Margin	Wide	Narrow
Continental	Contains inner, mid, and and outer shelf with sharp shelf break.	Contains inner shelf only
Direction of Velocity	Westerly and northerly	Northerly
Magnitude of velocities:		
westerly	0.15-1.5ft/sec	0.05-0.5ft/sec
northerly	0.7-3.5ft/sec	0.20-1.5ft/sec
Average axis of Gulf Stream	15 miles offshore	80 miles offshore
Coastal currents are primarily driven by	Gulf Stream	Wind and tidal forcing
Gulf Stream Effects	Present	Free
Dredged materials	90% sand (fine to medium)	90% sand (fine to medium)
	10% clay	10% clay

PART I: LITERATURE REVIEW

The Gulf Stream

11. The objective of the literature review is to identify the primary characteristics of the Gulf Stream and quantify its basic structure, magnitude, and limits of influence along the south and southeast coast of the United States. A brief summary of the origin and dynamics of the Gulf Stream is presented in this section as a preliminary background for the present ODMDS selection study as well as for future site selection studies. The terms Gulf Stream or stream are used throughout this section of the report to refer to the entire current system off the south and east coast of the United States, including the Florida Current.

12. Figure 1.3 presents a schematic diagram of the dominant currents and current induced secondary circulation patterns off the east coast of the United States. The origin of the Gulf Stream begins as the Atlantic and North Equatorial Current systems combine with the South Equatorial and Guyana Current systems. This combined flow discharges through the Caribbean Sea and Yucatan Channel into the southeastern portion of the Gulf of Mexico. Because the waters are colder than the surrounding Gulf of Mexico, a density differential is created which results in a deflection of the current from the Gulf of Mexico toward the Straights of Florida. This density driven flow is most pronounced during winter months. During this time, the current is often sharply deflected from the Yucatan Channel through the Straights of Florida as shown in Figure 1.3. However, the loop current can extend well into the Gulf of Mexico during the summer months (Leipper 1967). Regardless of the specific path, the current enters the Straights of Florida in nearly the same temperature, salinity, and density as when it entered the Caribbean Sea (Lee, et al. 1977).

13. The dynamics of the Gulf Stream are driven by the large tides of the Caribbean Sea which dominate the smaller tides of the Gulf of Mexico. These large tides force water through the long channel between the Florida Peninsula and the islands of Cuba and the Bahamas, developing a water level differential of about 2/3 ft (Stommel 1965) between the Gulf of Mexico and

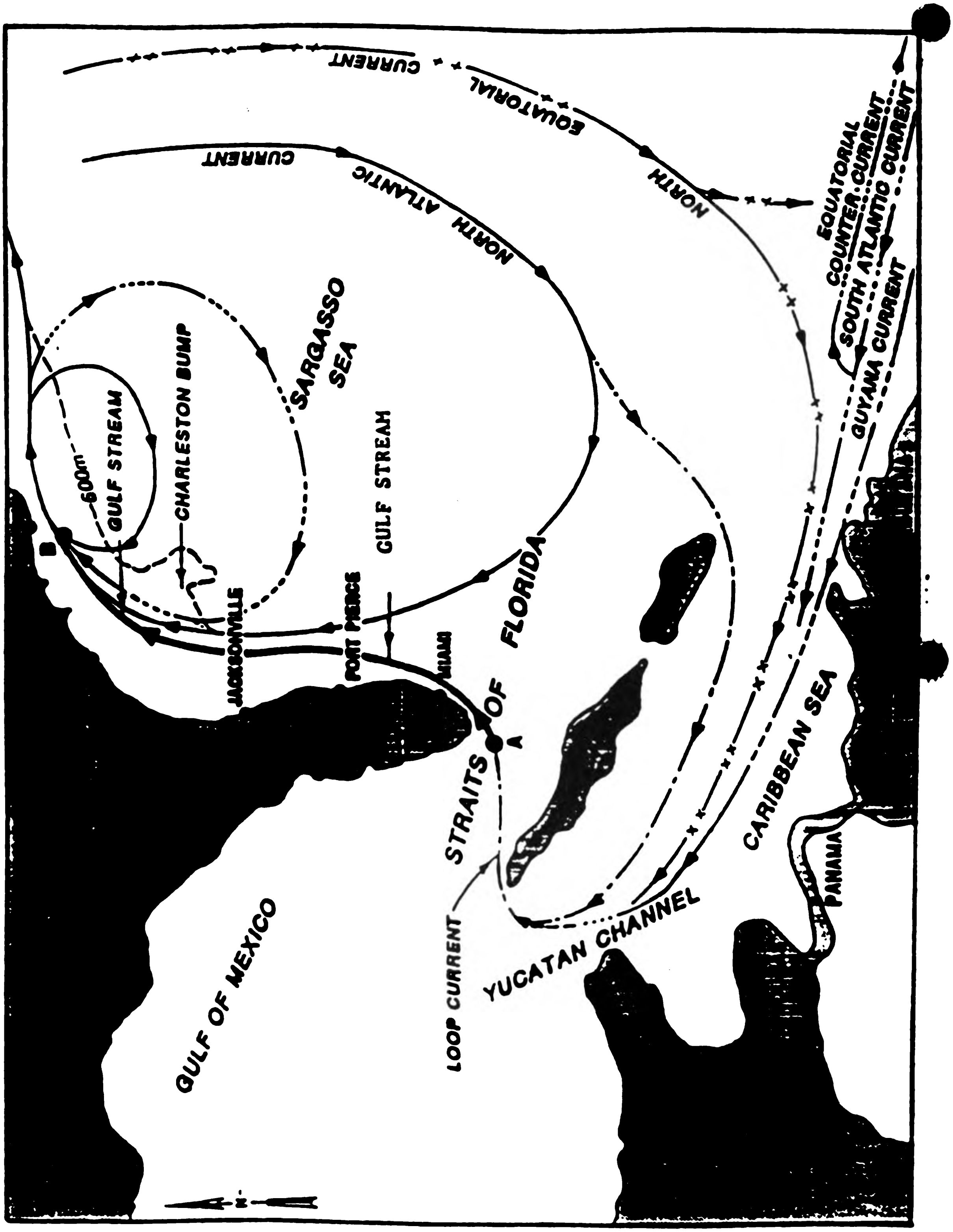


Figure 1.3. A schematic diagram of the origin of the Gulf Stream Current (after Sverdrup, Johnson, Flemming, and Stommel 1965)

the Atlantic Ocean. As the current flows through the Straights of Florida toward Miami, the axis of flow makes an abrupt 90 degree turn to the north and enters the continental shelf channel. The approximate point of deflection is indicated as position A in Figure 1.3. The cross-sectional area occupied by the stream undergoes a change from approximately 90 miles wide and 1 mile deep at Key West to approximately 50 miles wide and 0.5 miles deep in the vicinity of Miami. This reduction in flow area causes an increase in stream velocity with an accompanying decrease in free surface water level between Key West and Miami.

14. The Gulf Stream continues along the south and southeast coast of the United States as shown in Figure 1.3. It is seen that the stream hugs the continental shelf from the deep water region offshore of Miami, north to shallow water depths of less than 100 m at Cape Canaveral. Beyond Cape Canaveral, the stream is diverted into deeper water in the vicinity of the Charleston bump (Brooks and Bane, 1978; Legeckis 1979), a topography anomaly in the continental shelf slope between the 200 and 600 m isobaths. North of the bump, the stream moves back onshore into waters of about 300 m. This offshore shift of the current is primarily due to a steady increase in bottom slope north of Charleston. This increasing slope, coupled with ridge and trough bottom features, prevalent strong northwest winds, and baroclinic instabilities cause the stream to subsequently deflect off the continental shelf and become confined to a path between the 300 m and 400 m isobaths. Position B in Figure 1.3 indicates the approximate location of the offshore point of deflection.

15. The lateral extent of the width of the stream about its average axis is shown in Figure 1.4. This figure, obtained from the National Oceanic and Atmospheric Administration's (NOAA) field station at Miami and reproduced in the Journal of Geophysical Research (1983) represents satellite imagery of the Sea Surface Temperature (SST) structure of the Gulf Stream. The figure demonstrates the variability in width of influence of the Gulf Stream about its mean axis. The following section will investigate the spatial and temporal characteristics of the Gulf Stream.

Figure 1.4. Satellite-derived path of the Gulf Stream (NOAA 1983)

Gulf Stream Meanders

16. The Gulf Stream is a high velocity thermal current which flows along the outer continental shelf. The time-dependent structure of the stream is a function of a combination of forces including the current distribution, bottom topography, wind stress, entrainment of fluid from below the free surface, and rotational forces developed due to the rotation of the earth. The constantly changing spatial and temporal structure of the stream has been widely studied and documented in the literature. Although an attempt to quantify these dynamics are beyond the scope of this report, many of the references used in this literature review to document the characteristics of the Gulf Stream have been included in the list of references. Since this report is intended to determine whether the Gulf Stream can adversely affect either of the two proposed disposal sites, this section begins with a description of commonly observed features which may directly impact either ODMDS.

17. The high velocity main body of the Gulf Stream propagates in wave like patterns referred to as meanders. The dynamic features are a result of forces such as shearing instabilities of the stream, geostrophic imbalances, the transfer of kinetic energy to the mean flow, the passage of cold fronts, the random passage of wind events, etc. Although the mean axis of the stream propagates to the north, these forcings can produce localized undulations about the mean axis which can locally flow either upstream (southerly), downstream (northerly), onshore or offshore.

18. Many documenting measurements quantifying the spatial variation of meanders have been reported. Duing (1975) obtained 2 weeks of current profile measurements off the coast of Miami and identified a current meander with a 4-6 day period which was propagating to the north at approximately 45 cm/sec with a wave length of nearly 200 km. Duing's data showed that when the axis of the Gulf Stream was displaced offshore, southerly flows occurred over portions of the Miami terrace. Conversely, when the axis of the stream was displaced onshore, flows over the terrace were directed to the north. Thermal gradients can be used to measure the primary features of meanders as they grow in size or become skewed. Lee and Moore (1977), for example, have correlated the distribution of meanders with the propagation of SST derived isotherms.

19. Meanders of the stream are commonly observed between Jupiter Inlet and Cape Hatteras where the stream enters the wide continental shelf region after passing through the topographic constriction formed by the Florida coast and the Little Bahama bank. This discharge of water from a confined to an unconfined area results in meanders in the stream axis which are no longer primarily controlled by the continental shelf bathymetry (Lee et al 1981) but are strongly influenced by weather patterns, long waves from the deep sea, tidal forcing, and local wind fields. Northeast of Cape Hatteras, the Gulf Stream moves beyond our area of interest into deep water where they are no longer controlled by continental shelf bathymetry.

20. The meandering process is well illustrated in an example presented by Bane and Brooks (1979) and Bane (1983), shown in Figures 1.5 and 1.6. In Figure 1.5, a 64-week period of SST data are used to show the shoreward and seaward envelope of occupation of the Gulf Stream in relation to the location of the time-averaged mean axis shown by the dashed line. Figures 1.6 uses quarter-period (16-week) incremental plots of the axis to illustrates how two typical meanders (labeled A and B) occupy the shaded limits of the stream as they propagate northward. Table 1.2 lists the basic dimensions of meanders typical of those documented along the south and southeast coasts of Florida.

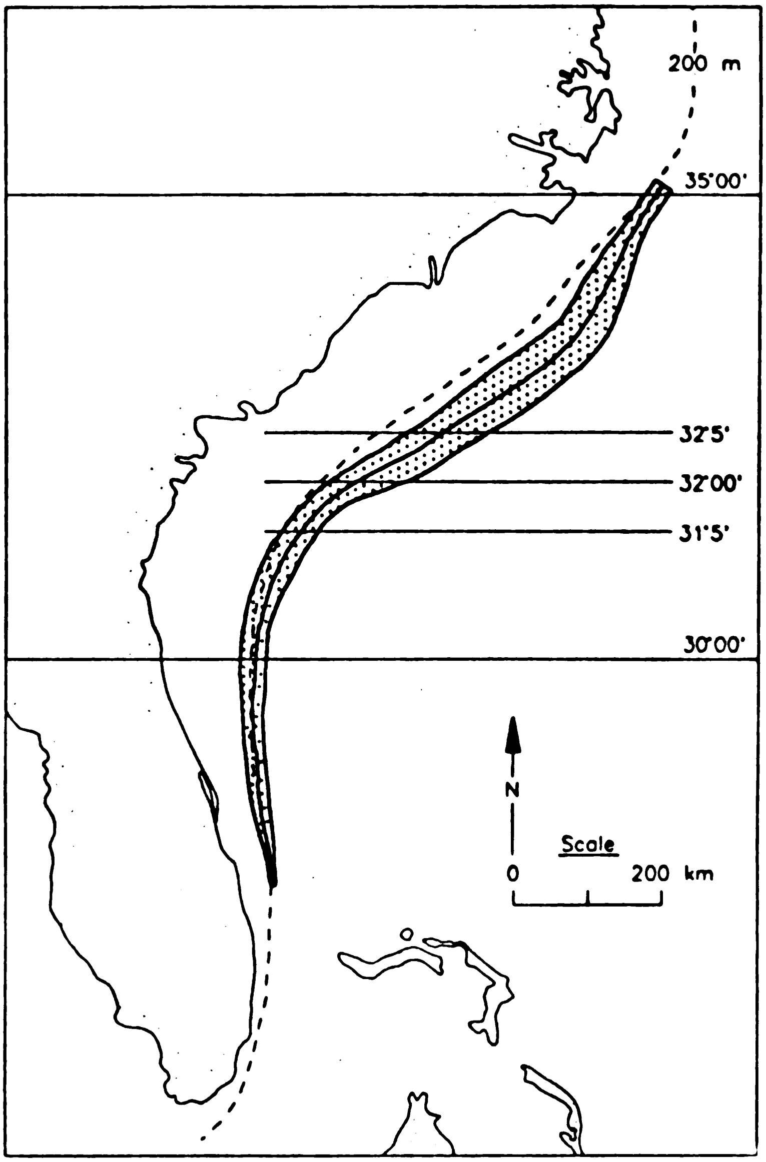


Figure 1.5. Mean position and meander deviation of the Gulf Stream surface (Bane and Brooks 1979)

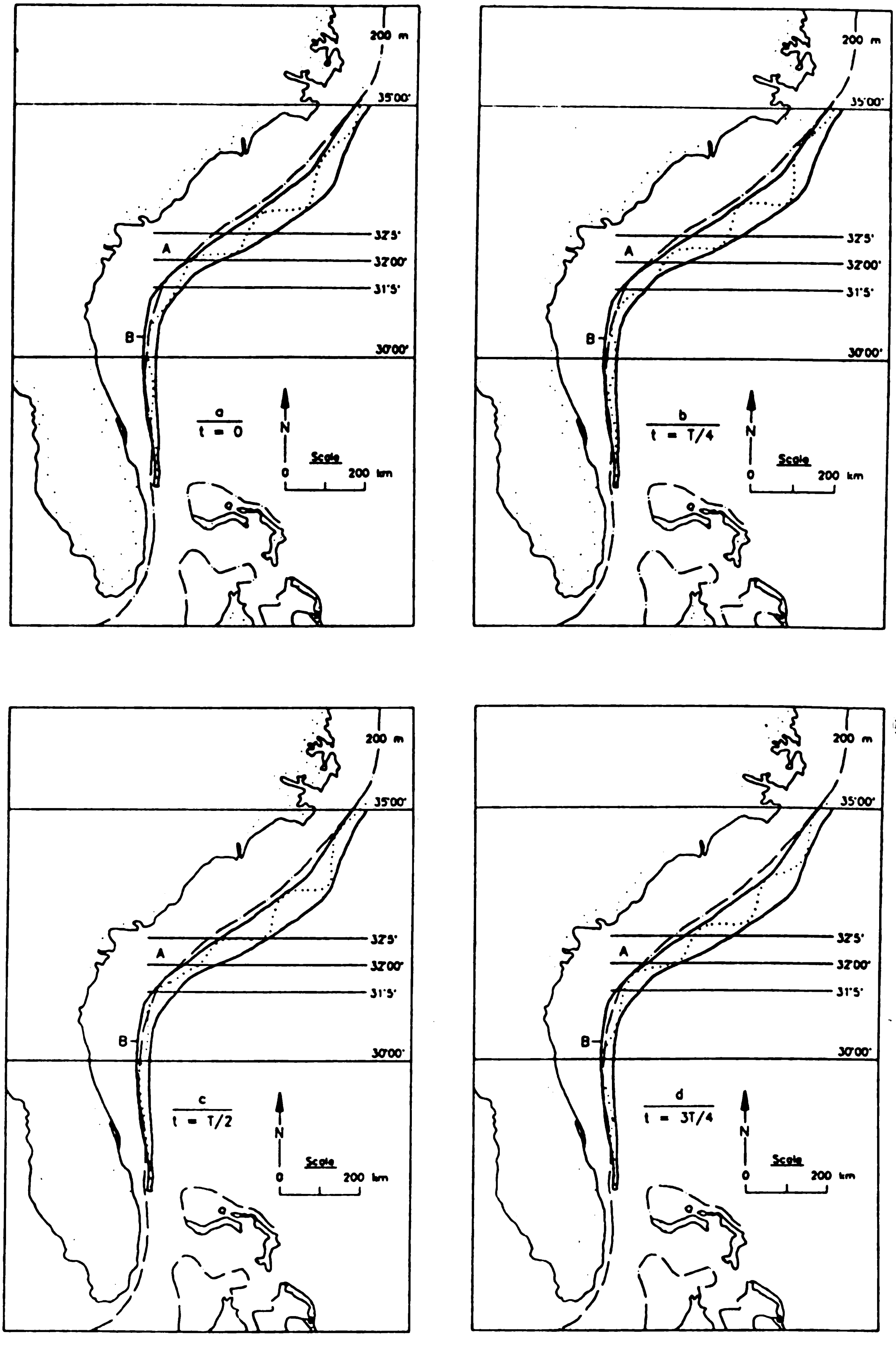


Figure 1.6. Example of the propagation of Gulf Stream meanders at quarter-period snapshots (Bane 1983)

Table 1.2

Basic Dimensions of the Gulf Stream Meanders

Features	Dimensions
Wave length (longitudinal)	90 - 260 km
Lateral displacement (east-west)	1 - 100 km
Average velocity of propagation	47 cm/sec
Maximum downstream current speed recorded	134 cm/sec

Results of this investigation have shown that much of the Continental Shelf area south of Cape Hatteras is subject to the direct influence of the Gulf Stream. Nearshore areas can also be affected by the Gulf Stream even though the area in question may not be directly impacted by the envelope of meanders. The following section will address Gulf Stream eddies in order quantify their potential impact on the proposed Miami and Fort Pierce disposal sites.

Spin-off Eddies

21. The movement of the Gulf Stream through the continental shelf often creates rotational patterns which propagate away from the main body of the Stream. These patterns generally represent unstable meanders which have become detached from the main body of the stream. This can occur if the meander becomes too pronounced or deviates too far from the main axis of flow, in which case, detachment into the low velocity ambient current can be caused by topography anomalies, wind fields, or barotropic instabilities. These detached secondary currents are referred to as spin-off eddies and are commonly observed in the shallow slope and terrace waters (40-80 m) off the coast of Florida. The following sections describe some of their basic characteristics.

22. Richardson (1985) identifies three distinct zones of the Gulf Stream. These are the clockwise rotating onshore eddy, the axis or main body of the Stream, and the counterclockwise rotating offshore eddy. The high velocity axis of the Gulf Stream acts as a barrier separating the onshore and offshore regions. Depending on the environmental conditions, detached onshore eddies can propagate to the north, shoreward, or to the south with short-lived

periods ranging from 2 days to 2 weeks. Eddy diameters range from 10 to km and can extend from the surface to a depth of approximately 200 m (Lee and Mayer 1977). Detached eddies have been observed to propagate with surface velocities ranging from 20 to 100 cm/sec.

23. The above sections of this report have documented the dynamic properties of the Gulf Stream and its spin-off eddies. The data presented indicate that, at times, the Gulf Stream does generate, or contribute to, shoreward directed velocity fields which may affect either or both of the proposed disposal sites. The effects can be compounded when coupled with shoreward-directed flood tide conditions. The magnitude of this total shoreward directed velocity field will be determined from the available data such that a boundary condition velocity field for each ODMDS can be defined as input to the short- and long-term sediment transport calculations. The following sections describe the selection of a maximum shoreward-directed velocity for each of the designated sites based on available prototype data.

Prototype Velocity Data

24. The site designation approach utilizes sediment transport theory and numerical modeling techniques to determine possible magnitudes of erosion and/or transport of sediment from a specified disposal site. The computations are based on a specific depth and background velocity field for each site which will be documented to be representative of the location. The site evaluation approach is inherently conservative in that a constant, maximum-valued, reef-directed velocity is selected as a boundary condition for sediment transport calculations. In reality, the velocity field is continuously fluctuating as a function of tides, wind fields, waves, the Gulf Stream, etc.; therefore, no single representative value is truly descriptive of any location. Also, two measuring periods would yield two different values; however, when the length of data is sufficiently long, the two computations should not vary significantly in magnitude. Data which cover sufficiently long periods of time to satisfy these criteria will be used in determining appropriate boundary conditions.

25. Since maximum values are to be selected, the degree of accuracy achieved by this approach is considered adequate as a basis for reliable

predictions of the dispersion characteristics of a disposal site. If it can be shown, for example, that the prototype velocity in 500 ft of water never exceeds 30 cm/sec (or 40, or 50) and that a velocity magnitude of 100 cm/sec is necessary for initiating and transporting sediment transport at that depth, then the data are adequate to show that the site under investigation is non-dispersive and will not represent a source of contamination. Severe storm conditions are not included in this analysis since it is assumed that disposal operations would be discontinued during storm events.

26. A large data base of published current meter data was identified which was acceptable for quantifying the velocity patterns off the eastern coast of Florida. Data included measurements at multiple depths in the water column for various mooring string sites extending from south of Miami to north of Fort Pierce and from less than 1 km to more than 100 km offshore. Although the spatial distribution of data is sparse in its coverage of the disposal site locations, the data base is adequate for determining a velocity field which is representative of each survey area and can be used to evaluate the transport potential of each disposal site. In the present context, adequacy refers to data which covers a sufficient length of time and number of vertical locations within the water column, that a reliable depth-averaged velocity can be computed.

27. Multiple sources of acceptable velocity data were located for application in the present Miami and Fort Pierce disposal site study. The following sections will use this data, in addition to other available data, to develop a spatially consistent data base of depth averaged velocity vectors. The intent of this multiple station analysis and inter-comparison is to develop velocity vectors which are consistent with surrounding data and are, therefore, truly representative of the area.

Depth Averaged Velocity

28. The site designation approach computes short-term and long-term potentials for sediment transport as a function of a site-specific, depth-averaged velocity field. The depth averaged condition was selected for two reasons. First, due to the limited time available for this study, a representative velocity field had to be defined from existing data. Available data

was sufficient for determining a maximum shore-directed, depth-averaged current but was not adequate in either duration or distribution to define any meaningful vertical velocity distribution trend. Secondly, an "average" vertical distribution probably does not exist, since the vertical velocity structure shows a continuously changing current gradient due to variations in the wave fields, salinity gradients, thermoclines, and Gulf Stream meanders. Also, attempting to compute site-specific sediment movement as a function of a three-dimensional velocity distribution is not feasible. For these reasons, a depth-averaged current was selected for input to both the DIFID and long-term sediment models. The computation of the selected velocity field is described in the following sections.

29. Two examples data sources are used here to demonstrate the computation of a shoreward-directed depth-averaged velocity field. Both sources of data are reported by Lee, Brooks, and Duing (1977). The Miami data was collected as a portion of the SYNOPS 71 (Synoptic Observations of Profiles in the Straights) project. The research vessels Calanus (C), Humble (H), Pillsbury (P), and Gerda (G) simultaneously collected 16 days of vertical profiles of horizontal velocities. These measurements were taken every 3 hours at the four locations between Miami and Bimini shown in Figure 1.7. Ship-deployed measurement stations for the Fort Pierce area are shown in Figure 1.8. These reported data are based on the analysis of multiple data sets, collected at each of the data collection stations over a period of approximately 5.5 years.

30. Velocity measurements for the Miami transects are based on Profiling Current Meter data (PCM). The data were reduced to u (+ to the east) and v (+ to the north) velocity components and then averaged over 5 m depth intervals. Details of the deployment can be found in Lee, Brooks, and Duing 1977, Duing and Johnson 1972 and Duing 1973. Figure 1.9 displays three types of velocity profiles which were constructed from the velocity time series data records for mooring sites C, H, P, and G. These represent the measured maximum, minimum, and mean velocity. The depth averaged value is also indicated in the figure. The minimum u velocity (negative referring to westward) and corresponding v component were used to compute the shore-directed depth-averaged velocity vector indicated by the dotted line.

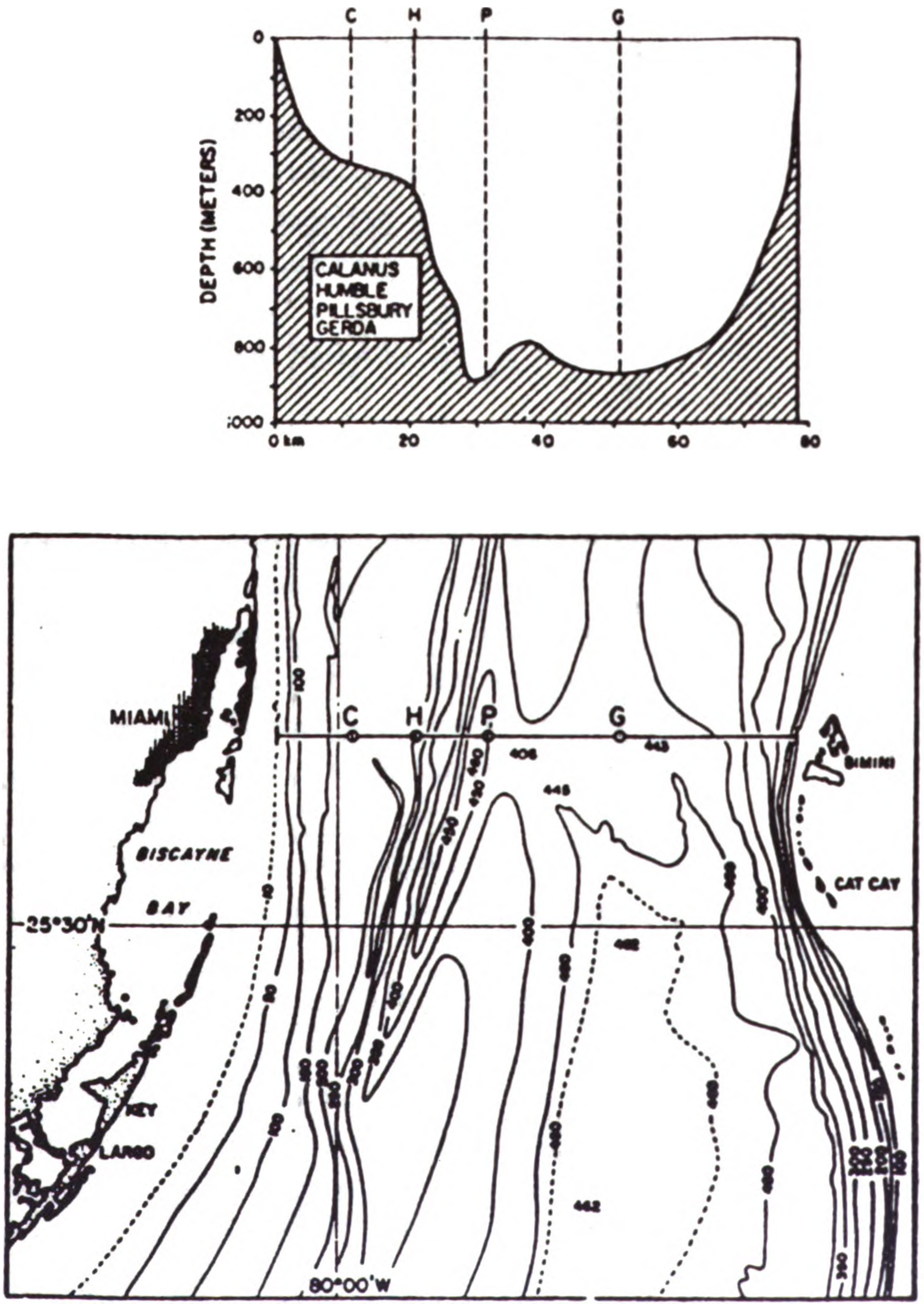


Figure 1.7. Current meter locations for Miami (Lee, Brooks, and Duing 1977)

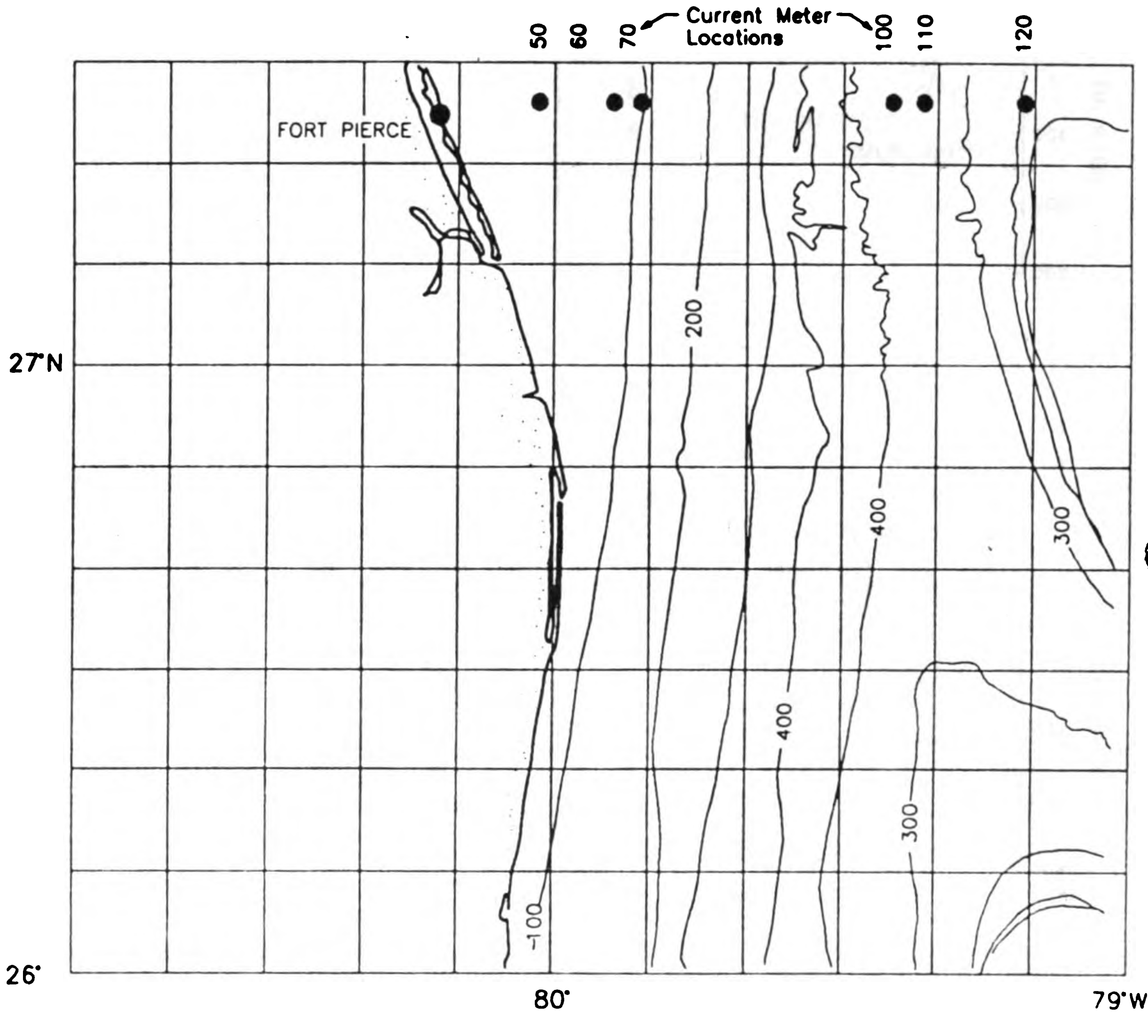


Figure 1.8. Current meter locations for Fort Pierce (Lee, Brooks, and Duing 1977)

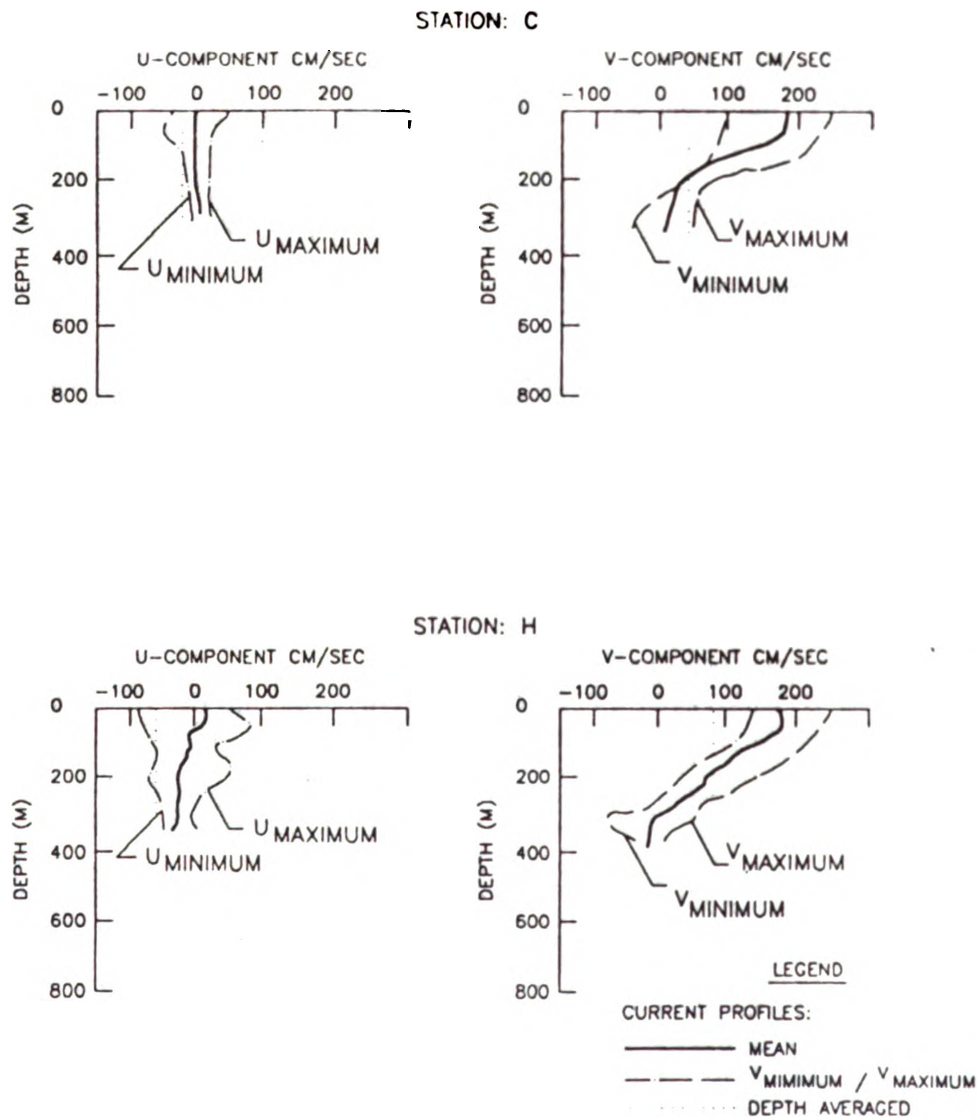


Figure 1.9. Measured velocity profiles offshore of Miami

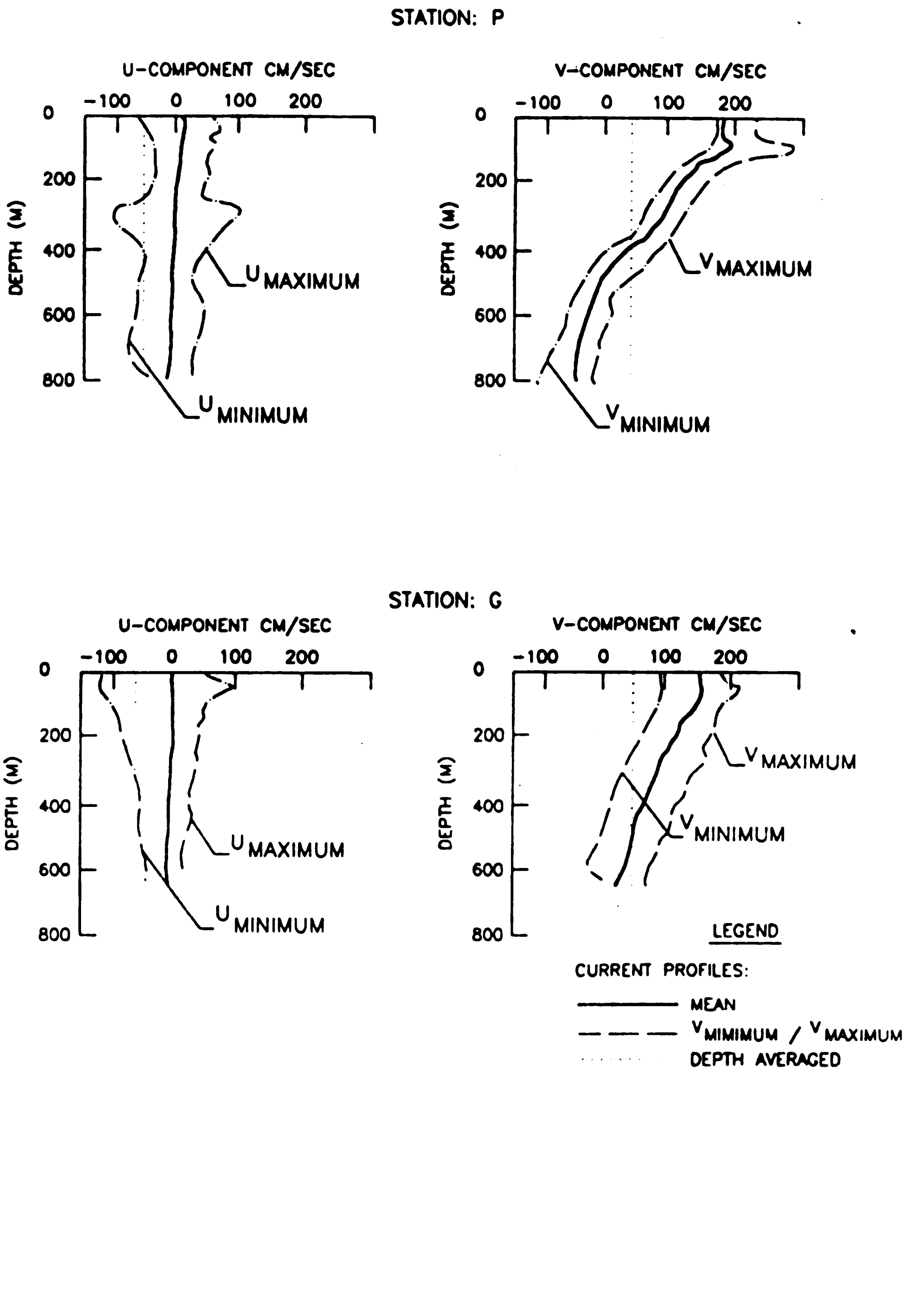
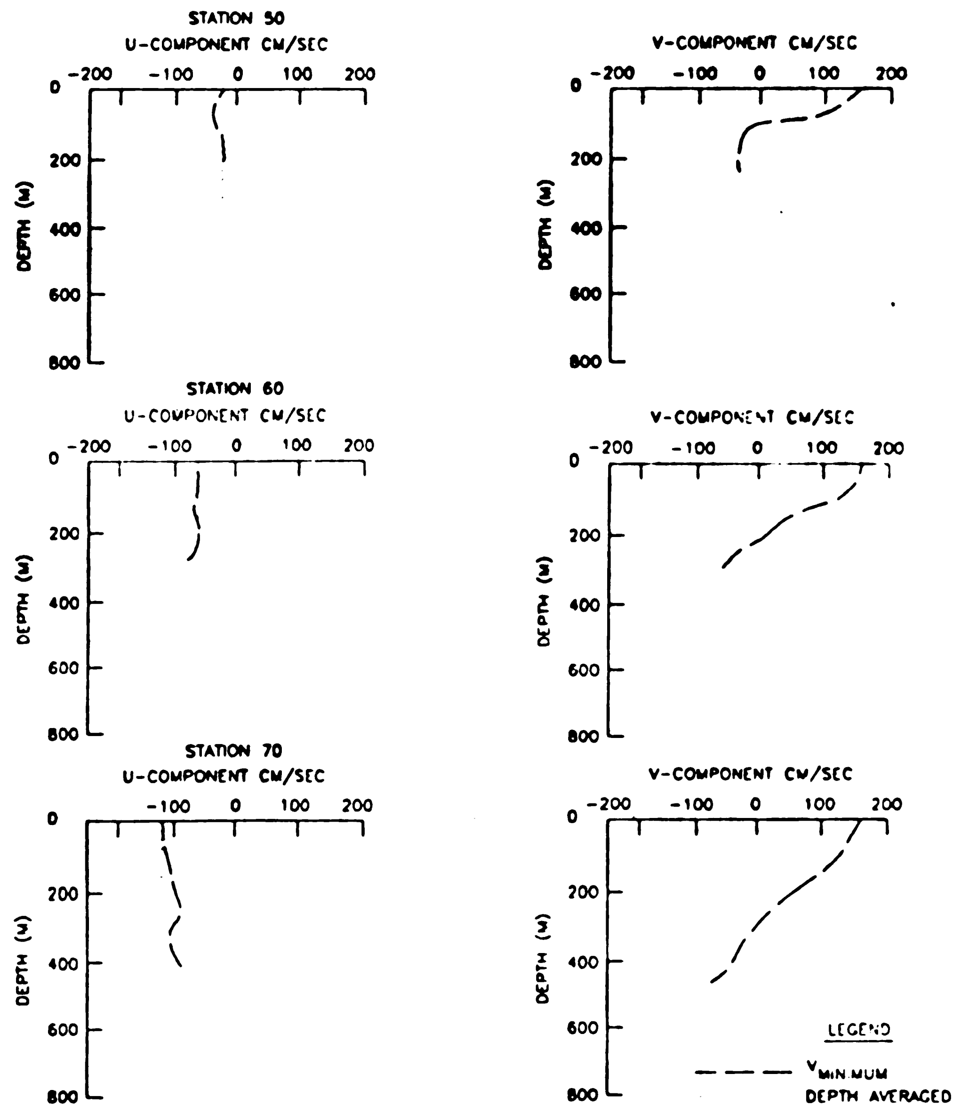


Figure 1.9. (Continued)

31. The Dropsonde data collection method was used to measure the velocity distribution for the Fort Pierce transects shown in Figure 1.8. This technique involves the deployment of multiple Dropsonde instruments which record the vertical distribution of the horizontal velocity field as the instrument descends through the water column. A cubic spline function is then used to compute a vertically averaged velocity vector at 50-m increments throughout the water column. The data set for Fort Pierce is based on 18 days of Dropsonde deployment (Lee, Brooks, and Duing 1977). Details of the measurement technique are reported in Richardson and Schmitz 1965. The minimum (westerly) u , corresponding v , and computed depth averaged values for each of the Fort Pierce stations are shown in Figure 1.10.



Figures 1.10. Measured velocity profiles offshore of Fort Pierce

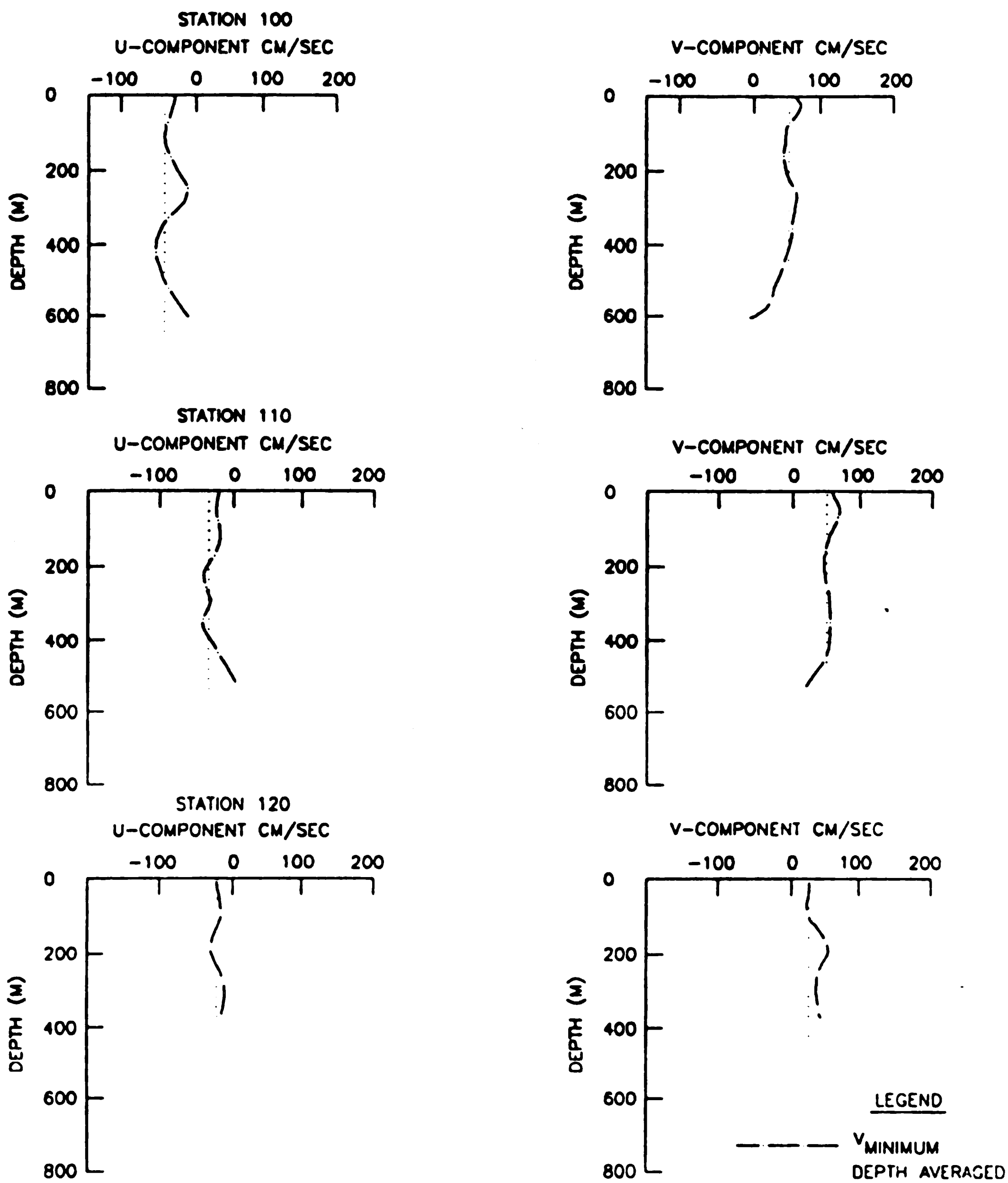


Figure 1.10. (Continued)

32. Available current meter data for all additional locations between Miami and Fort Pierce were similarly analyzed. The purpose was to demonstrate a spatial consistency in depth averaged velocities in order to show that the velocities assigned to each proposed site are representative of their respective locations. Table 1.5 identifies the current meter stations, coordinates, and depth-averaged u and v velocity components for all gage locations identified in the literature review.

Table 1.5

Current Meter Locations and Depth Averaged Velocities

Current Meter Stations	Latitude (North)	Longitude (West)	Eastward Velocity cm/sec	Northward Velocity cm/sec	Vector cm/sec	Direction (from north) degs
Lee, Brooks, and Duing 1977 Miami(Spring)						
10	25 32.0	80 3.0	17.5	55.5	58.2	342
20	25 31.0	80 0.0	12.2	45.3	46.9	345
30	25 32.0	79 57.1	7.1	66.8	67.2	354
40	25 32.0	79 54.1	8.2	59.7	60.3	352
50	25 32.0	79 51.1	22.6	26.9	35.2	320
[illegible]	25 32.0	79 48.1	21.2	50.8	55.0	337
70	25 32.0	79 42.1	12.5	54.9	56.3	347
80	25 32.0	79 36.2	21.3	43.5	48.4	334
90	25 32.0	79 30.2	19.1	34.2	39.2	330
100	25 32.2	79 24.2	20.4	23.4	31.1	319
110	25 32.2	79 21.2	22.7	26.3	34.8	319
120	25 32.2	79 19.5	24.5	20.9	32.2	310
130	25 32.2	79 17.1	35.3	20.4	40.8	300
Lee, Brooks, and Duing 1977 Miami						
C	25 45.0	79 59.0	25.6	20.4	49.3	343
H	25 45.0	79 52.5	29.3	44.7	53.4	327
P	25 45.0	79 47.0	21.2	50.8	55.0	337
G	25 45.0	79 36.0	24.0	58.8	63.5	328
10	25 44.5	80 3.0	14.5	47.0	49.3	343
20	25 44.5	80 0.0	25.6	20.4	32.8	309
30	25 44.5	79 57.0	29.0	5.3	29.4	280
40	25 44.5	79 54.0	31.4	14.0	34.4	294
50	35 44.5	79 51.1	29.3	44.7	53.4	327
60	25 44.5	79 48.1	25.2	12.4	28.1	296
70	25 44.5	79 42.1	26.3	57.1	63.0	335
80	25 44.5	79 36.1	24.0	58.8	63.5	338
90	25 44.5	79 30.1	23.4	35.8	42.8	327
100	25 44.5	79 19.4	13.5	26.8	30.0	333
100	25 44.5	79 27.1	15.2	38.9	41.8	339

110	25 44.5	79 24.1	12.1	43.3	45.0	344
120	25 44.5	79 21.2	16.2	43.5	46.4	340
130	25 44.5	79 19.4	13.5	26.8	30.0	333
Lee, Brooks, and Duing 1977 Miami Bal Harbor						
10	25 51.0	80 5.7	21.0	46.0	50.6	335
20	25 51.0	80 4.5	18.0	46.0	76.2	346
30	25 51.0	80 1.6	21.5	28.8	35.9	323
40	25 51.0	79 58.6	32.6	3.8	32.8	276
50	25 51.0	79 56.1	30.5	1.8	30.6	275
60	25 51.0	79 53.6	37.8	43.0	57.3	319
70	25 51.0	79 51.1	36.2	64.0	73.5	330
80	25 51.0	79 47.4	29.4	24.1	38.0	309
90	25 51.0	79 41.0	21.1	44.8	49.5	335
100	25 34.6	79 34.6	19.6	44.0	48.2	336
110	25 51.0	79 28.3	10.1	33.0	34.5	343
120	25 51.0	79 21.2	12.1	14.0	14.8	305
130	25 51.0	79 17.8	12.3	6.0	13.7	296
Lee, Brooks, and Duing 1977 Near Miami						
R	25 50.7	80 05.0	31.0	72.4	78.9	337
R2	25 50.9	80 4.3	34.8	79.0	86.3	334
R3	25 51.0	80 3.3	29.1	10.5	30.9	290
R5	25 51.1	79 57.3	41.2	20.4	45.0	296
R6	25 51.1	79 51.1	52.4	17.5	55.3	289
N1	25 51.2	79 47.4	25.1	55.0	60.5	336
N2	25 50.9	79 22.0	5.0	5.0	7.1	315
R7	25 34.5	80 04.0	26.2	57.4	63.1	336
R9	26 8.9	80 3.7	18.2	55.5	58.4	342
R10	26 23.0	80 1.8	28.7	55.4	62.4	333
Lee, Brooks and Duing 1977 Fort Pierce						
40	27 26.0	79 53.7	21.3	78.0	80.8	345
50	27 26.0	79 50.7	12.6	31.0	33.5	338
60	27 26.0	79 47.6	32.5	69.8	77.0	335
70	27 26.0	79 44.6	17.6	86.4	88.2	349
80	27 26.0	79 38.5	7.7	100.0	100.2	356
90	27 26.0	79 32.5	10.4	74.5	75.2	352
100	27 26.0	79 26.4	28.5	48.8	56.5	330
110	27 26.0	79 20.3	29.0	49.5	57.4	330
Leaman and Vertes 1982 Near Jupiter Inlet						
1	27 01	79 52	11.8	91.2	92.0	353
2	27 01	79 48	7.9	103.6	103.9	355
3	27 01	79 42	2.9	106.8	106.9	359
4	27 01	79 38	27.9	96.2	100.4	344
5	27 01	79 31	2.3	79.8	78.9	358
6	27 01	79 25	11.8	65.0	66.0	350
7	27 01	79 18	11.1	70.0	70.9	351
8	27 01	79 12	10.5	45.4	46.7	347

Richardson, Schmitz, and Niiler 1969 Cape Kennedy

S[illegible]5	28 20	80 06	16.2	33.5	37.2	334
	28 20	79 58.5	19.0	51.8	55.2	339
	28 20	79 52.5	16.3	75.0	77.0	348
	28 20	79 33	18.0	80.7	82.0	347
	28 20	79 07	31.7	33.5	46.1	317

Lee et al 1986 Ponce De Leon Inlet

1	26 58.0	79 56.8	17.2	58.2	60.6	344
2	27 29.9	79 59.1	19.9	75.1	77.7	345
3	28 00.2	79 59.8	19.2	22.1	29.0	345
4	28 58.2	80 39.2	5.7	44.8	45.0	353
5	29 00.7	80 21.7	15.1	44.6	47.0	341
6	29 00.0	80 08.2	25.5	52.9	58.7	334
7	29 00.2	80 02.2	23.5	35.4	42.5	327
8	29 03.9	79 50.9	11.7	39.3	41.0	344
9	29 00.2	79 00.2	27.1	11.1	29.3	293
10	29 00.1	79 07.5	16.8	20.4	26.1	320
11	30 00.6	80 16.3	20.7	53.4	57.3	339

Lee and Atkinson 1983 Near St. Augustine Inlet

4	29 10.0	80 10.0	20.0	6.0	20.9	287
5	29 30.0	80 30.0	14.0	14.0	19.8	315
6	29 30.0	80 20.0	12.0	75.0	76.0	351
9	30 00.0	80 30.0	30.0	28.1	41.1	313
10	30 00.0	80 20.0	35.0	75.0	82.8	345
[illegible]	30 40.0	80 15.0	18.0	10.0	20.6	300
1[illegible]	30 50.0	80 10.0	10.0	8.0	12.8	307
25	32 30.0	78 30.0	30.0	15.1	33.5	297

Lee and Waddel 1983

A	30 00.0	80 15.0	20.2	31.4	37.3	327
B	30 00.0	79 40.0	32.2	1.2	32.3	270
C	30 00.0	79 20.0	19.6	5.4	20.4	286
D	30 00.0	78 10.0	20.4	26.6	33.5	323
E	30 00.0	77 00.0	26.0	34.4	43.6	323

Williams and Lee 1987

A1	28 35.8	80 31.2	5.2	60.3	60.5	355
A2	28 37.9	80 21.2	14.3	46.3	48.5	343
B1	29 53.6	81 14.9	2.8	12.0	12.3	347
B2	29 57.8	81 1.2	4.2	34.0	34.3	353
C1	31 1.1	81 16.6	5.6	15.0	20.0	340
C2	30 57.2	80 56.1	4.9	31.5	31.9	351

33. The velocity data presented in Table 1.5 are shown in vector f[illegible] in Figure 1.11 for the lower east coast (Miami to Fort Pierce) and Figure 1.12 for the upper east coast. At Miami the mainstream vectors are directed toward the shore due to the combined effects of a complex bathymetry and the approximate 90 degree northerly deflection of the Gulf Stream at Miami. Flow is generally directed to the north at Jupiter Inlet and Fort Pierce, as demonstrated by the vectors at these two locations. This uniform orientation is partially due to the fact that the offshore topography at Jupiter Inlet and Fort Pierce is smooth and mild in gradient across the entire continental shelf (Lee and Atkinson 1983). In addition to the mild bathymetry and shallow water depth, the area is relatively free from the direct influence of the Gulf Stream.

34. The velocity data presented in Table 1.5 and shown in Figures 1.11 and 1.12 were analyzed to produce summary velocity vectors at 2 mile intervals across transects offshore of Miami and Fort Pierce. The proposed disposal site locations are each located approximately 4 miles offshore. Tables 1.6 and 1.7 present these vector data along with the corresponding distance offshore, water depth, and bottom slope. The results presented in Tables [illegible] and 7 are shown in vector form in Figures 1.13 and 1.14.

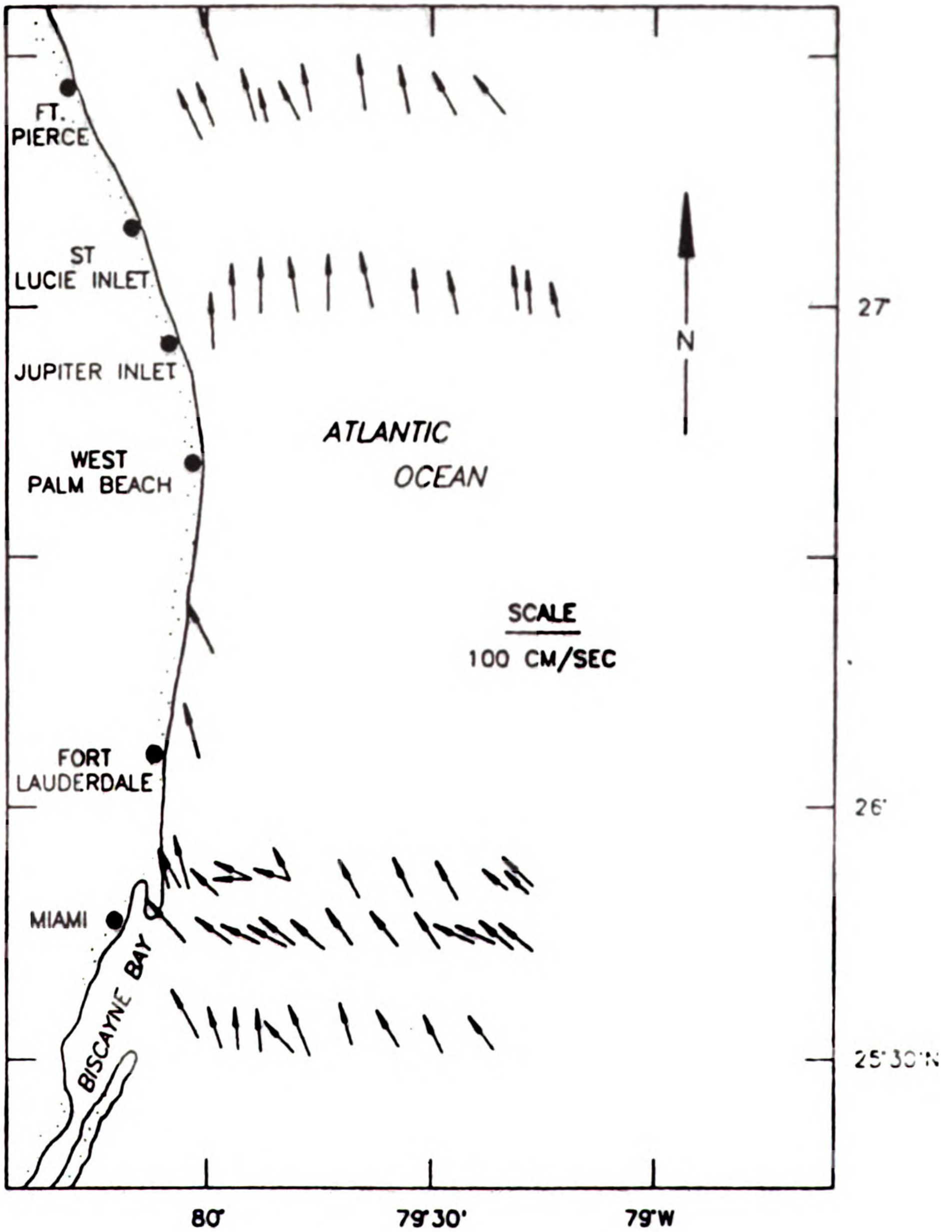


Figure 1.11. Depth-averaged current vectors from Miami to Fort Pierce

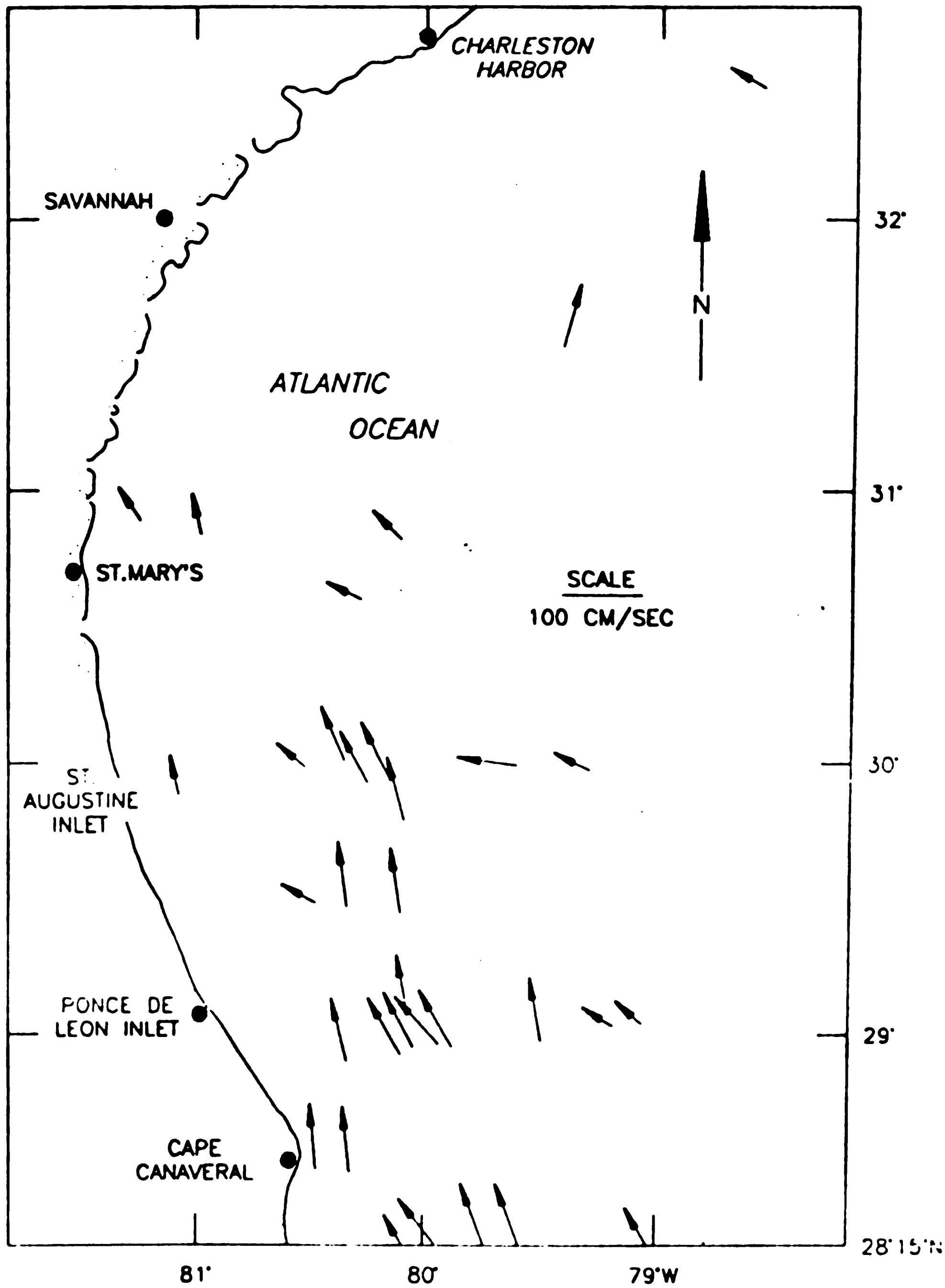


Figure 1.12. Depth-averaged current vectors north of Fort Pierce

Table 1.6

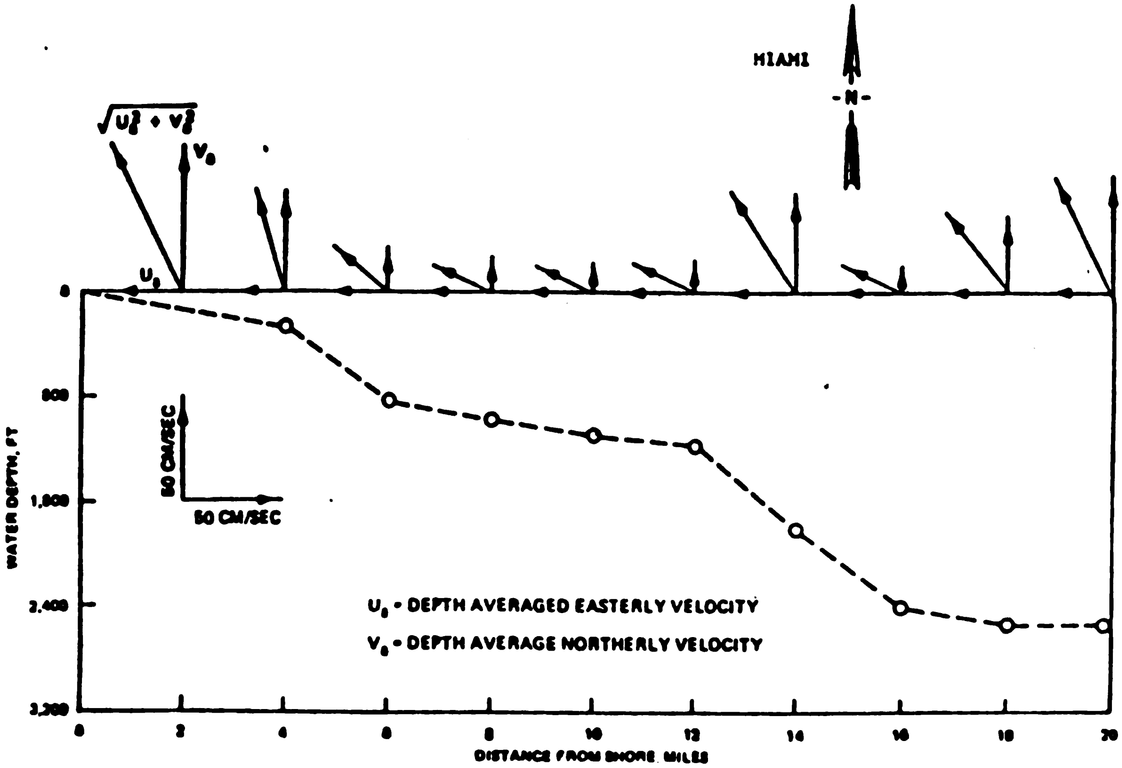
Velocity Distribution Offshore of Miami

Distance miles	Depth ft	Slope	U cm/sec	V cm/sec	Magnitude cm/sec	Direction Degrees "N"	Remark
2	24	0.0222	34.4	71.9	79.7	335.	Too shallow to dump
4	258	0.0222	14.4	47.0	49.3	343.	
6	834	0.0545	25.6	20.4	32.8	309.	
8	960	0.0119	27.3	12.9	30.2	295.	
10	1092	0.0125	30.2	9.7	31.7	288.	
12	1152	0.0057	31.4	14.0	34.4	294.	
14	1800	0.0670	29.3	44.7	53.4	327.	
16	2400	0.0568	25.2	12.4	28.1	296.	
18	2562	0.0153	26.3	34.8	43.6	323.	
20	2568	0.0006	26.2	57.1	63.0	335.	

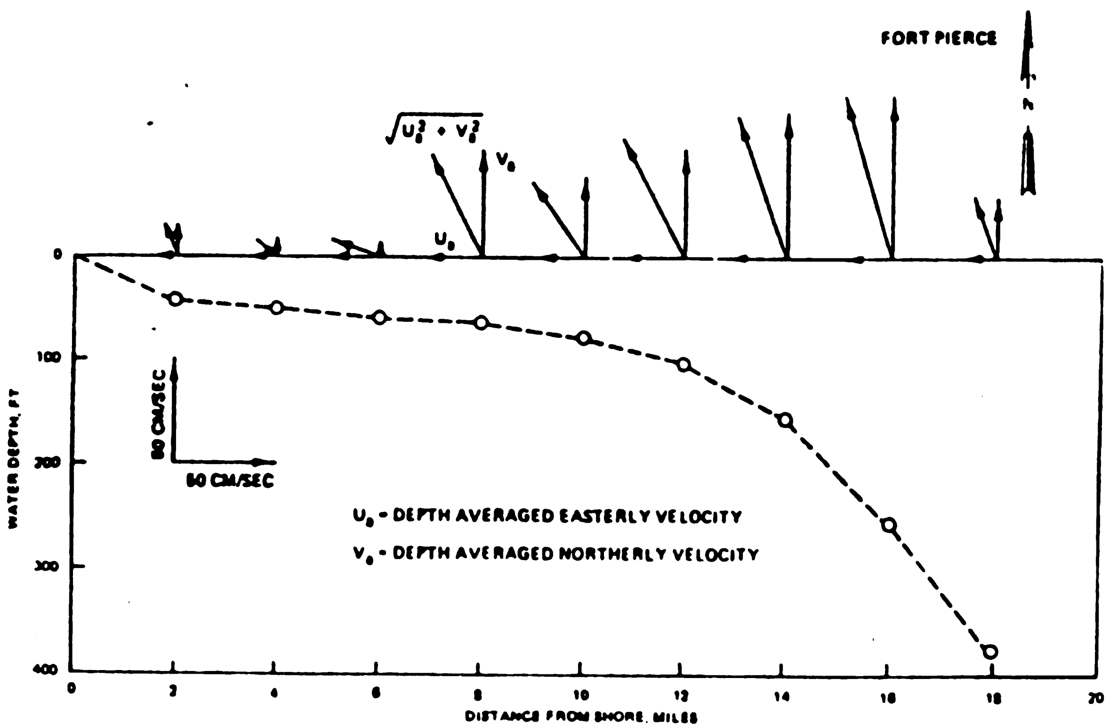
Table 1.7

Velocity Distribution Offshore of Fort Pierce

Distance miles	Depth ft	Slope	U cm/sec	V cm/sec	Magnitude cm/sec	Direction Degrees "N"	Remark
2	32	0.0021	5.6	15.0	16.0	340.	Too shallow to dump
4	43	0.0010	10.0	8.0	12.8	308.	
6	50	0.0009	20.0	6.0	20.9	287.	
8	60	0.0009	25.5	52.9	58.7	334.	
10	63	0.0003	23.5	35.4	42.5	326.	
12	77	0.0013	28.7	55.4	62.4	333.	
14	102	0.0024	25.0	66.7	71.2	339.	
16	155	0.0050	21.3	78.0	80.85	345.	
18	255	0.0095	12.6	31.0	33.5	338.	
20	376	0.0115	32.5	69.8	77.0	335.	



Figures 1.13. Velocity vector distribution offshore of Miami



Figures 1.14. Velocity vector distribution offshore of Fort Pierce

Velocity Field Input Data

35. The short-term DIFID model and the long-term sediment transport model require a velocity field boundary condition for each site in order to calculate sediment transport. The velocity fields for driving the long-term simulations were based on an approximate average of the 2, 4, 6, and 8 mile offshore values for the Miami and Fort Pierce data shown in Tables 1.6 and 1.7. Values of 50 cm/sec (1.64 ft/sec) for Miami and 30 cm/sec (0.98 ft/sec) for Fort Pierce were used. In order to account for short-term velocity fluctuations about the selected long-term values, the approximate maximum of the inner 8-mile values shown in Tables 1.6 and 1.7 were selected for the short-term simulations. Values of 85 cm/sec (2.79 ft/sec) and 60 cm/sec (1.97 ft/sec) were adopted for the Miami and Fort Pierce sites. The corresponding angles of orientation (measured clockwise from true north) for the velocity vectors are approximately 320 and 317 degrees for Miami and Fort Pierce.

36. The depth averaged non-storm related velocity field approach for analyzing the stability of each proposed ODMDS was used to analyze sediment dispersion during dumping and to investigate long-term erosion resulting from normal meteorological conditions. However, storm-induced erosion of an existing mound may initiate sediment transport which may adversely impact the reefs when normal long-term conditions would not. For this reason, a storm-related velocity field was selected for simulation with the long-term model.

37. Peak velocities for a storm event were based on prototype observations during hurricane David. Smith (1982) investigated the influence of this hurricane on the continental shelf waters off south Florida north of Fort Pierce Inlet. On 3 September 1979 hurricane David passed over an inner and middle shelf prototype data collection area near Fort Pierce, producing a record water level at the Fort Pierce inlet. Bottom pressure fluctuations recorded on the inner shelf indicated a storm surge of approximately 3 ft above the normal high water mark with a corresponding current of over 2.7 ft/sec. Based on these prototype velocity data, a numerical model input velocity of 6 ft/sec for Miami and 4 ft/sec for Fort Pierce were used in the long-term sediment transport model to simulate storm effects at the respective sites.

Upwelling and Downwelling

38. All prototype velocity data obtained in the literature review represent horizontal velocities and all numerical modeling efforts are depth averaged; therefore, vertical transport of sediments are not addressed in the present approach. This section of the report briefly investigates the occurrences of upwelling and downwelling in the vicinity of the Gulf Stream as a possible source of transport of dredged material from the disposal site onto the reefs. During upwelling, the deep waters are brought into the euphotic zone (water depth less than 50 m) along the outer continental shelf (Lee et al 1981). The intent of this section is to determine whether these vertical currents are adequate to erode and transport sediment.

39. The precise origin of upwelling and downwelling appears unclear; however, it is suspected that they are a response to the movement of the Gulf Stream (Smith 1983). Upwelling and downwelling events have been observed in the vicinity of meander crests (Brooks and Bane, 1983) and have been correlated with wind stress forcings which contribute to the formation of meanders. Green (1944) documented an upwelling event off Daytona Beach which was associated with southerly winds during July and August. Brooks and Mooers (1977) investigated the relationship between wind fields and upwelling and downwelling offshore of Miami. They concluded that southerly winds cause upwelling while northerly winds produce downwelling on both side of the Stream axis. The purpose of this section is to review the available literature and document the magnitude of the vertical velocity w associated with an upwelling event in order to assess its potential for transporting sediment.

40. Lee and Atkinson (1983) documented upwelling velocities associated with a frontal eddy to be on the order of 0.01 cm/sec based on the measured movement of an isotherm associated with an upwelling event. They also estimated w by using vorticity conservation principles and calculated a value of 0.014 cm/sec. Osgood et al. (1987) used surface floats and current meter data to compute a value of 0.048 cm/sec for a time series of data from a documented event. A summary of reported upwelling velocity magnitudes reported by Osgood et al. (1987), is shown in Table 1.8.

Table 1.8

Summary of Upwelling Related Velocity Calculations
(Osgood et al. 1987)

Researchers	Method of Calculation	Depth of Calculation (m)	w cm/sec
Lee and Atkinson (1983)	tracking an isotherm	50	0.010
Lee and Atkinson (1983)	vorticity conservation	50	0.014
Chew et al. (1985)	tracking an isotherm	28-45	-0.010
Chew et al. (1985)	thermal wind balance	200	0.100
Rossby et al. (1985)	Rafos floats	500	0.100
Levine et al. (1986)	Swallow float	400	0.080
Osgood et al. (1987)	Heat equation	219	0.048

41. The results of this brief examination indicate that vertical velocities during an upwelling event are on the order of 0.1 cm/sec. As a sediment transporting mechanism, velocities of this magnitude are not considered significant with respect to horizontal velocities on the order of 30 to 40 cm/sec. Any possible transport by these vertical velocities would be insignificant in comparison to sediment transported by the horizontal velocity field. The following sections will, therefore, address sediment transport as a function of only the horizontal velocity fields previously described.

PART II: THE SHORT-TERM SIMULATION OF DISPOSAL OPERATIONS

42. Section II of this report investigates the short-term fate (less than a day) of dredged material at the proposed Miami and Fort Pierce disposal sites. The analysis approach will determine whether the combined effects of the local topography at the site and the depth-averaged velocity field developed in Section I, impact the effectiveness of the dredged material disposal operation. Can the dredged material be physically placed within the designated ODMDS limits as the material descends through the water column to the ocean floor or are the local currents of sufficient magnitude to transport material from the disposal vessel onto sensitive coral reefs? If the dredged material can not be confined within the designated ODMDS limits, then an alternate site further offshore should be evaluated for site designation.

43. The short-term site evaluation phase is made by numerically modeling the disposal operation using the DIFID numerical model. Theory and background of the model are reported in Johnson and Holliday (1978), Johnson (1987), and Johnson, Trawle, and Adamec (1988). The model computes the time history of a single disposal operation from the time the dredged material is released from the barge until it reaches equilibrium on the ocean floor. The DIFID model separates the dumping operation into three distinct phases. In the first phase, material released from the bin is assumed to form a hemispherically shaped cloud which descends through the water column under the influence of gravity. This phase is called the convective descent phase. In shallow water, such as the Fort Pierce site, this can be completed within a few seconds of the initial dump. In deep water, such as the Miami site, this time can be greater than 3 minutes. The increased descent time is due to both the greater depth and to a corresponding loss of momentum of the released material as it travels through the water column.

44. The cloud of material continues to descend through the water column until it either impacts the bottom or has reached a stable point of neutral buoyancy. In either case, the horizontal spreading of material marks the end of the descent phase and beginning of the dynamic collapse phase. If the disposal load is primarily composed of non-cohesive material, this phase may simply represent a settling and consolidation of the sediment into a mound; however, if the load contains cohesive sediment, a combination of buoyanc and

suspension may occur in which the cloud of suspended sediment may be transported a considerable distance from the point of disposal.

45. When the rate of horizontal spreading in the dynamic collapse phase becomes less than the spreading rate due to turbulent diffusion, the material begins the final transport-diffusion phase. The termination of this phase marks the end of the short-term investigation. The resulting post-disposal sediment mound represents the initial boundary condition for the long-term transport computations to be described in Section III. An idealization of all three phases of the short-term disposal are shown in Figure 2.1

Input Data Requirement

46. The DIFID model requires site-specific input data in order to quantitatively predict the short-term fate of sediment released during a disposal operation. Input data include the characteristics of the dredge, a description of the local environment to include the local depth and velocity field, and a knowledge of the characteristics of the dredged material. In addition, certain modeling parameters and coefficients must be specified. A brief description of these input parameters is presented here.

47. The primary goal of the short-term modeling effort is to determine whether disposed material could be transported from the disposal site onto the reefs. Since the potential for reef contamination increases with increasing volumes of material in the water column, a conservative approach was adopted in which a large capacity dredge was specified for model simulation. The selected dimensions shown in Table 2.1 are representative of the largest instantaneous dumping type dredge anticipated by SAJ (Tapp, 1988) to be involved with the Miami and Fort Pierce dredging operation. A dredge of these dimensions was, therefore, used for both the Miami and Fort Pierce simulations.

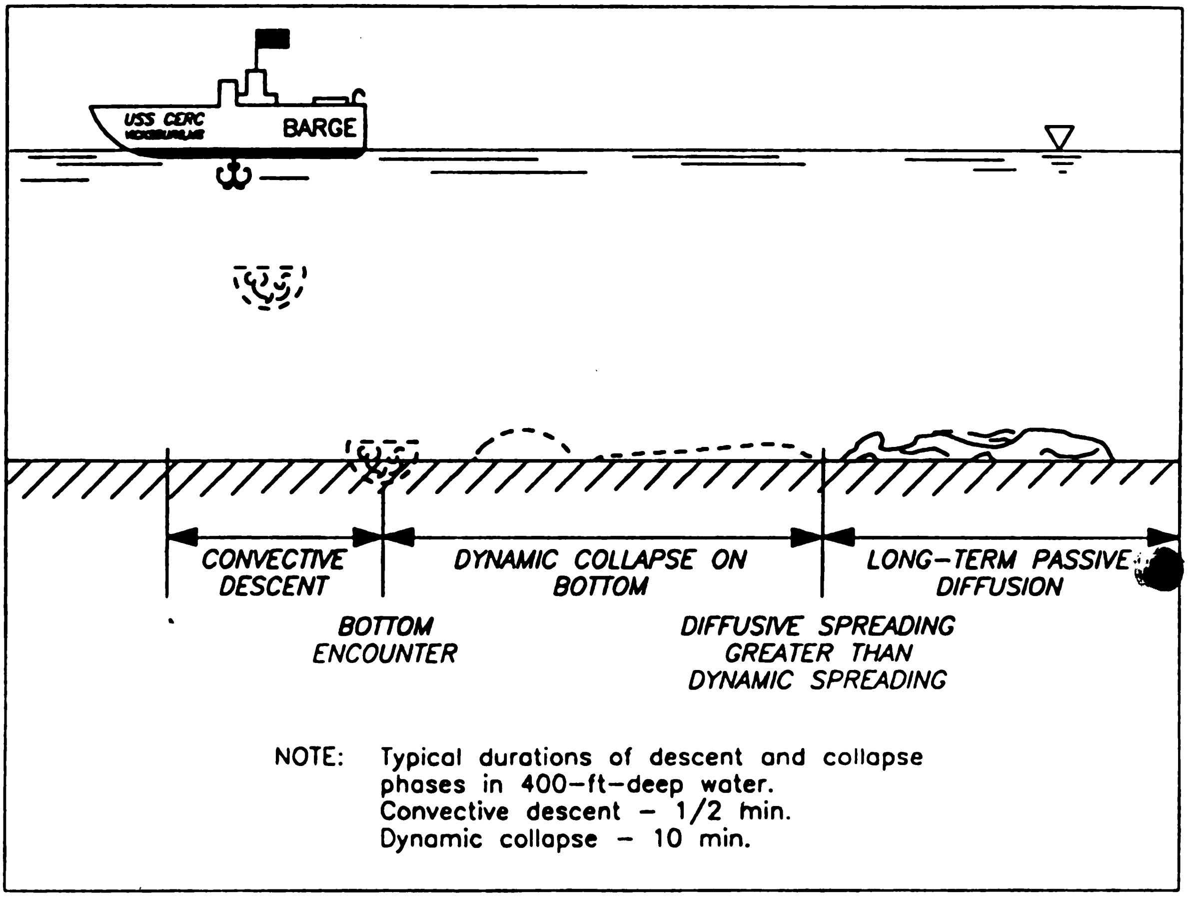


Figure 2.1. Computational phases of the DIFID model (from Brandsma and Divorky, 1976)

Table 2.1

Instantaneous Dredge Capacities and Dimensions

Overall length	236 ft
Beam length	53 ft
Depth of container	21 ft
Opening width of bin	12 ft
Unloaded draft of vessel	3.9 ft
Loaded draft of vessel	19.7 ft
Volume	4000 cu yds
Capacity	5400 tons

The location maps shown in Figures 1.1 and 1.2 show the disposal site environment for Miami and Fort Pierce.

48. The Miami site is located in deep water with bathymetry contours between approximately 400 and 750 ft. A depth of 400 feet, corresponding to the shoreward limit of the designated site, with a bottom slope of 0.0658 was specified for the simulations. An examination of bathymetry at the Fort Pierce site indicates that the water depth varies between approximately 40 and 54 ft.

49. The DIFID model computes the convective descent of a cloud of sediment from the bottom of the loaded dredge through the water column. In order to properly model the descent phase, the total water depth must be greater than the loaded draft of the dredge plus the computed radius of the released sediment cloud. The specified dredge dimensions used for both site simulations required a minimum of 60 ft of depth. The shallower depth at Fort Pierce produced unstable results because the sediment cloud corresponding to the 4000 cu yd load did not have a chance to complete the convective descent stage. The choice of utilizing the 60 ft depth for the Fort Pierce simulations was selected over the option of specifying a smaller capacity dredge. This is not a severe assumption considering that depths of almost 55 ft are representative of that site. A bottom slope of 0.0 was specified.

50. Depth-averaged velocities of 2.79 ft/sec (85 cm/sec) for the Miami site and 1.97 ft/sec (60 cm/sec) for the Fort Pierce site were selected as input to

the DIFID model. The angles of orientation of the velocity vectors for the Miami and Fort Pierce sites is 320 and 317 degrees, measured clockwise from magnetic north. The simulations performed in this section are relative to this axis.

51. Additional input required for the DIFID model include specifying the composition of the material in the dredge. Normally, the dredged material is composed of a solid fraction (rock, sand, clay, etc.) and a fluid component. Each component must be defined according to its respective density, concentration by volume (component percentage of total load volume), fall velocity, and voids ratio (volume of water to volume of solids ratio). In addition, the in-barge percent distribution of solids must be specified. The selection of material densities, fall velocities, and void ratios for both the Miami and Fort Pierce sites was based on information obtained from SAJ (Tapp 1988), from a recent DIFID application in Mobile Bay (Reese 1988), and from numerous DIFID applications reported by Johnson and Holliday (1978). The selected composition of the disposal load used for both sites is shown in Table 2.2

Table 2.2

Characterization of Dredged Material for Miami and Fort Pierce

Description	Density g/cc	Volumetric ratio	Fall Velocity ft/sec	Voids Ratio	Cohesive? (1 or 0)
SAND	2.650	0.6300	0.04660	0.00	0
SIL-CLAY	2.650	0.0700	0.00256	1.00	1
WATER	1.023	0.3000	0.00		

52. The concentration percentages of the total load are based on an assumed solids content of 70 percent by volume of the material in the barge. Sieve analyses received from SAJ (Tapp 1988) showed medium well graded sand (non-cohesive) was representative of at least 90 percent of the solids in the load (90% of 70% = 63%). Cohesive silts and clays were specified for the remaining 10 percent of solids. A bulk density of 2.16 gm/cc and an aggregate

void ratio of 1.4 was specified for both sites to compute the final thickness of the composite mound.

53. There are numerous model parameters in addition to the internal model coefficients required as input to the DIFID model. Grid resolution and time step parameters were selected to best represent each disposal site. The internal model coefficients recommended by Johnson and Holliday (1978) and used by Reese (1988) were used for both site simulations. The parameters and coefficients used are shown in Table 2.3.

Table 2.3

Input Data Related to Disposal Operation for the Miami and Fort Pierce ODMDS

Variables	Miami	Fort Pierce
Grid size (ft)	200	200
Number of cells:		
cross-shore direction	105	105
Alongshore direction	28	28
Time step (sec)	100	100
Duration of simulation (sec)	6000*	10800
Ambient velocity (ft/sec)	2.79	1.97
Ambient density (gm/cc)	1.023	1.023
DINCR1	1.0	1.0
DINCR2	1.0	1.0
Entrainment coefficient ALAPHO	0.200*	0.235
BETA	0.0	0.0
CM	1.0	1.0
Drag coefficient for sphere, CD	0.5	0.5
GAMA	0.25	0.25
Drag coefficient for elliptic cylinder, CDRAG	1.0	1.0

CFRIC	0.01	0.01
CD3	0.10	0.10
CD4	1.00	1.00
Entrainment due to cloud collapse, ALPHAC	0.0010	0.0010
Bottom friction, FRICTN	0.0100	0.0100
ALAMDA	0.005	0.005
Vertical diffusion coefficient, AKYO	0.0100	0.0100

* Adjustments in value from those of Fort Pierce were required for the deeper depths of the Miami site.

Method and Procedure for Short-Term Model Simulations

54. The objective of the short-term simulations was to determine whether dredged material could be effectively placed within the limits of the designated disposal sites under the action of a realistic localized velocity field. Of particular interest was whether the settling material (primarily sand) or the suspended sediment cloud (silts and clays) could be transported from the dredge onto the reef area. Data received from SAJ (Tapp, 1988) and shown in Figures 1.1 and 1.2 indicated that the reef areas are located a minimum of approximately 1.5 miles due west of the shoreward edge or 2.0 miles from the center of either ODMDS. If the average release point is considered to be at the center of the designated site, an effective distance between the disposal site and the nearest reef of approximately 3.0 miles is computed from the angle of orientation of the velocity vector. In order to investigate these far field effects, the model grid dimensions were specified to be 105 cells in the flow direction by 28 cells in the transverse direction. The grid spacing of 200 ft produces an effective modeling area of 1 mile by 4 miles. The disposal release point was selected at approximately 0.4 miles (grid cell 10) from the upstream boundary.

55. The approach taken to investigate the possibility of reef contamination was to determine both the depth and extent of deposition and the sediment plume concentration impact produced by a single disposal load under the maximum, reef-directed, non-storm condition likely to be encountered during a dumping operation. Two parameters were of interest. First, the total deposition pattern was computed to indicate the maximum distance from the dredge at which measurable (above 0.01 ft) deposition could be expected. This maximum excursion distance provides an indication of the spatial extent of direct deposition of material on the bottom.

56. The second measure of impact, and the primary parameter of interest to this study, quantifies the movement and concentration of the moving cloud of suspended sediments. As the cloud is transported from the dredge by the ambient currents, it grows larger (diffuses) and, correspondingly, less concentrated. The second phase of investigation looks at the change in time of the location and concentration of this cloud of sediment as it is diffused and transported toward the reef area. An example of transport and diffusion of the cloud is shown in Figures 2.2, 2.3, 2.4, and 2.5 in which the horizontal distribution of the suspended sediment concentration of the silt-clay cloud is shown at the 200 ft level (below the surface) for the Miami simulation. With the release point assumemed to be at the center of the disposal site (specified as cell 10, the nearest reef is located at approximately grid cell number 89. The 1500, 3000, 4500, and 6000 sec snapshots shows the increase in size and corresponding decrease in concentration of the settling cloud as it is transported toward the reef area.

57. Results of the concentration computation are used to produce a concentration (in ppt or mg/l above ambient conditions) versus distance relationship along the axis of the grid at five discrete depths for four specified time periods (i.e., along the axis of symmetry at grid N = 14 of Figures 2.2-2.5). Quarter-point times were selected to show results at the 1/4, 1/2, 3/4 and final point of any specified time period following the initial release of material from the barge. The following sections present the results of these simulations for the Miami and Fort Pierce sites.

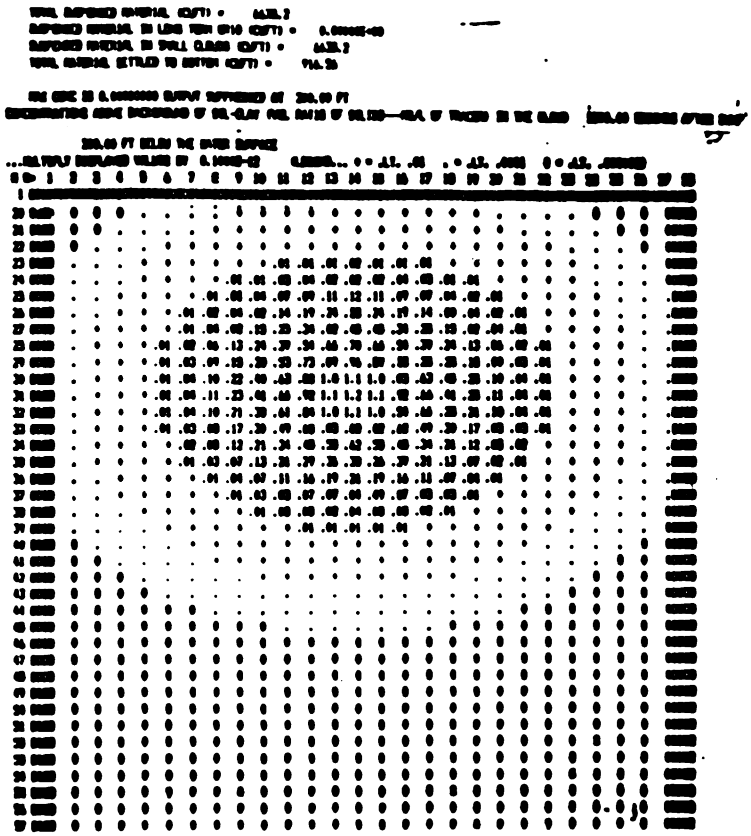


Figure 2.2. Suspended sediment cloud at 200 ft deep at 1500 sec after dump

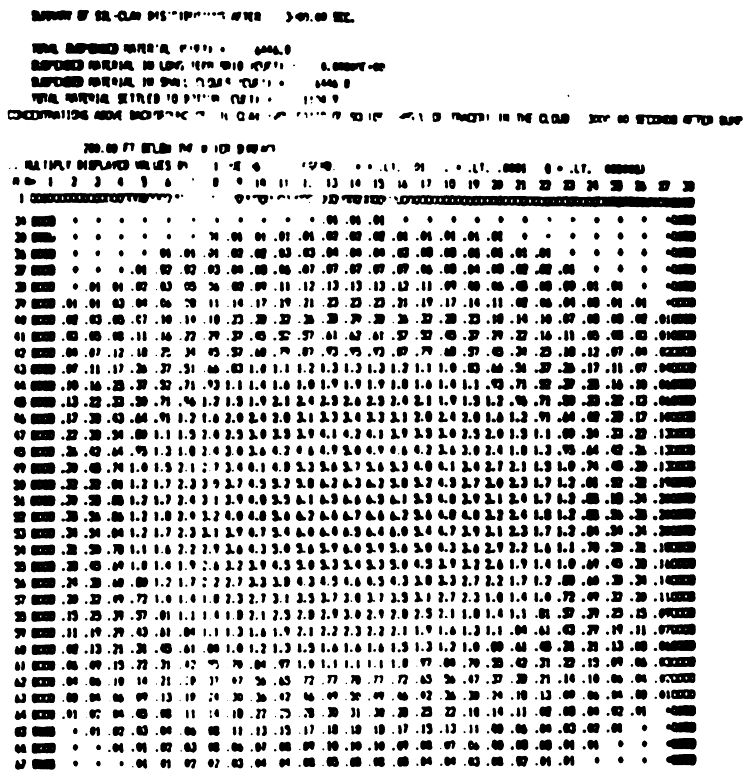


Figure 2.3. Suspended sediment cloud at 200 ft deep at 3000 sec after dump.

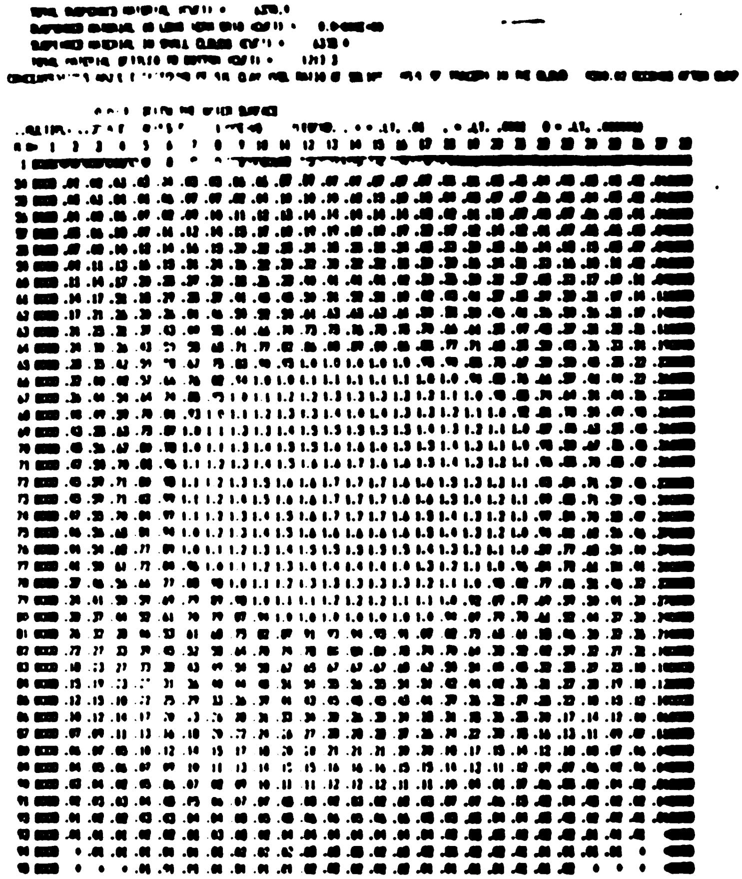


Figure 2.4. Suspended sediment cloud at 200 ft deep at 4500 sec after dump

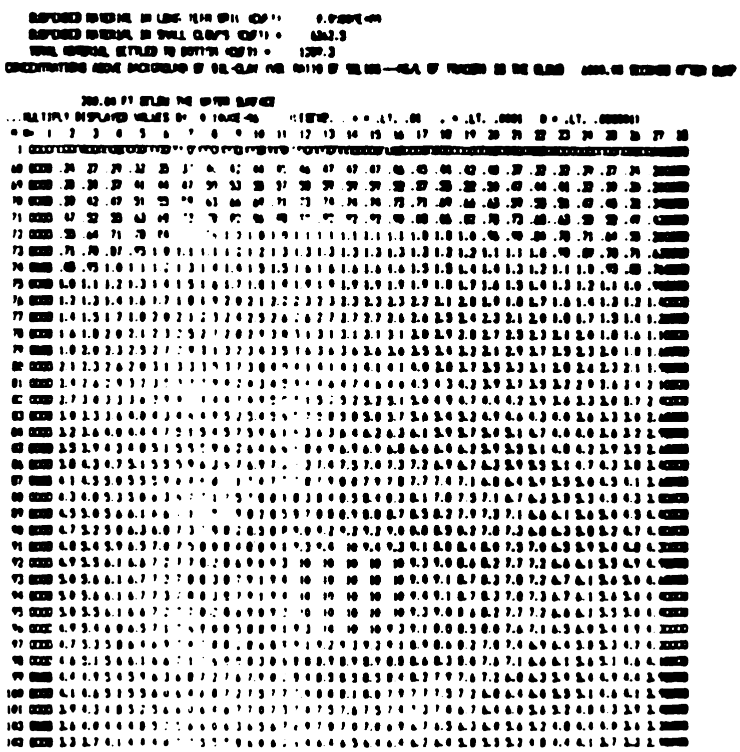


Figure 2.5. Suspended sediment cloud at 200 ft deep at 6000 sec after dump

Miami Disposal Site

58. Results of the sediment concentration computation for Miami are shown in Figure 2.6. The disposal release point is located at approximately mile 0.4 and the reef at approximately mile 3.5. Note that these figures represent distance-concentration plots at the quarter-point times along the reef-directed cloud axis. The uppermost graph of Figure 2.6, for example, summarizes the data presented in Figures 2.2 through 2.5. The depths of 200, 250, 300, 350, and 400 ft were used in order to present an overall representation of the numerical results. For example, at 1500 sec after the initial dump, simulations of the disposal operation shows concentrations of suspended silt and clay at the 200 ft depth to be 10^{-12} ppm. Results demonstrate that the descent phase of the hemispherically shaped cloud passes through the water rapidly leaving little sediment in the upper water column. The examples presented in Figure 2.6 indicate that a point of maximum concentration is reached at a depth of approximately 350 ft and that a concentration decrease is seen both above and below this point. This relationship of maximum concentration is maintained for each quarter point as the cloud disperses. All results indicate a decreasing concentration in both time after disposal and distance from the release point as shown in the summary Table 2.4.

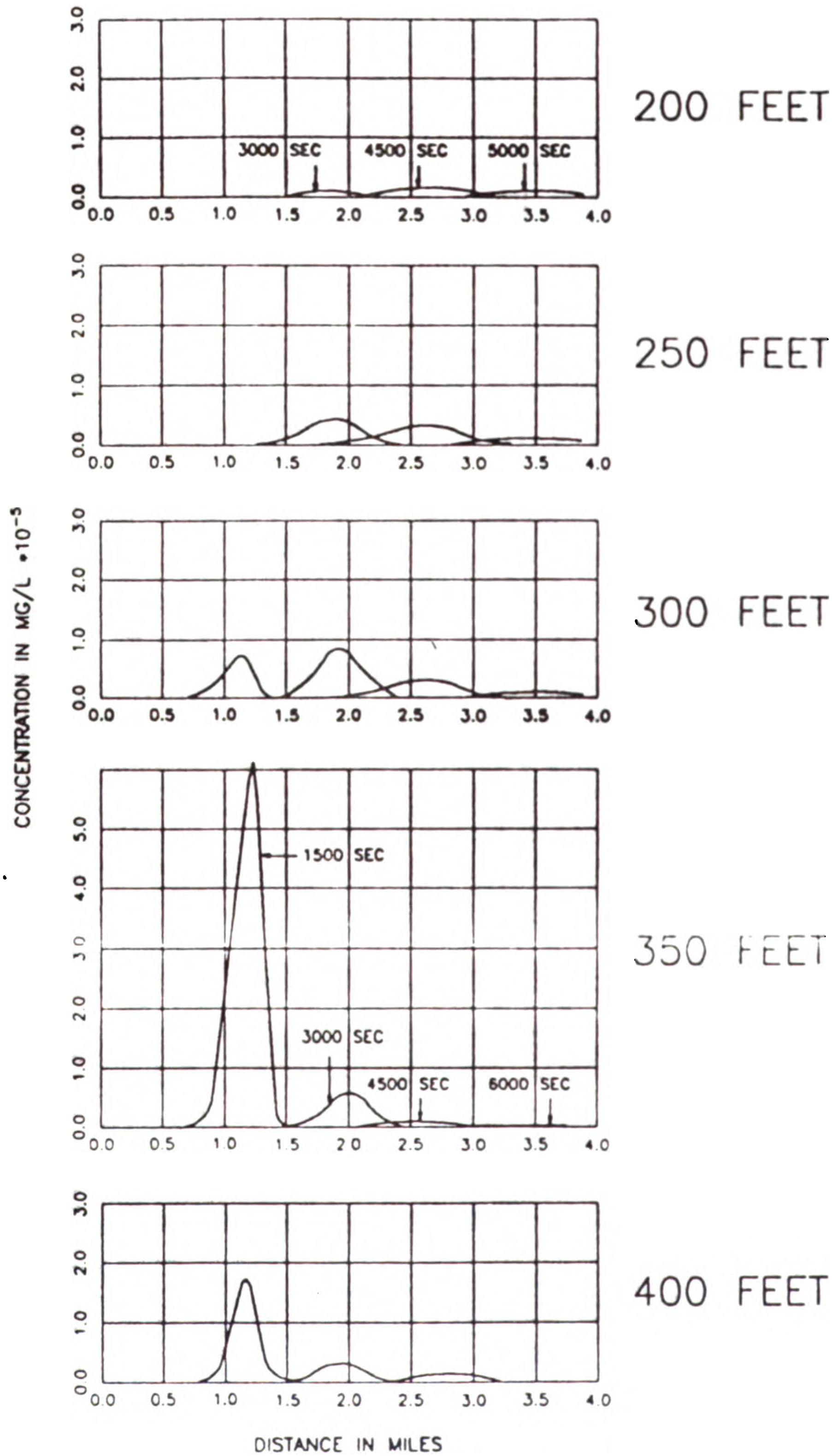


Figure 2.6. Time-concentration for Miami at 200, 250, 300, 350, and 400 ft.

Table 2.4

Summary of Computed Maximum Suspended Silt and Clay Concentration

(Concentration in mg/l above ambient)

Depth (ft)	Elapsed Time (sec)/Approximate Distance from Dredge (Miles) 1500 0.8	3000 1.6	4500 2.3	6000 3.2
200	1.2×10^{-13}	6.7×10^{-7}	1.7×10^{-6}	1.0×10^{-6}
250	7.1×10^{-9}	4.3×10^{-6}	2.5×10^{-6}	9.2×10^{-7}
300	5.5×10^{-6}	8.7×10^{-6}	2.2×10^{-6}	6.6×10^{-7}
350	5.7×10^{-5}	5.8×10^{-6}	1.1×10^{-6}	3.8×10^{-7}
400	1.5×10^{-5}	2.4×10^{-6}	6.9×10^{-7}	2.6×10^{-7}

59. A plot of the total sediment deposition versus distance along the axis of the disposal grid is shown in Figure 2.7. A three-dimensional view of the resulting disposal pattern is shown in Figure 2.8 with the corresponding contour plot shown in Figure 2.9. The stable material mound is composed primarily of the sand portion of the disposal load and will be the subject the long-term disposal simulations described in Section III.

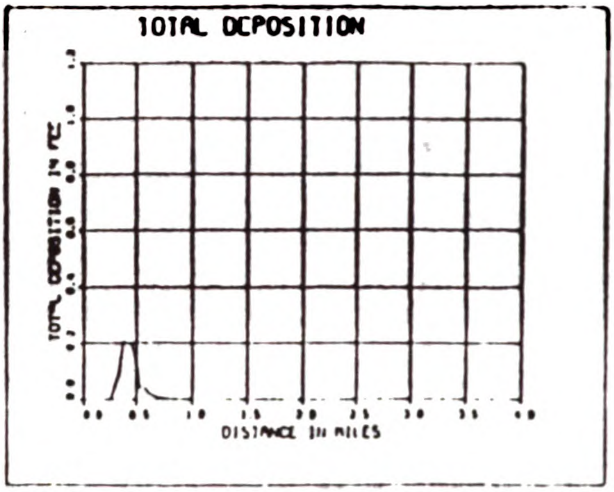


Figure 2.7. Deposition pattern for the Miami site

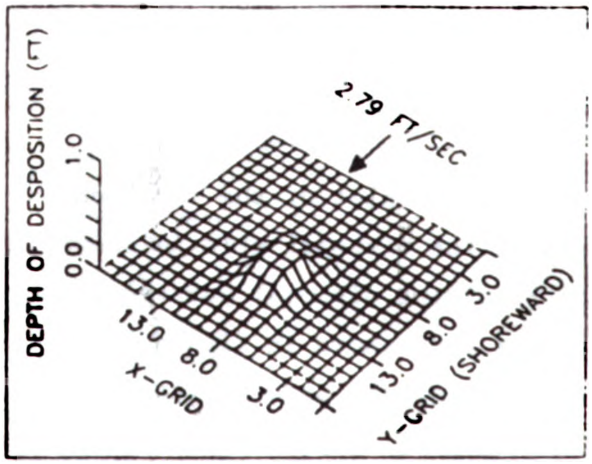


Figure 2.8. Three-dimensional view of the Miami site disposal mound

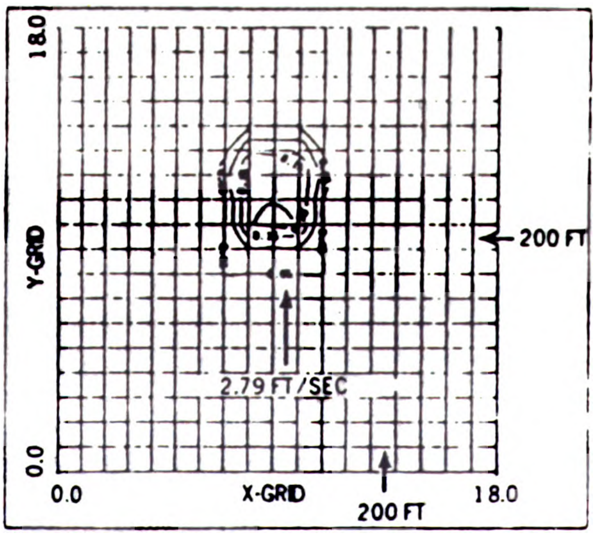


Figure 2.9. Contour plot of the deposition pattern for the Miami site

Fort Pierce Disposal Site

60. Results of the sediment concentration computation for the Fort Pierce site are shown in Figure 2.10. Depths of 10, 20, 30, 40, and 50 ft were specified in the simulation. Note that because of the shallow depth, sediment remains in suspension throughout the water column. Also, the figures show the depth of maximum concentration to be located at approximately the 30 ft depth. A trend, similar to that shown in the Miami simulations, of decreasing concentration with increasing distance and time is seen. This trend can be seen in the concentration summary Table 2.5.

61. A plot of the total deposition in ft versus distance along the axis of the disposal grid is shown in Figure 2.11. Three-dimensional results of the disposal mound are shown in Figure 2.12 with the corresponding contour plot shown in Figure 2.13. Due to the shallow water depths and relatively low velocities, the stable mound can be seen to be conical in shape.

Table 2.5

Summary of Computed Maximum Suspended Sediment Concentration

(Concentration in mg/l above ambient)

Depth (ft)	Time (sec)/Approximate Distance from Dredge (Miles) 2700 1.0	5400 2.0	8100 3.0	10800 4.0
10	1.2x10-5	2.4x10-6	7.8x10-7	*
20	2.3x10-5	4.4x10-6	1.4x10-6	*
30	2.8x10-5	5.5x10-6	1.7x10-6	*
40	2.3x10-5	4.4x10-6	1.4x10-6	*
50	1.2x10-5	2.4x10-6	7.8x10-7	*

* Results at the 10800 sec were below the computational threshold of the model, hence, no values are reported.

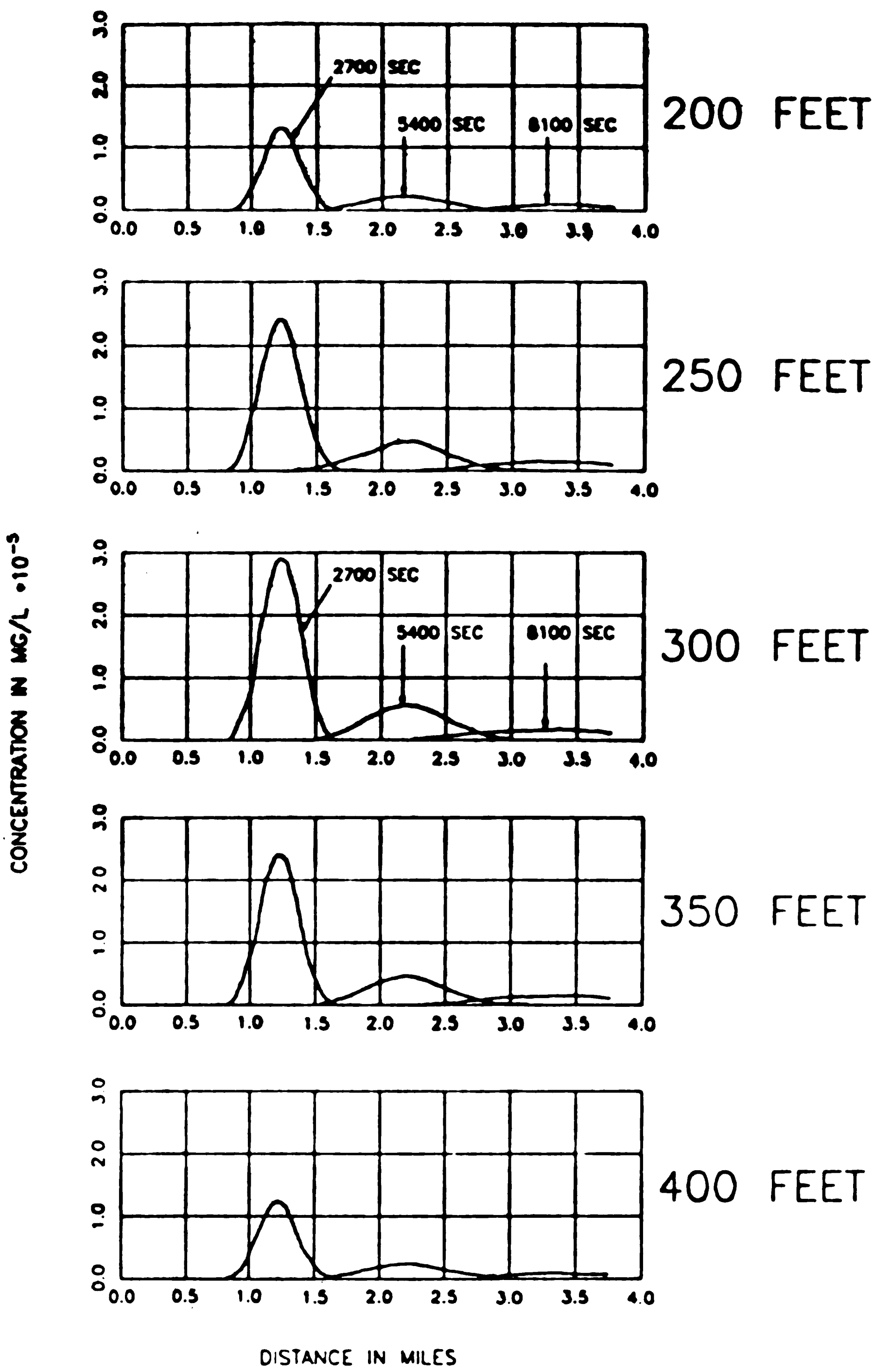


Figure 2.10. Time-concentration for Fort Pierce at 10, 20, 30, 40, and 50 ft

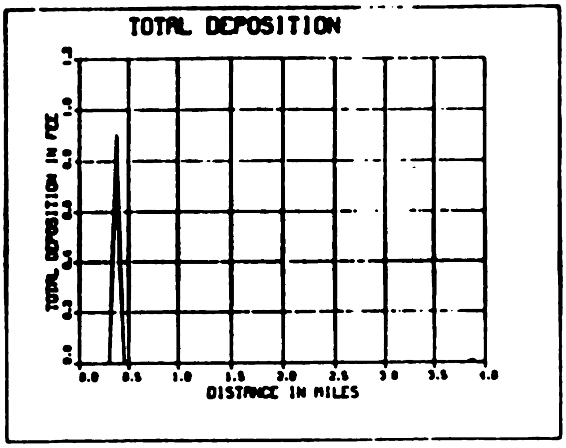


Figure 2.11. Deposition pattern for the Fort Pierce site

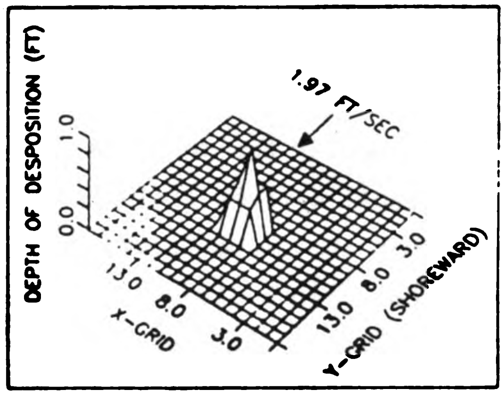


Figure 2.12. Three-dimensional view of the Fort Pierce site disposal mound

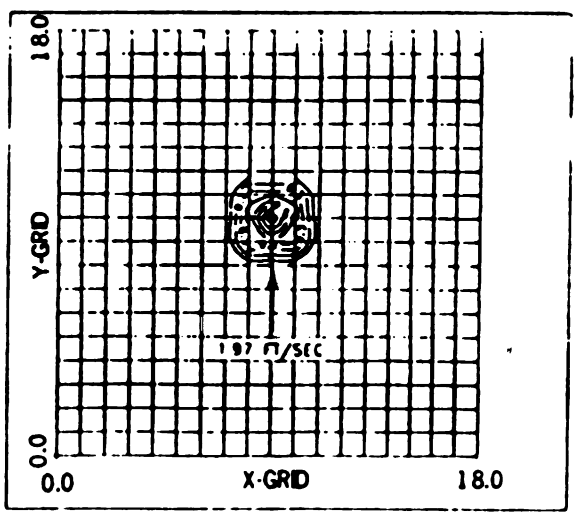


Figure 2.13. Contour plot of the deposition pattern for the Fort Pierce site

PART III: THE SIMULATION OF LONG-TERM DISPOSAL FATE

62. The final task of the evaluation study investigates the long-term fate of disposed material in open water. This analysis will concentrate on classifying the disposal sites as either dispersive or non-dispersive based on whether the local velocity field is adequate to erode and transport material from the mound onto the coral reefs. Transport simulations will be made for periods of time ranging from a day to a year. This phase of the project differs from Phase II in that the short-term investigation determined whether the material could be effectively placed within a designated site during the dumping process when material descends through the water column and collapses on the ocean bottom. The long-term analysis assumes that the material has been successfully deposited on the bottom and has assumed a stable mound configuration. Whether the mound is dispersive or non-dispersive now depends on whether the local current field is capable of resuspending and transporting material such that the mound deformes and is moved from its initial position. Changes in the computed sediment transport patterns are used to compute these changes in location and configuration. For example, as material is eroded from the higher velocity regions near the top of the mound and deposited in areas of lower velocity in the lee of the mound, the shape, orientation, and center of mass of the mound change.

63. The long-term analysis will consist of two approaches. The first will utilize the long-term velocity field developed in Section I of this report to determine whether these velocities are sufficient in magnitude to suspend and transport bottom sediments from an existing disposal mound of a specified initial configuration. The second phase will simulate the passage of a storm surge over the mound. Both approaches will use a sediment transport model to compute non-cohesive sediment transport and the associated bathymetric change as a result of a time varying velocity field around the mound. A brief description of the modeling approach follows.

Sediment Transport

64. Empirical relationships for computing sediment transport as a primary function of ambient water velocity, depth, and sediment grain size were reported by Ackers and White (1973). These relationships were subsequently modified by Swart (1976) to reflect an increase in sediment transport when a wave field is superimposed on the ambient current field. This additional transport reflects the fact that additional sediments are suspended by wave induced bottom orbital velocities. These additional sediments in the water column are available for transport by the localized velocity field. Details of an application of the combined Ackers-White and Swart modification methodology were reported by Vemulakonda et al. (1987) in which computed erosion and deposition volumes were shown to adequately reproduce measured bathymetric changes computed from periodic maintenance dredging surveys in the entrance channel of St Marys Inlet, Florida.

65. Prior to computing long-term simulations, a sensitivity test of the transport predictions was performed for the local conditions at the proposed Miami and Fort Pierce disposal locations. The goal of this testing was to determine threshold velocities needed to initiate sediment movement at each site under the localized environmental conditions of depth and wave field. Sediment transport curves were prepared for each site for a velocity range of 0.0 to 4.0 ft/sec and for a sediment diameter size of 0.1 mm to 0.2 mm in increments of .02 mm. These curves are shown in Figures 3.1 and 3.2.

66. Approximations for wave height and period used in the generation of Figures 3.1 and 3.2 were determined from the Wave Information Study (WIS) 20-yr hindcast data base (Jensen, 1983). Figures 3.3 and 3.4 represent a reproduction of the wave summary statistics for WIS Stations 163 (for the Miami site) and 153 (for the Fort Pierce site). Note that the wave heights and periods selected are representative of larger than average wave conditions; hence the transport rates used in this analysis will be conservative. Average depths of 600 ft for Miami and 50 ft for Fort Pierce were selected from Figures 1.2 and 1.3 to represent depths at the center of the designated sites.

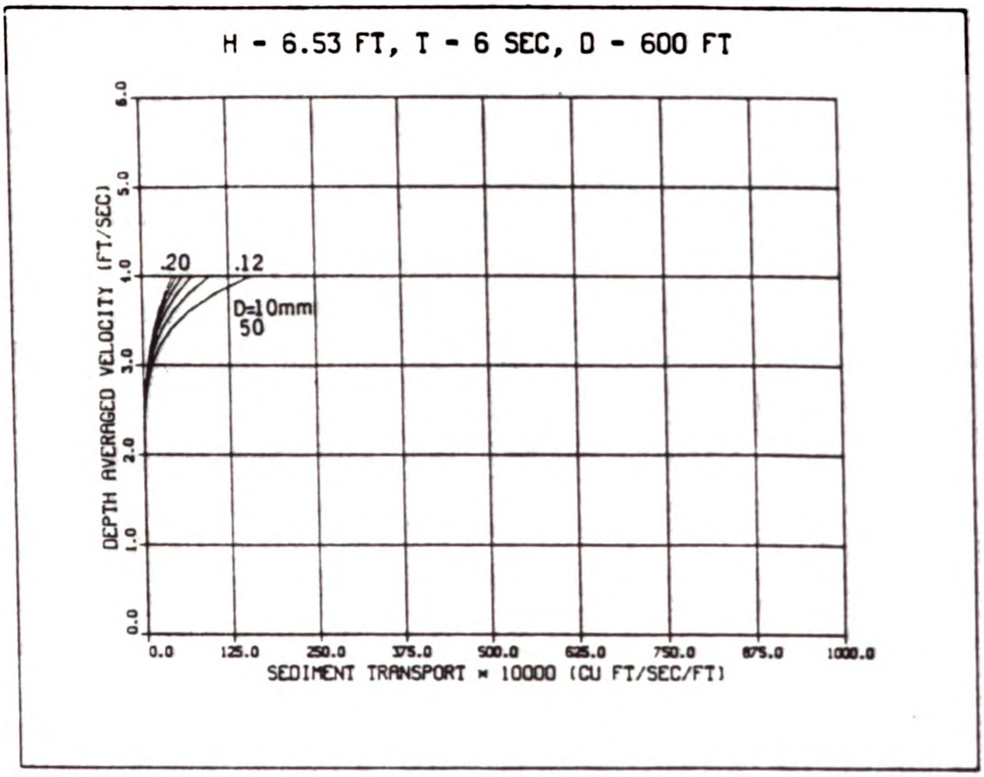


Figure 3.1. Sediment transport vs velocity - Miami disposal site

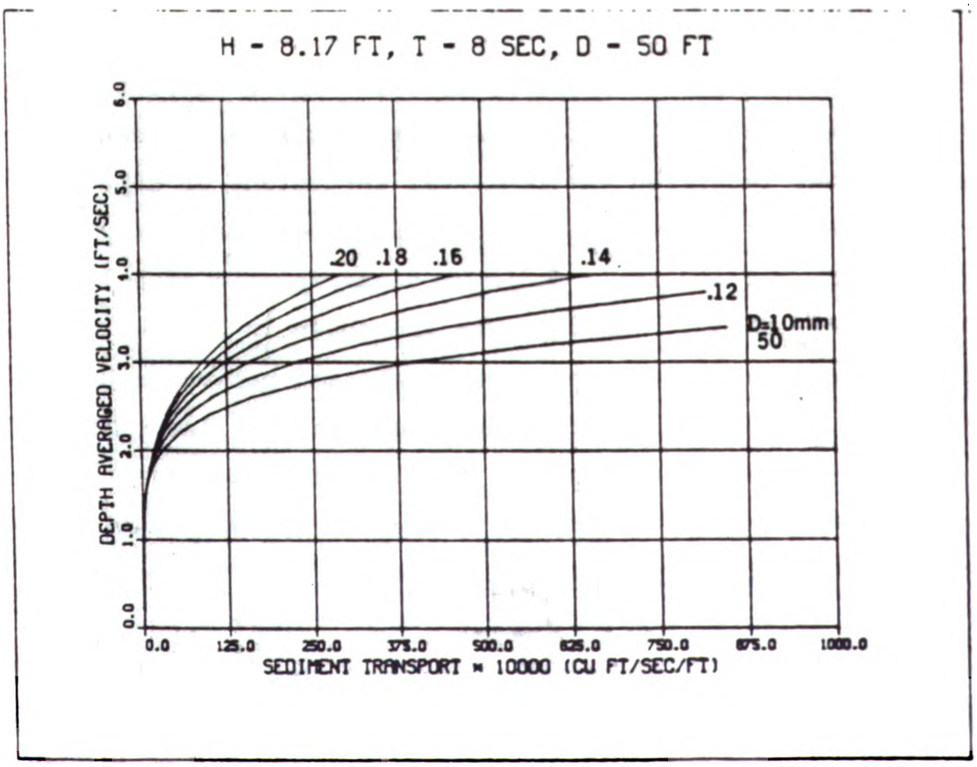


Figure 3.2. Sediment transport vs velocity - Fort Pierce disposal site

STATION 163 20 YEARS FOR ALL DIRECTIONS
SHORELINE ANGLE = 6.0 DEGREES AZIMUTH
WATER DEPTH = 10.00 METRES
PERCENT OCCURRENCE(X100) OF HEIGHT AND PERIOD FOR ALL DIRECTIONS

HEIGHT(METRES)	PERIOD(SECONDS) 0.0-2.9	3.0-3.9	4.0-4.9	5.0-5.9	6.0-6.9	7.0-7.9	8.0-8.9	9.0-9.9	10.0-10.9	11.0-LONGER	TOTAL
0. - 0.49	1883	1953	388	294	127	241	156	56	160	97	5355
0.50 - 0.99	.	706	1898	414	75	35	4	.	1	1	3134
1.00 - 1.49	.	.	23	708	182	50	9	.	.	.	972
1.50 - 1.99	.	.	.	16	130	61	10	1	.	.	218
2.00 - 2.49	.	.	.	.	41	50	5	2	.	.	98
2.50 - 2.99	.	.	.	.	.	2	.	.	.	.	2
3.00 - 3.49	.	.	.	.	.	.	.	.	.	.	0
3.50 - 3.99	.	.	.	.	.	.	.	.	.	.	0
4.00 - 4.49	.	.	.	.	.	.	.	.	.	.	0
4.50 - 4.99	.	.	.	.	.	.	.	.	.	.	0
5.00 - GREATER	.	.	.	.	.	.	.	.	.	.	0
TOTAL	1883	2659	2309	1432	555	439	184	59	161	98	

AVE HS(M) = 0.53 LARGEST HS(M) = 2.91 TOTAL CASES = 58440

Figure 3.3. WIS station 163 wave characteristic summary for the Miami site

STATION 153 20 YEARS FOR ALL DIRECTIONS
SHORELINE ANGLE = 339.0 DEGREES AZIMUTH
WATER DEPTH = 10.00 METRES
PERCENT OCCURRENCE(X100) OF HEIGHT AND PERIOD FOR ALL DIRECTIONS

HEIGHT(METRES)	PERIOD(SECONDS) 0.0-2.9	3.0-3.9	4.0-4.9	5.0-5.9	6.0-6.9	7.0-7.9	8.0-8.9	9.0-9.9	10.0-10.9	11.0-LONGER	TOTAL
0. - 0.49	644	904	234	149	290	416	311	179	116	173	3416
0.50 - 0.99	.	535	1171	257	59	369	349	417	282	432	3871
1.00 - 1.49	.	.	230	585	104	174	153	103	55	264	1668
1.50 - 1.99	.	.	.	86	205	150	64	28	10	80	623
2.00 - 2.49	.	.	.	.	59	203	45	8	6	16	337
2.50 - 2.99	.	.	.	.	.	22	24	2	.	6	54
3.00 - 3.49	.	.	.	.	.	.	6	.	.	3	9
3.50 - 3.99	.	.	.	.	.	.	.	.	.	.	0
4.00 - 4.49	.	.	.	.	.	.	.	.	.	.	0
4.50 - 4.99	.	.	.	.	.	.	.	.	.	.	0
5.00 - GREATER	.	.	.	.	.	.	.	.	.	.	0
TOTAL	644	1439	1635	1077	717	1334	952	737	469	974	

AVE HS(M) = 0.78 LARGEST HS(M) = 3.61 TOTAL CASES = 58440

Figure 3.4. WIS station 153 wave characteristic summary for the Fort Pierce site

67. Depth-averaged non-storm velocity fields were shown in Section I of this report to be approximately 1.64 ft/sec (50 cm/sec) for the Miami site and 0.98 ft/sec (30 cm/sec) for the Fort Pierce site. Results shown in Figures 3.1 and 3.2 indicate that these velocities are marginally adequate to transport sediment; however, locally elevated velocity vectors in the vicinity of the mound crest may be adequate to transport sediment from the mound. The following section will address the velocity field distribution as the ambient current field flows over the mound.

Velocity Field Distribution

68. The sediment transport modeling approach is based on an accurate velocity distribution around the mound. A steady state numerical model was developed specifically for this purpose. The model, based on the simplified equations of motion and the continuity equation, computes a velocity distribution around a mound of specified dimensions as a result of a constant imposed "upstream" velocity field boundary condition. A sample computation is shown in Figure 3.5 in which the depth averaged velocity vectors can be seen to increase in magnitude and change orientation as the velocity field is influenced by the presence of the disposal mound.

69. A sediment transport rate corresponding to each vector is computed for the entire numerical grid in order to yield a spatial transport distribution. This distribution is input to a non-cohesive sediment continuity model which computes bathymetric changes as a result of transport gradients. When more sediment enters a computational cell than exits the cell, deposition will occur. Conversely, when more leave than enter, erosion will be shown. No net change occurs for a uniform flow field in which equal amounts of sediment enter and leave a cell. When the velocity field is below the local transport threshold value (such as those shown in Figures 3.1 and 3.2), no transport occurs and no net erosion or deposition results.

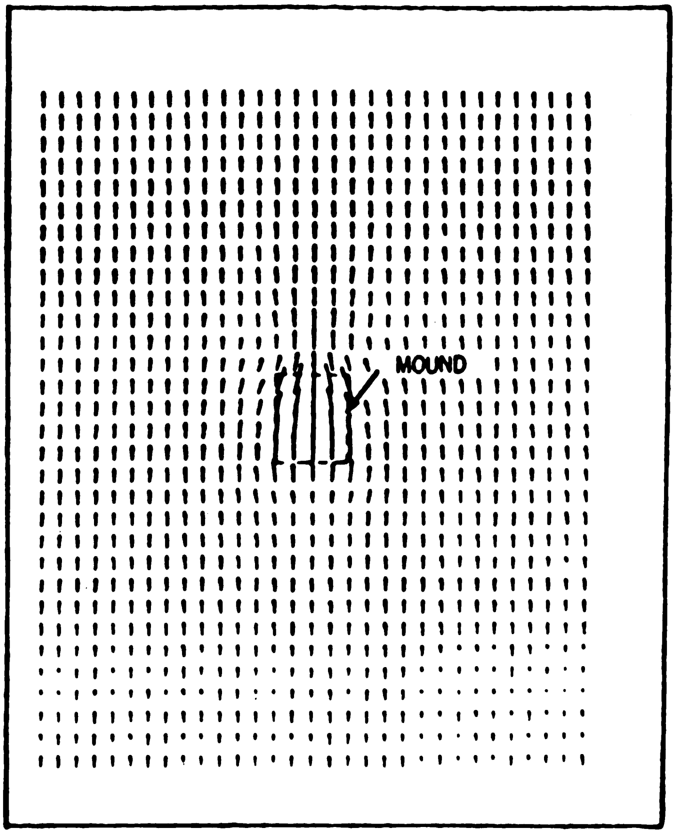


Figure 3.5. Velocity vectors around an idealized disposal mound

70. Velocity field simulation computations are updated at a 3-hr time step to reflect the changing shape of the mound. As the transport patterns adjust in response to the time-varying velocity field, material is transported from regions of high velocity and deposited in regions of low velocity. This process will continue until either the velocities fall below the threshold value required to transport sediment or the mound reaches an equilibrium condition in which equal amounts of sediment enter and leave a computational cell. In the latter scenario, the mound has dispersed to the point that the identity of the mound has been lost and it no longer effects the current regime.

71. Erosion and deposition patterns associated with the changing shape of the disposal mound are also computed at every 3-hr time step. These computations indicate the time variation in depth of sediment deposition versus distance from the mound. The distance at which zero depth changes occur will indicate the first location from the mound at which no mound material has been deposited; hence, the maximum radius of mound influence on the environment. If material from the mound is deposited beyond a designated

point, i.e., on the reefs, then the disposal site can be considered dispersive. For the present study, the critical distance of excursion is the distance from the disposal mound to the reefs.

72. Two simulations will be used to determine whether the presence of the mound poses a potential threat to the coral reef area. The first is a long-term simulation in which the mean non-storm velocity field and wave condition for each site is continually subjected to the mound. Simulations are performed to determine either an excursion rate of the mound in feet per day or to demonstrate that a point of equilibrium has been reached and the mound ceases to move. The second is to simulate a storm related event and compute the total excursion associated with that storm. This simulation will utilize a sustained storm driven velocity surge for a duration of 24 hours, a time scale typical of a hurricane event. If either the long-term average velocities or the high intensity storm induced velocities can be shown to be of sufficient magnitude to transport material from the mound onto the reef areas, it can be concluded that the site is potentially dispersive with respect to long-term events, and that alternate disposal areas further offshore should be investigated.

Sediment Transport Due to Non-Storm Velocity Fields

73. The results shown in Figures 3.1 and 3.2 indicate that sediment transport is initiated at velocity threshold values of approximately 1.0 ft/sec and 2.0 ft/sec for the Fort Pierce and Miami sites respectively. Although the observed ambient velocities at both sites are below these critical values (0.98 and 1.64 ft/sec), the effect of the mound on the velocity distribution may result in elevated velocities on the mound which are sufficient in magnitude to erode and transport material. In addition to the velocity magnitude, model input includes the specification of a single sediment size.

74. Although Figures 3.1 and 3.2 show that the mean sediment diameter is not a critical parameter when the velocity magnitude is near the sediment transport threshold, a sediment size of 0.2 mm was selected for all simulations. The specification of a fine-grained non-cohesive sediment for both sites provides a threshold evaluation of the onset of mound erosion since

fine grained materials are eroded before coarse grained materials are. Results obtained from SAJ (Tapp, 1988) indicate average specific gravities of materials which will be disposed of at the Miami and Fort Pierce sites to be 2.78 and 2.70 respectively, indicative of quartz sand. A typical grain size analysis of a sample obtained from the Fort Pierce harbor is shown in Figure 3.6. The report classifies the material as "poorly graded sand (SP)." In view of this classification, a fine sand specification will provide an estimate of maximum erosion potential. The analysis further indicates a D50 diameter of approximately 3 mm; therefore, the use of a 0.2 mm material in the transport computations serves two functions. It provides a threshold indication of fine material transport, and it provides an indication of fine grain mound transport; as such, it yields a "worst case" prediction of sediment erosion from the mound.

75. A test mound measuring 250 ft square and 10 ft high was used as the design mound configuration for both simulations. A mound of this dimension would contain a volume of approximately 20,000 cubic yards. Although idealized, this configuration will provide an indication of mound stability. The following sections will address the long-term and storm event analysis.

Fort Pierce

76. The proposed disposal site offshore of Fort Pierce (Figure 1.1) is located in shallow water, with an average depth of only approximately 50 ft. A wave with a height of 8.17 ft (2.49 m) and period of 8 seconds was used to indicate a rough, but non-storm, sea state. Results of Section I indicate this area to be outside of the direct influence of the Gulf Stream; therefore, depth averaged velocities are relatively low, on the order of 0.98 ft/sec (30 cm/sec). This velocity represents a maximum, non-storm, depth-averaged velocity field and does not represent a sustained flow field; therefore, long-term simulations using this velocity field represent a highly conservative condition. In reality, the velocity field at this location is primarily a function of tidal forcing and wind induced flow and is not necessarily directed toward the reefs. However, long-term simulations were made using this maximum velocity in order to determine the maximum possible rate of mound erosion and migration.

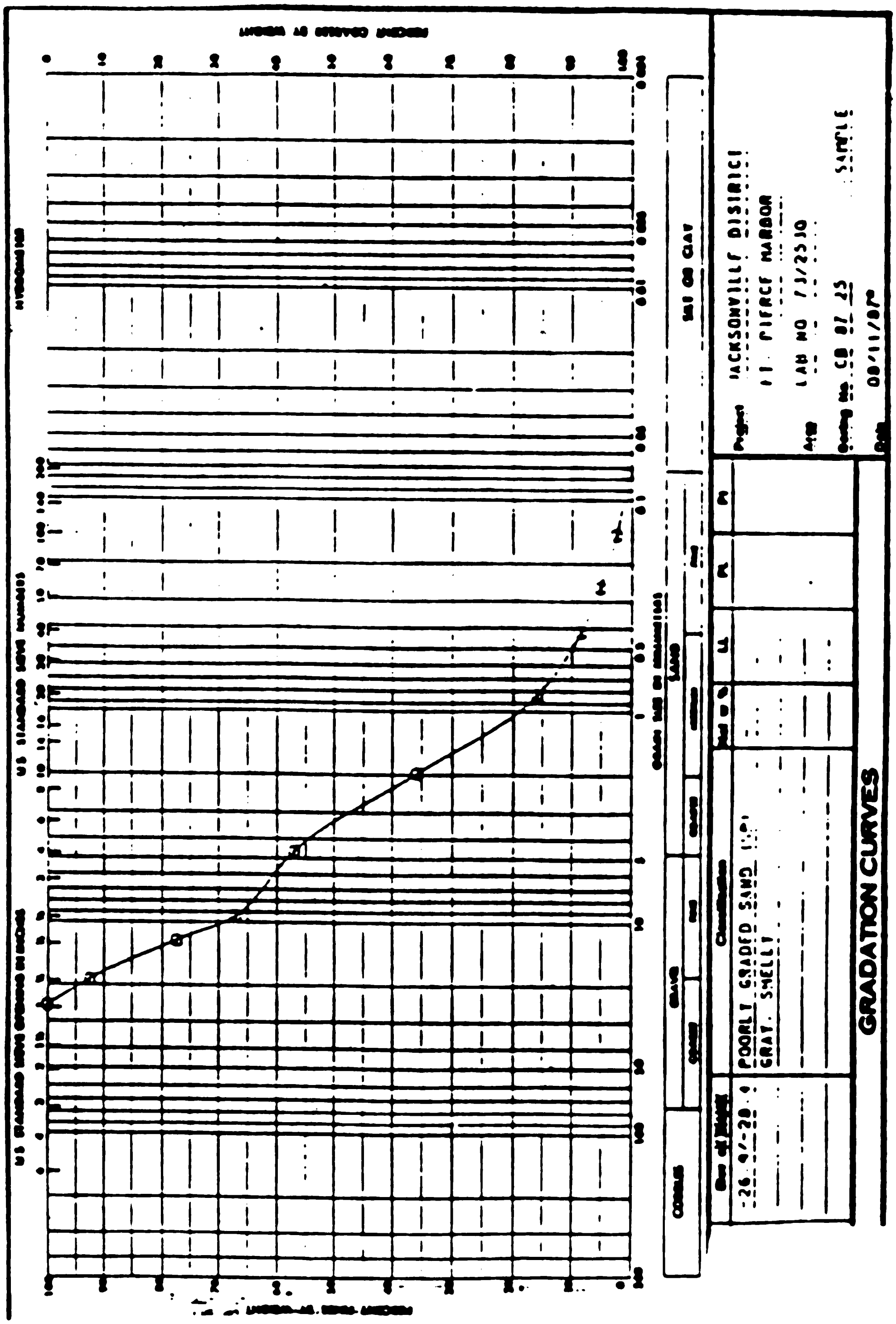


Figure 3.6. Gradation curve of Fort Pierce sediment

77. A 1-year simulation of the idealized mound at the Fort Pierce site was made. Results indicate that material from the mound migrated a total distance of 600 ft in 6 months of sustained maximum current. At this point, the outer edge of the mound reached the computational boundary. The approximate center of mass of the mound migrated approximately 700 ft during the 1 year simulation. During this time, the shape of the mound became elongated, and a scour hole developed in front of the mound. Figures 3.7, 3.8, and 3.9 show the initial configuration, the mid-simulation shape, and the configuration at the end of the simulation. Figure 3.10 presents the monthly change of shape through a central cross-section of the mound. The rate of excursion of the leading edge of the mound is approximately 3 ft per day. Center of mass migration is less than 2.0 ft per day. At either rate, a migration onto the reef area would require in excess of 10 years. During this time, the mound would realistically erode and disperse in many directions, resulting in a lower, less dispersive profile.

78. In order to investigate the erosion producing capability of a storm event, a hypothetical hurricane was constructed with a sustained 24-hour depth-averaged surge velocity of 4 ft/sec. The initial mound configuration is identical to that shown in Figure 3.7. The final mound shape at the end of the storm event is shown in Figure 3.11. Cross-sectional profiles at 6-hr intervals are shown in Figure 3.12. Results indicate that the maximum radius of transport resulting in deposition of more than 0.1 ft to be approximately 500 ft. The corresponding mound crest migration is 350 ft.

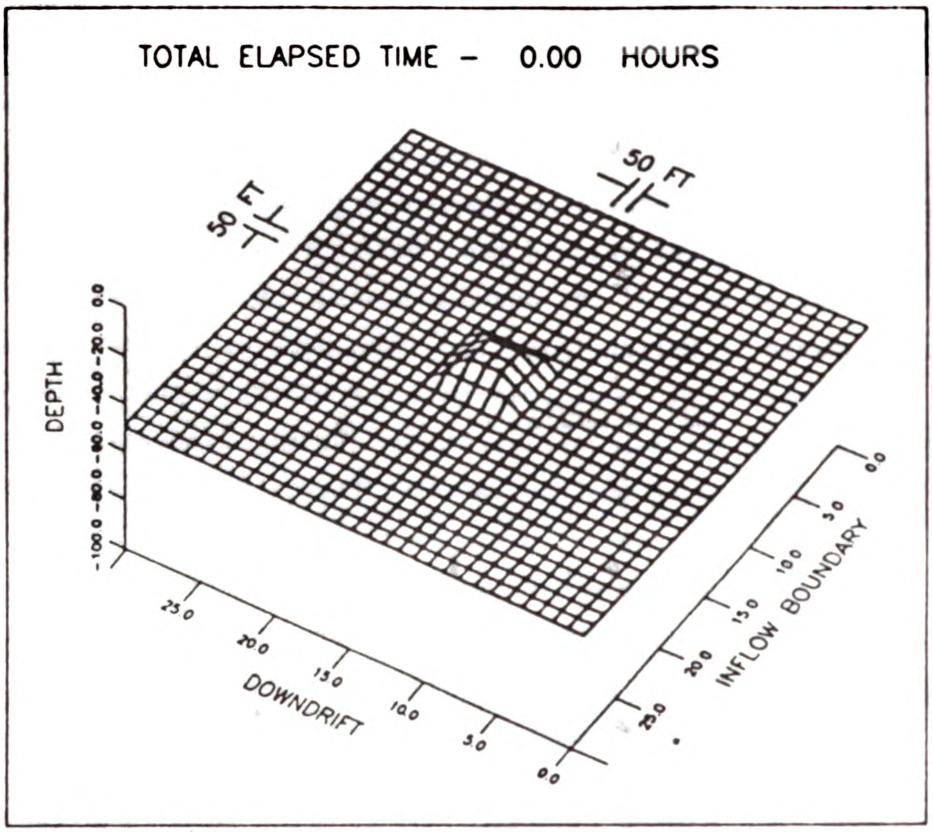


Figure 3.7. Initial mound configuration for Fort Pierce

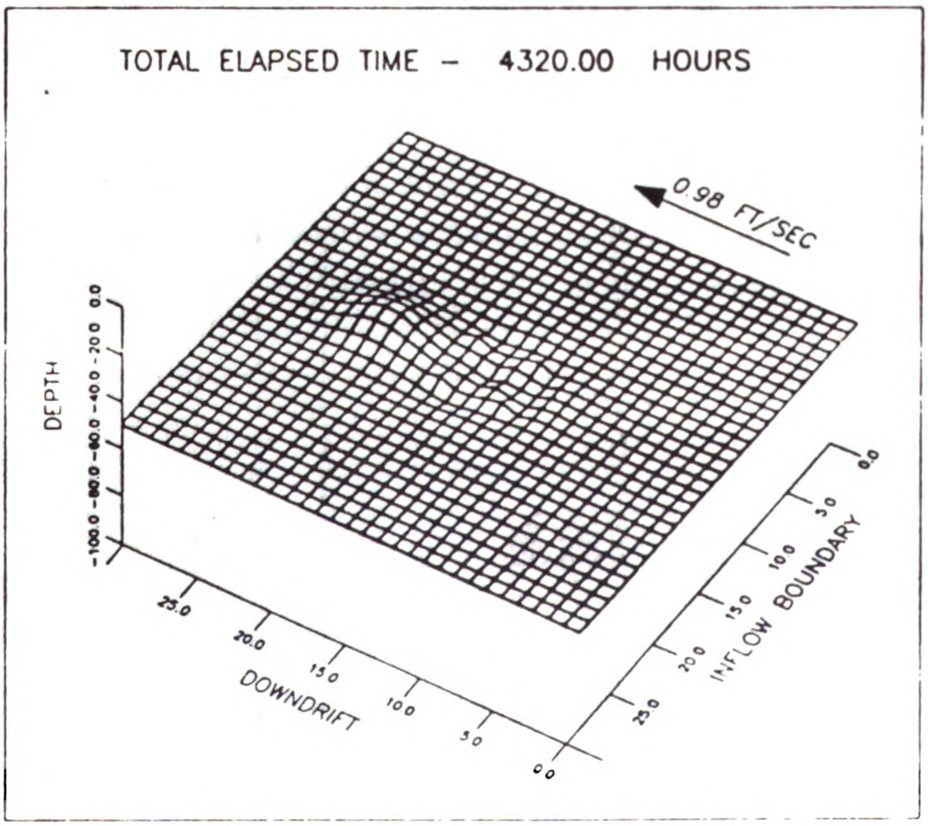


Figure 3.8. Fort Pierce mound configuration at 6 months

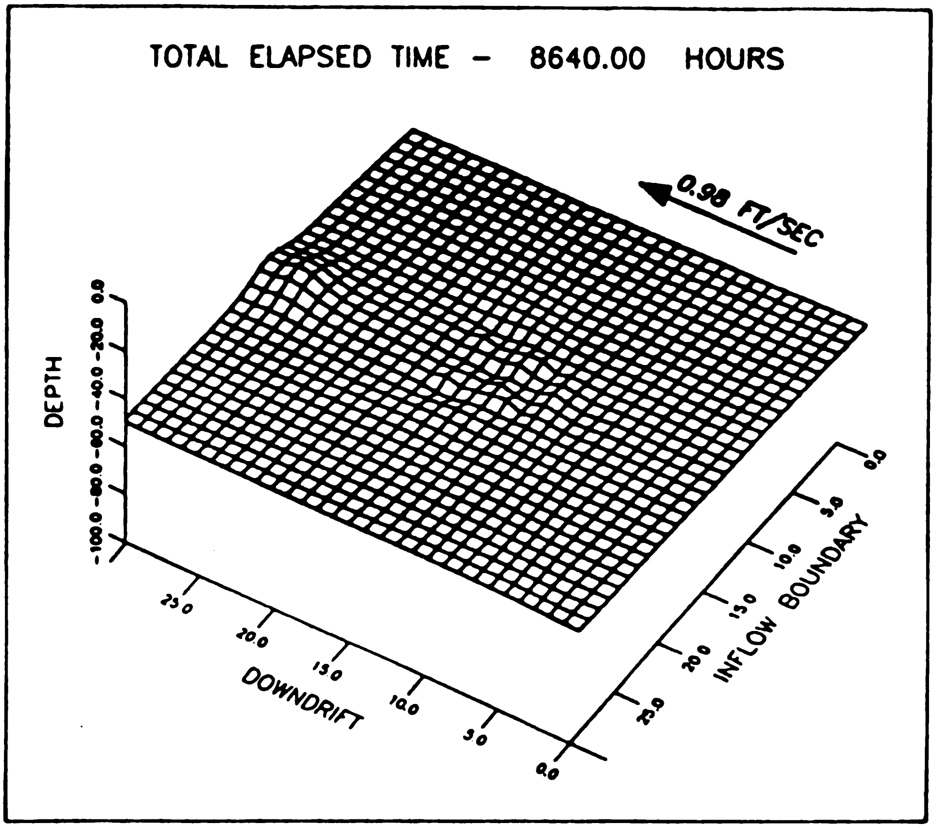


Figure 3.9. Final Fort Pierce mound configuration at 12 months

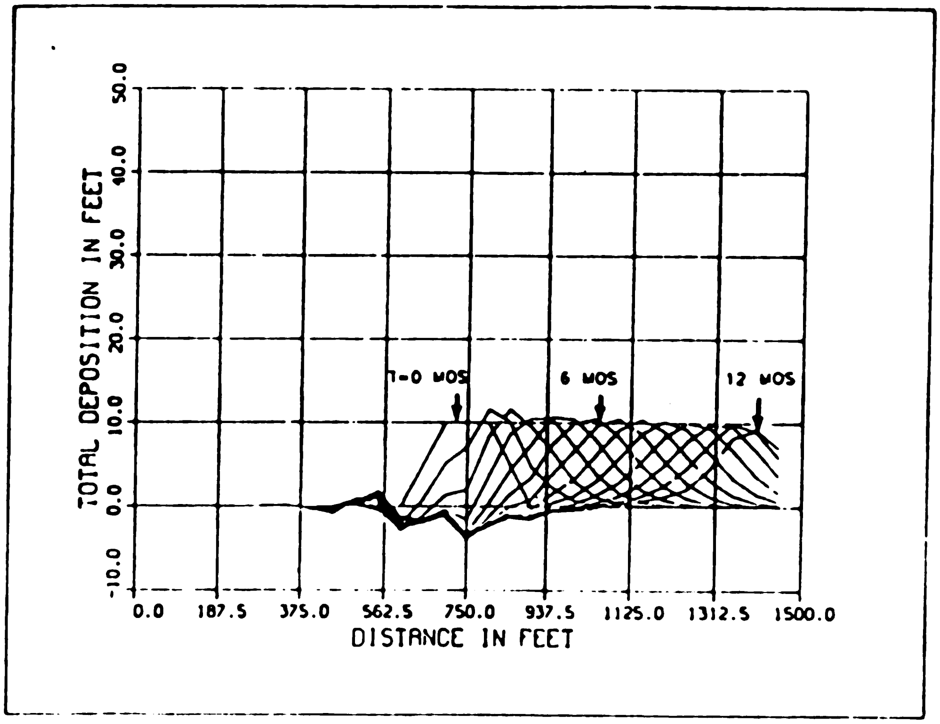


Figure 3.10. Time history of long-term erosion of the Fort Pierce mound

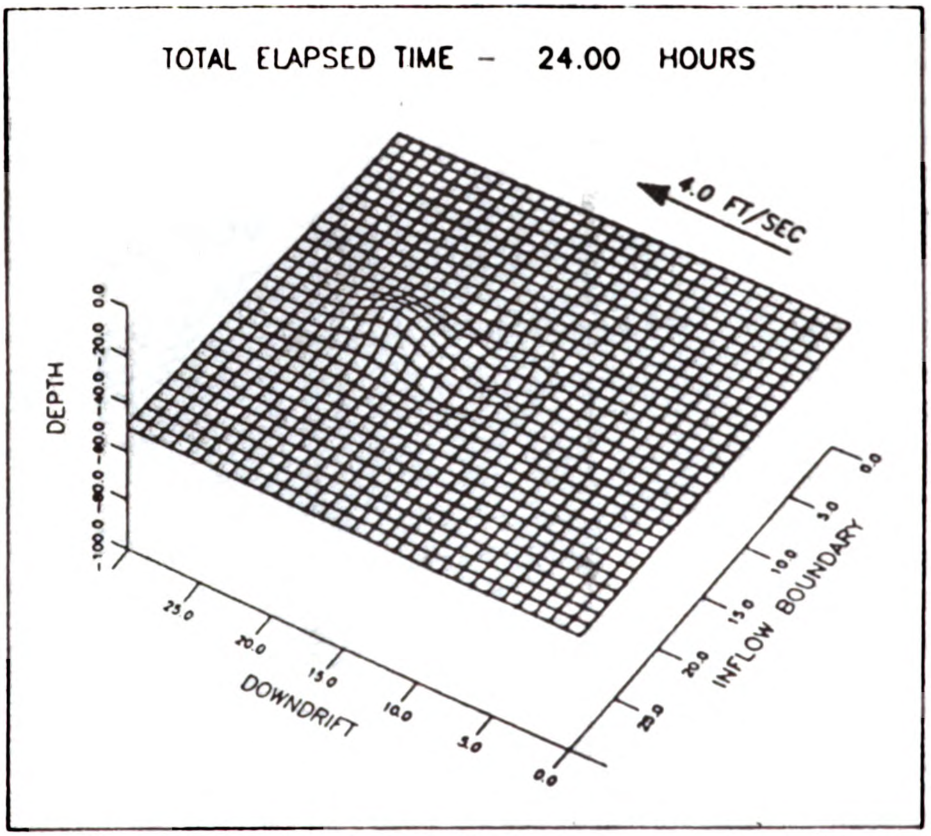


Figure 3.11. Final (24 hr) Fort Pierce storm mound configuration

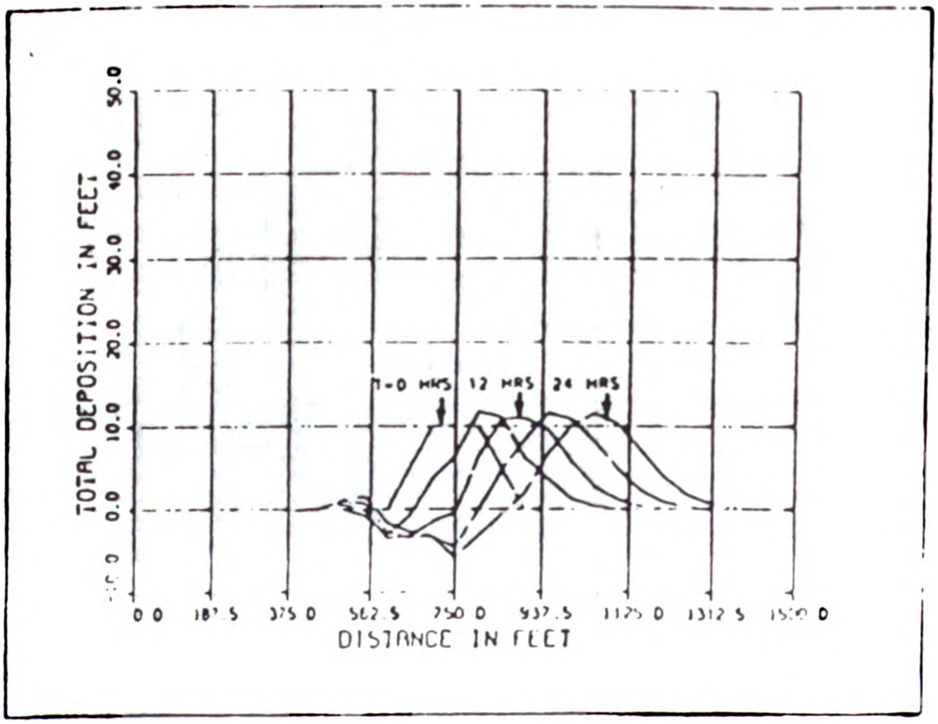


Figure 3.12. Time history of storm erosion of Fort Pierce mound

<u>Miami</u>

79. The proposed disposal site for Miami is located at a depth of approximately 600 ft with a corresponding maximum velocity field of approximately 1.64 ft/sec (50 cm/sec). A 3-month simulation of the idealized mound, using a wave height of 6.53 ft (1.99 m) and period of 6 secs, was performed. The initial and final mound configuration and the evolution of the mound with time, shown on Figures 3.13, 3.14, and 3.15, indicate no transport or erosion. The result that the velocity field is not adequate to either suspend or transport material at a depth of 600 ft is not surprising in view of the threshold values shown in Figure 3.1.

80. A storm event for the Miami site was assumed to have a sustained velocity of 6.0 ft.sec for 24 hours. The post-storm mound configuration is shown in Figure 3.16. The corresponding time changes of the cross-section at 6-hr intervals is shown in Figure 3.17. As can be seen in the figures, a mound located in 600 ft of water is little effected by velocities of a magnitude realistically representative of the disposal site offshore of Miami.

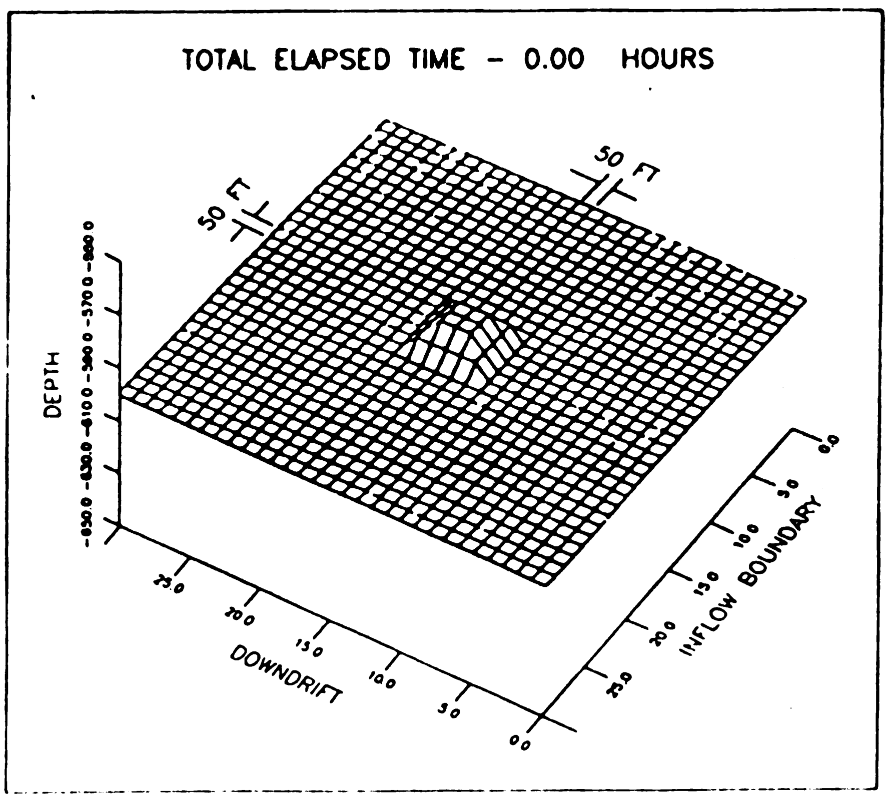


Figure 3.13. Initial mound configuration for Miami

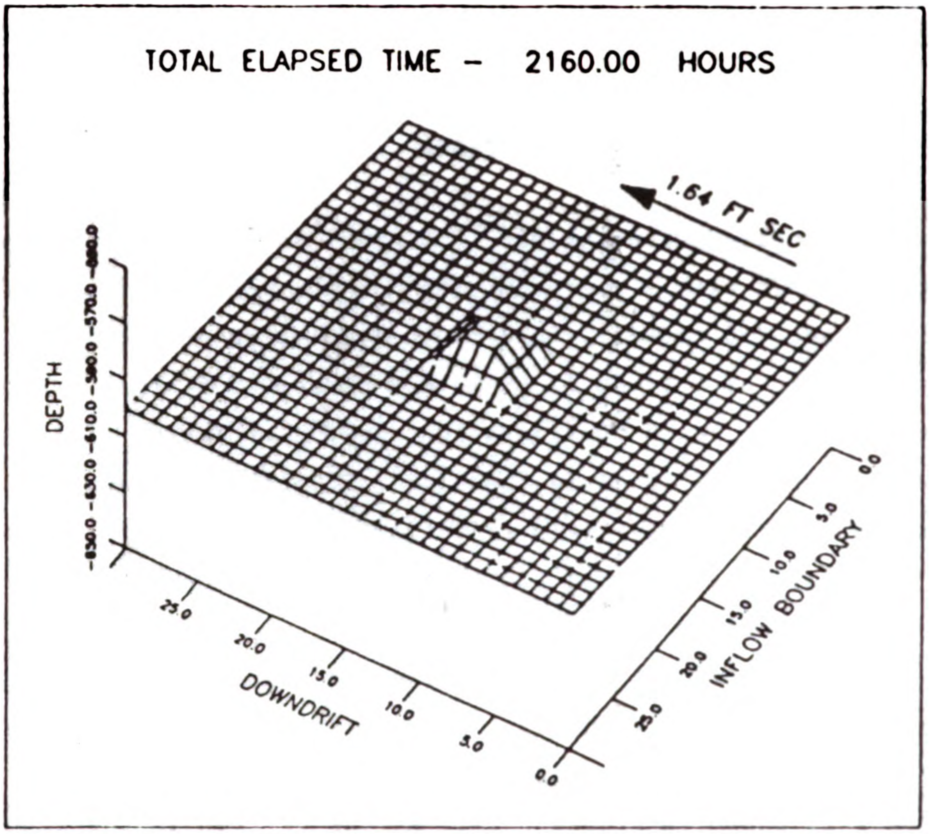


Figure 3.14. Final Miami mound configuration at 3 months

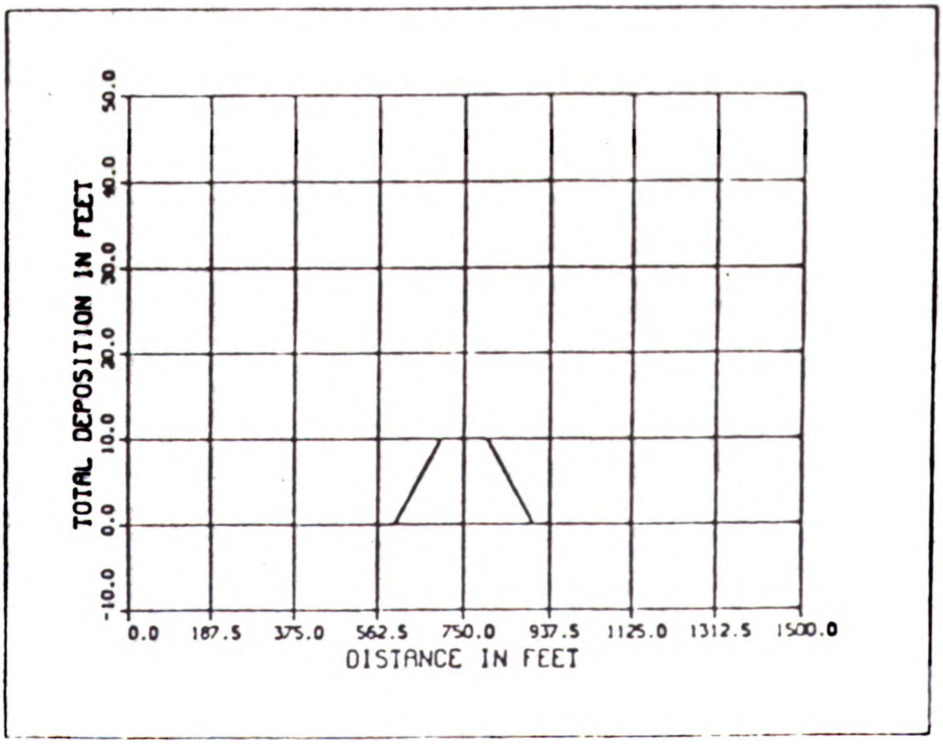


Figure 3.15. Time history of long-term erosion of the Miami mound

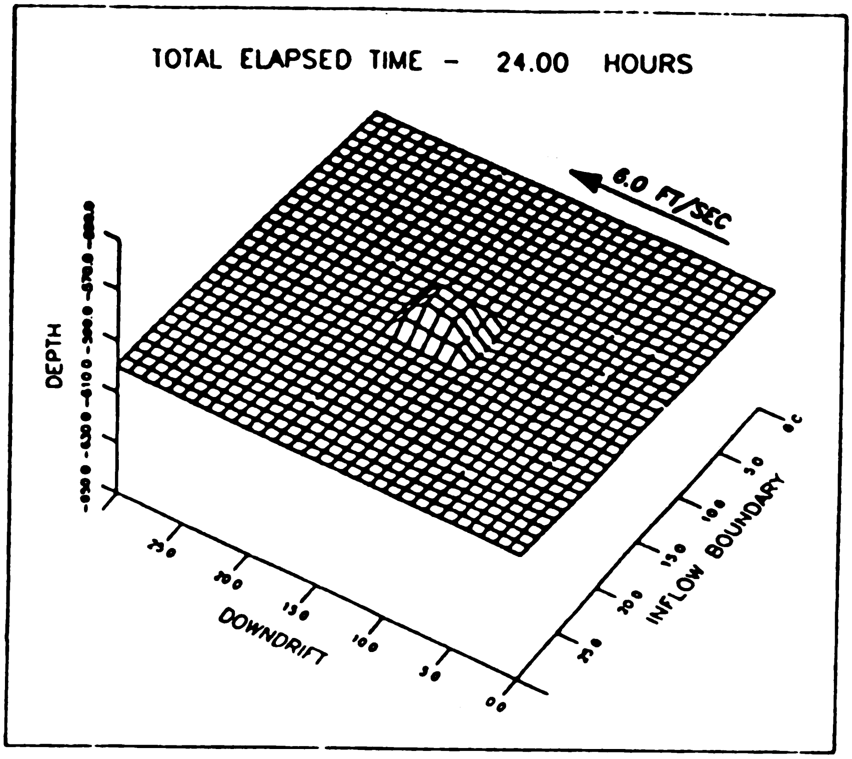


Figure 3.16. Final (24 hr) Fort Pierce storm mound configuration

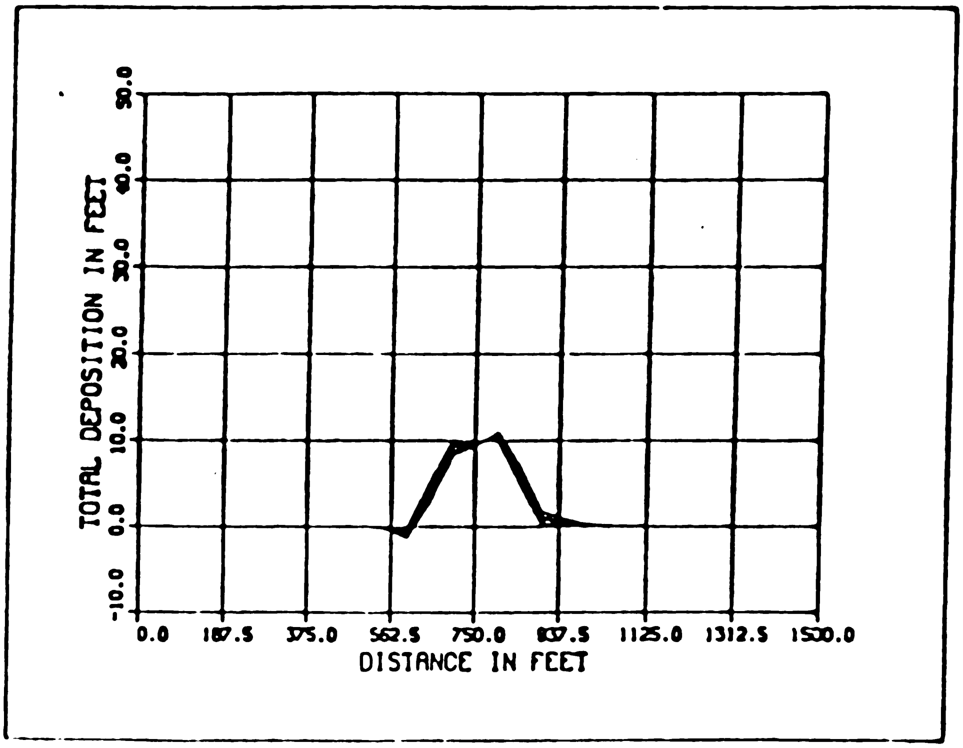


Figure 3.17. Time history of storm erosion of Miami mound

PART IV: CONCLUSION

81. The purpose of this investigation is to determine whether sediment from the proposed Miami and Fort Pierce disposal sites could be transported onto the sensitive near-shore coral reefs. Numerical modeling techniques were utilized to answer these questions. The approach taken was first to review the available literature and document the magnitude of velocities which are representative of each site. The question of reef contamination was then addressed in a two-phase modeling approach. In the short-term analysis, the actual disposal operation was modeled to determine whether material from the descending sediment plume could be catrried in suspension by the ambient velocity field onto the reefs before settling into the disposal site. The long-term investigation computes sediment transport and the associated erosion and deposition of the disposal mound as a function of the local velocity field. Results of the study indicate that neither the Miami nor the Fort Pierce site pose an environmental threat to the reef areas. These results are briefly summarized below.

82. The first level of investigation requires the defining of a non-storm velocity field for both proposed disposal sites. Existing velocity records were extensively examined to quantify a depth-averaged velocity field which would represent the most severe reef-directed currents. The approach is based on the assumption that shore parallel or offshore directed velocities present no environmental threat to the reefs but that a worst case condition of maximum shoreward directed velocities could possibly effect the reef areas. The review of data showed that a maximum depth-averaged, velocity of 0.97 ft/sec (30 cm/sec) and 1.64 ft/sec (50 cm/sec) was representative of the Fort Pierce and Miami sites. In order to simulate a more extreme condition, larger values of 2.79 ft/sec (85 cm/sec) for Miami and 1.97 ft/sec (60 cm/sec) for Fort Pierce were selected for the short-term simulation phase.

83. The short-term modeling of the disposal operation shows that most of the material from the disposal load settles into a mound within several hours after the initial release of sediment from the dredge. Model results indicate the maximum distance from the barge showing deposition in excess of 0.01 ft was 1600 ft for Miami and 400 ft for Fort Pierce. The silt and clay portion of the disposal load creates a suspension cloud or turbidity plume

which is transported toward the reefs by the specified ambient currents. This cloud increases in size and decreases in concentration with distance from the point of disposal. The concentration of the suspended sediment cloud was computed at five specified depths for each site simulation. Results at the conclusion of the simulation indicate maximum concentrations above background levels at the reef (taken to be approximately 3 miles from the disposal area) to be 0.00000089 mg/l at a depth of 200 feet for the Miami site. This value corresponds to an elapsed time of 1.66 hours after the initial sediment release. At 2.25 hours after disposal, a maximum concentration of 0.0000017 mg/l at a depth of 30 ft was computed for the Fort Pierce site. As shown, both values are less than one part per million. The short-term modeling efforts, therefore, indicate that the local ambient velocity fields are not adequate in magnitude to transport any significant amount of material from the dumping operation onto the reef area.

84. The long-term modeling effort was conducted to determine whether a disposal mound is stable over long periods of time. Two types of simulations were conducted. A long duration simulation of a specified mound configuration was conducted for each site using a reef directed non-storm depth-averaged velocity field of 0.97 ft/sec (30 cm/sec) and 1.64 ft/sec (50 cm/sec) for the Fort Pierce and Miami sites. Results of these simulations show that the local velocity field at Miami is below the threshold value required for eroding and transporting material, i.e., a 3-month simulation showed no erosion of a mound located in 600 ft of water. The mound at Fort Pierce was shown to erode, deform, and migrate at a rate of approximately 2-3 ft/day. These results were based on a 1-year simulation in which the centroid of the mound moved approximately 700 ft. Additional shorter duration simulations were made for each site in order to investigate storm related transport of material from the mound onto the reefs. A 24-hour sustained storm surge velocity of 4.0 ft/sec for Fort Pierce and 6.0 ft/sec for Miami was input to the long-term sediment transport model. Results for the Fort Pierce simulation show that material was moved a maximum distance of approximately 550 ft in 24 hours. The Miami simulation showed that essentially no material was transported as a result of the surge. Conclusions of the long-term simulation indicate that sediment will be transported from the Fort Pierce site during both ambient and storm conditions, but that the rate of movement should not effect the reef system.

For the proposed Miami site, simulations show that local velocity fields are simply not adequate to move material in 600 ft of water.

85. The simulation approach taken in this study involves the specification of a local velocity field directed to maximize the transport of material from the disposal site onto the sensitive reef area. Numerical simulations are used to evaluate whether this velocity field is adequate to contaminate the coral reef with dredged material. The disposal operation and the disposal mound are modeled as a potential source of contamination. Both the short-term disposal and long-term erosion simulations of sediment transport as a function of local velocity fields indicate little possibility of reef contamination as a direct result of either proposed Miami or Fort Pierce disposal sites.

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APPENDIX D

Site Management and Monitoring Plan

Fort Pierce

Ocean Dredged Material Disposal Site

1993

TABLE D-1: Fort Pierce Dredge Material Disposal Volumes and Site Locations 1949-1990.

Completion Date	Volume (cubic yards)	Composition	Disposal Site
1949	164,423	not known	Ocean
Not known	63,412	" "	"
Not known	153,190	" "	"
1955	76,700	" "	"
1956-57	73,656	" "	"
1958	6,587	" "	"
1959	23,988	" "	"
1966	184,916	" "	"
1973-74	219,000	" "	Beach/Upland
1974	12,276	Sand	Ocean
1976	14,566	Sand	Ocean
1978	49,773	Sand	Beach
1980	14,592	Sand/Shell	Ocean
1982-83	106,268	Silty Sand	Ocean
1985	11,000	Shell/Sand	Ocean
1987	29,773	Sand	Beach
1988-89	47,792	Sand	Beach
1990	55,700	Sand	Beach

No restrictions are presently placed on disposal volumes. Disposal of unrestricted volumes is dependent upon results from future monitoring surveys.

<u>Material suitability</u>. Material from two sources are to be placed at the site , i.e. construction or new work dredged material and maintenance dredged material. These materials will consist of mixtures of silt, clay and sand in varying percentages.

The disposition of any significant quantities of beach compatible sand from future projects will be determined during permitting activities for any such projects. It is expected that the State of Florida will exercise its authority and responsibility, regarding beach nourishment, to the full extent during any future permitting activities. Utilization of any significant quantities of beach compatible dredged material for beach nourishment is strongly encouraged and supported by EPA. Disposal of coarser material should be planned to allow the material to be placed so that it will be within or accessible to the sand-sharing system, to the maximum extent practical, and following the provisions of the Clean Water Act.

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1958	6,587	" "	"
1959	23,988	" "	"
1966	184,916	" "	"
1973-74	219,000	" "	Beach/Upland
1974	12,276	Sand	Ocean
1976	14,566	Sand	Ocean
1978	49,773	Sand	Beach
1980	14,592	Sand/Shell	Ocean
1982-83	106,268	Silty Sand	Ocean
1985	11,000	Shell/Sand	Ocean
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In addition, the suitability of dredged material for ocean disposal must be verified by the COE and agreed to by EPA prior to disposal. Verification will be valid for three years from the time last verified. Verification will involve: 1) a case-specific evaluation against the exclusion criteria (40 CFR 227.13(b)), 2) a determination of the necessity for bioassay (toxicity and bioaccumulation) testing for non-excluded material based on the potential for contamination of the sediment since last tested, and 3) carrying out the testing and determining that the non-excluded, tested material is suitable for ocean disposal.

Documentation of verification will be completed prior to use of the site. Documentation for material suitability for dredging events proposed for ocean disposal more than 5 years since last verified will be a new 103 evaluation and public notice. Documentation for material suitability for dredging events proposed for ocean disposal less than 5 years but more than 3 years since last verified will be an exchange of letters between the COE and EPA.

Should EPA conclude that reasonable potential exists for contamination to have occurred, acceptable testing will be completed prior to use of the site. Testing procedures to be used will be those delineated in the 1991 EPA/COE Dredged Material Testing Manual and 1992 Regional Implementation Manual. Only material determined to be suitable through the verification process by the COE and EPA will be placed at the designated ocean disposal site.

Time of disposal. At present no restrictions have been determined to be necessary for disposal related to seasonal variations in ocean current or biotic activity. As monitoring results are compiled, should any such restrictions appear necessary, disposal activities will be scheduled so as to avoid adverse impacts. Additionally, if new information indicates that endangered or threatened species are being adversely impacted, restrictions may be incurred.

Disposal Technique. Prior to disposal of each dredging project, an agreement will be reached between the EPA and COE concerning the exact placement for each project with permits/contracts specifying the exact locations for disposal. Fine-grained materials will be placed in the southeastern corner in accordance with Figure 1 to afford greater protection of live bottoms to the northwest.

SITE MONITORING

Part 228 of the Ocean Dumping Regulations establishes the need for evaluating the impacts of disposal on the marine environment. Section 228.9 indicates that the primary purpose of this monitoring program is to evaluate the impact of disposal on the marine environment by referencing the monitoring results to a set of baseline conditions. Section 228.10(b) states that in addition to other necessary or appropriate considerations, the following types of effects will be considered in determining to what extent the marine environment has been impacted by materials disposed at an ocean site (excerpted):

1. Movement of materials into estuaries or marine sanctuaries, or onto ocean-front beaches, or shorelines;

2. Movement of materials toward productive fishery and shellfishery areas;

3. Absence from the disposal site of pollution-sensitive biota characteristic of the general area;

4. Progressive, non-seasonal, changes in water quality or sediment composition at the disposal site, when these changes are attributable to materials disposed of at the site;

5. Progressive, non-seasonal, changes in composition or numbers of pelagic, demersal, or benthic biota at or near the disposal site, when these changes can be attributed to the effects of materials disposed at the site; and

6. Accumulation of material constituents (including without limitation, human pathogens) in marine biota at or near the site.

Part 228.10(c) states: "The determination of the overall severity of disposal at the site on the marine environment, including without limitation, the disposal site and adjacent areas, will be based on the evaluation of the entire body of pertinent data using appropriate methods of data analysis for the quantity and type of data available. Impacts will be classified according to the overall condition of the environment of the disposal site and adjacent areas based on the determination by the EPA management authority assessing the nature and extent of the effects identified in paragraph (b) of this section in addition to other necessary or appropriate considerations."

The monitoring approach for the Fort Pierce ODMDS will be based on the attached generic figure entitled "ODMDS Monitoring" (Figure 2). Frequency of monitoring will be based on frequency of disposal and previous monitoring results.

<u>Baseline Monitoring</u>. The results of investigations presented in the designation EIS will serve as the main body of baseline data for the monitoring of the impacts associated with the use of the Fort Pierce ODMDS (see DEIS).

A bathymetric survey will be conducted by the COE or site user prior to dredging cycle or project disposal. The number of transects required will be dependent upon the length of the disposal operation and the quantity of material proposed for disposal. The surveys will be taken along lines spaced at 200-foot intervals or less and be of sufficient length to adequately cover the disposal area. Accuracy of the surveys will be ± 1.0 feet. These surveys will be referenced to the appropriate datum and corrected for tide conditions at the time of survey. No additional pre-disposal monitoring at this site is proposed.

Disposal Monitoring. For all disposal activities, the dredging contractor will be required to prepare and operate under an approved electronic verification plan for all disposal operations. As part of this plan, the contractor will provide an automated system that will continuously track the horizontal location and draft condition (vertical) of the disposal vessel from the point of dredging to the disposal area, and return to the point of dredging. Required digital data are as follows:

(a) Date;

(b) Time;

(c) Vessel Name;

(d) Captain of Vessel;

(e) Number of Scows in tow and distance from vessel or other vessel used;

(f) Vessel position, every five (5) minutes (time recorded) when within the channel limits, every two (2) minutes between the dredging area and the disposal area, every thirty (30) seconds when within the disposal area limits, where disposal occurs, and similar intervals on the return of vessel and scow(s) to the dredging area;

(g) Actual location at points of initiation and completion of disposal event;

(h) Dredge scow draft, coincidental measurement with "f" above;

(i) Volume of material dispos ed; and

(j) Disposal technique used.

As a follow-up to the baseline bathymetric survey, the COE or other site user will conduct a survey after disposal. The number of transects required will be the same as in the baseline survey. The user will be required to prepare and submit to the COE daily reports of operations and a monthly report of operations for each month or partial month's work. The user is also required to notify the COE and the EPA if a violation of the permit and/or contract conditions occur during disposal operations.

Material Tracking and Disposal Effects Monitoring. Based on the type and volume of material disposed, various monitoring surveys could be used to determine if and where the disposed material is moving, and what environmental effect the material is having on the site and adjacent area. Previous studies on this site have begun these tasks. A tiered approach will be used to determine the level of monitoring effort required following each future disposal event. An interagency SMMP team, consisting of representatives of EPA, COE, State of Florida and the user(s), will be established to finalize this SMMP. Other agencies, such as National Marine Fisheries Service (NMFS), will be asked to participate where appropriate. This SMMP team would evaluate existing monitoring data, the type of proposed disposal (i.e., O&M vs. construction), the type of material (i.e., sand vs. mud), location of placement within the ODMDS and quantity of proposed material. This team would then make recommendations to the EPA and the COE on appropriate monitoring techniques, level of monitoring, significance of results and potential management options.

The monitoring program proposed for the area addresses possible changes in bathymetric, sedimentological, chemical, and biological aspects of the ODMDS and surrounding area as a result of the disposal of dredged material at the site. Proposed monitoring includes a study to determine ambient levels of suspended load and levels during disposal operations at the nearest resource. In addition, a sediment tracking survey and subsequent benthic assessment will be completed within 2 to 4 years of final designation. Additional sampling techniques such as remote bottom video and/or side scan sonar may be used as deemed necessary by SMMP team to determine the overall effects of disposal in the Fort Pierce ODMDS. Should the future disposal at the permanently-designated ODMDS result in unacceptable adverse impacts, further studies may be required to determine the persistence of these impacts, the extent of the impacts within the marine system, and/or possible means of mitigation. In addition, the management plan presented may require revision based on the outcome of the monitoring program.

Reporting and Data Formatting. Any data collected will be provided to federal and state agencies as appropriate. Data will be provided to other interested parties requesting such data to the extent possible. Data will be provided for all surveys in a report generated by the action agency. The report should indicate how the survey relates to the SMMP and list previous surveys at the Fort Pierce ODMDS. Reports should be provided within 90 days (bathymetric surveys within 45 days) after completion. Exception to the time limit will be possible if outside contracts stipulate a longer period of time. The report should provide data interpretations, conclusions, and recommendations, and should project the next phase of the SMMP.

Modification of ODMDS SMMP. A need for modification of the use of the Fort Pierce ODMDS because of unacceptable impacts is not anticipated. However, should the results of the monitoring surveys indicate that continuing use of the ODMDS would lead to unacceptable impacts, then either the ODMDS Management Plan will be modified to alleviate the impacts, or the location of the ODMDS would be modified.

MATERIAL PLACEMENT
FORT PIERCE
ODMDS

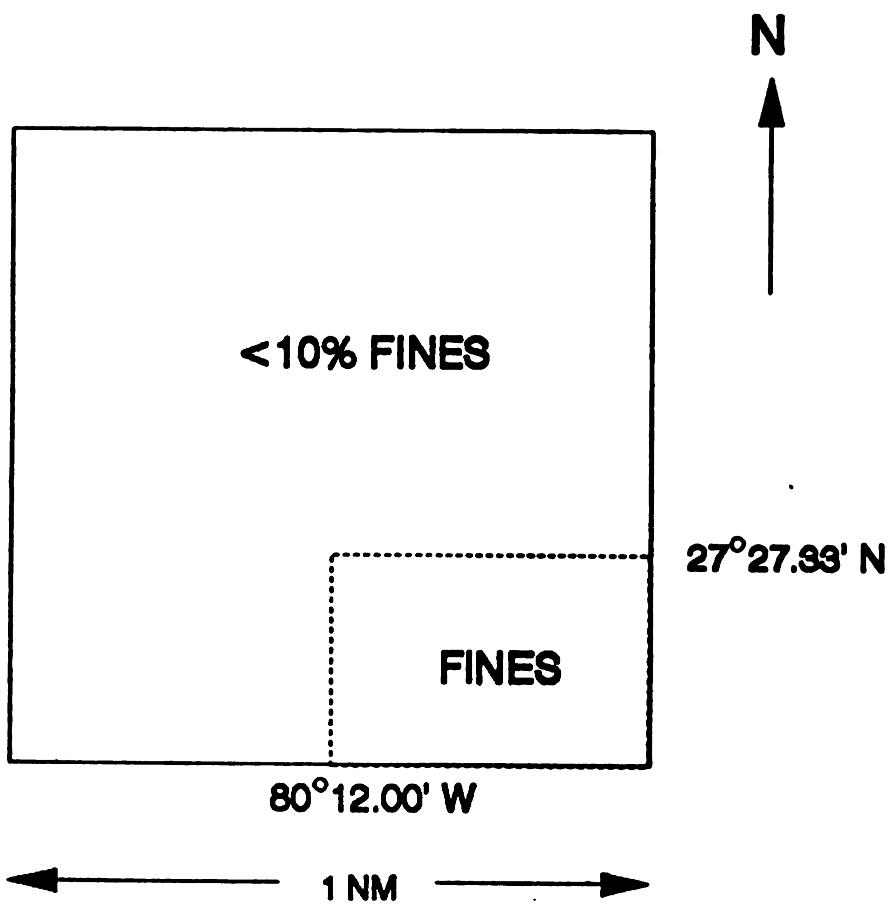


FIGURE 1

ODMDS MONITORING

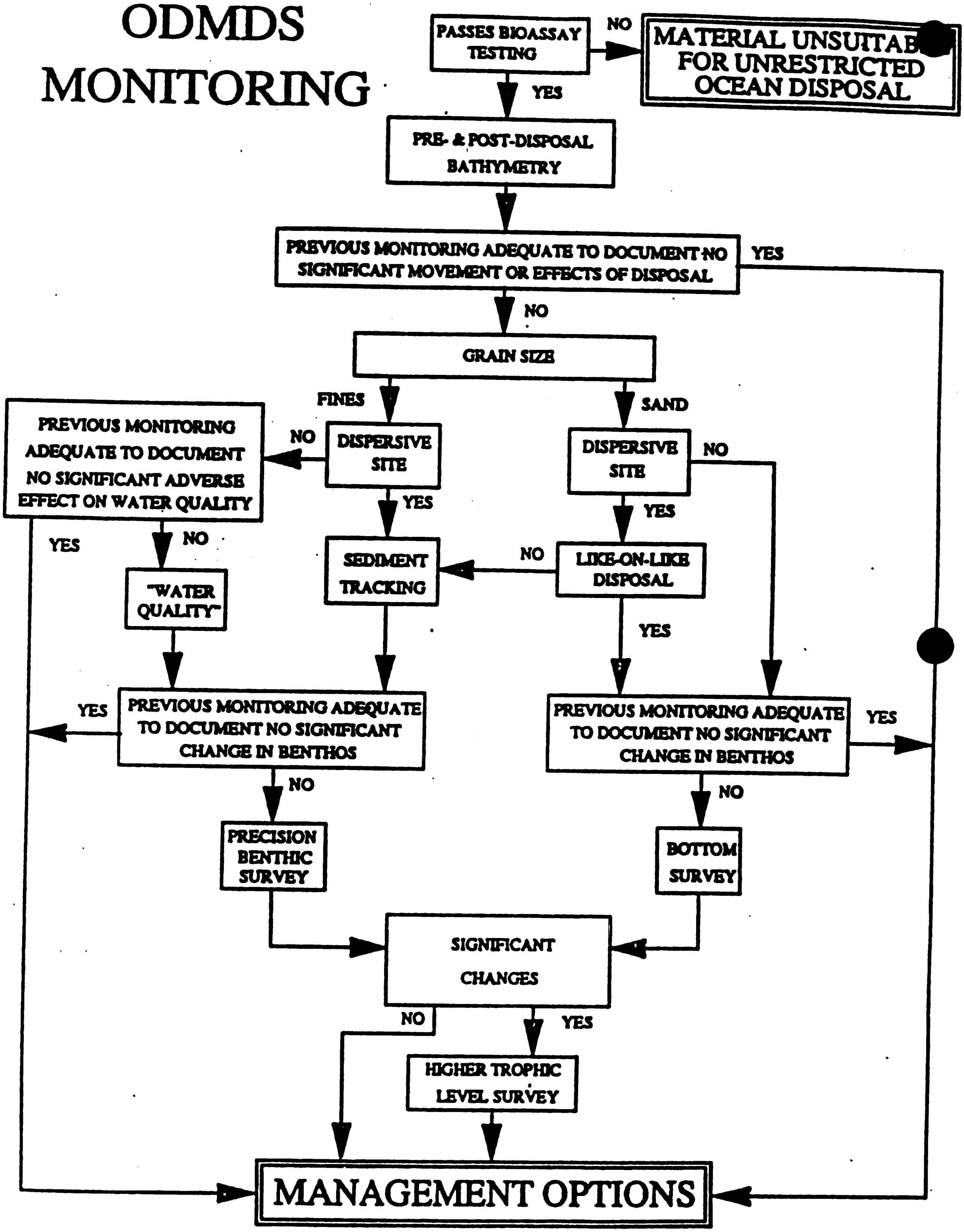


FIGURE 2

APPENDIX E

Initial Video Mapping Survey Report

Fort Pierce

Ocean Dredged Material Disposal Site

1991

INITIAL SURVEY REPORT
FT. PIERCE, FLORIDA ODMDS
VIDEO MAPPING SURVEY
JANUARY 28-30, 1991

Prepared by
U.S. EPA, REGION IV, ESD
COLLEGE STATION ROAD
ATHENS, GEORGIA

for

OFFICE OF MARINE & ESTUARINE PROTECTION
OMEP WH55F, 401 M STREET, SW
WASHINGTON, DC 20460

Submitted by: Philip Murphy 2/5/91
Mission Chief Scientist, EPA, Athens, Ga. Date

Received by: ______________________________
Chief Marine Scientist, Washington DC Date

Ft. Pierce, Florida ODMDS
Video Mapping Survey
Initial Survey Report

INTRODUCTION

During the period January 27-30, 1991 personnel from the Environmental Protection Agency, Region IV, Environmental Services Division and Water Division conducted a video mapping survey of the Ft. Pierce, Florida ODMDS. The work was conducted to supplement and upgrade site video clearing which was initially conducted under contract by the Jacksonville District, Corps of Engineers. Video transects at that time were limited in their extent of area coverage as well being non-definitive due to poor visibility and excessive boat speed.

OBJECTIVES

The objective of the survey, as specified in the survey plan for the cruise, was to map the ODMDS using continuous video supplemented by selective 35mm still camera photos of unique features. Video coverage was proposed along transects with a line spacing of approximately 700 feet. Initial plans called for transect orientation along the east/west axis but due to currents at the time of the survey, transect orientation was repositioned along the north/south axis. Each transect was to be a minimum of two nautical miles with additional coverage afforded by continuing visual coverage during ship turns between each transect, thus adding an addition quarter mile to half mile to each transect.

All objectives of the survey were accomplished. All predetermined transects were completed and, because of live bottom findings within the northern sector of the survey area, additional transects along the western and southern sides of the survey area were conducted to clear an area for possible repositioning of the site to gain separation from live bottom habitat.

Figure 1 depicts the survey configuration and transects. Observed live bottom areas are indicated by small blocks imposed on the ship track. The "Y' marks are positions, located generally 700 feet apart, where coordinates and visual observations were manually logged and voice recorded on the video tape for reference. A total of 23 transects were completed with 420 logged coordinates of observed bottom features.

PROBLEMS ENCOUNTERED

The Ft. Pierce ODMDS survey marked the first test of the new Hydro Vision pan and tilt camera system purchased by Region IV and assigned to the OSV Anderson. Unfortunately, upon first deployment, the camera system suffered a "ground loop" electrical short which delayed start of the video survey for one and one-half days. To temporarily correct the problem, Hydro Vision International air freighted the necessary parts overnight from Houston. With the appropriated insulators installed, the mission was accomplished well ahead of the actually expected survey time. This factory error in camera design will be corrected by Region IV personnel shipping the camera back to the manufacturer for repair.

RECOMMENDATIONS FOR IMPROVEMENT IN SHIPBOARD DATA ACQUISITION

Region IV and Headquarters have been working for over two years having Battelle Ocean Science develop a "VIDLOG" tracking and data logging system for video mapping surveys. This system still remains unusable and, accordingly, we are still logging data and coordinates manually. Additionally, with the video camera and lighting controls now installed in the wet lab, thus removed from the shipboard computers, it is essential that an additional computer and navigation plotter be installed in conjunction with the video system if we are ever to achieve the efficiency we have planned for the video surveys.

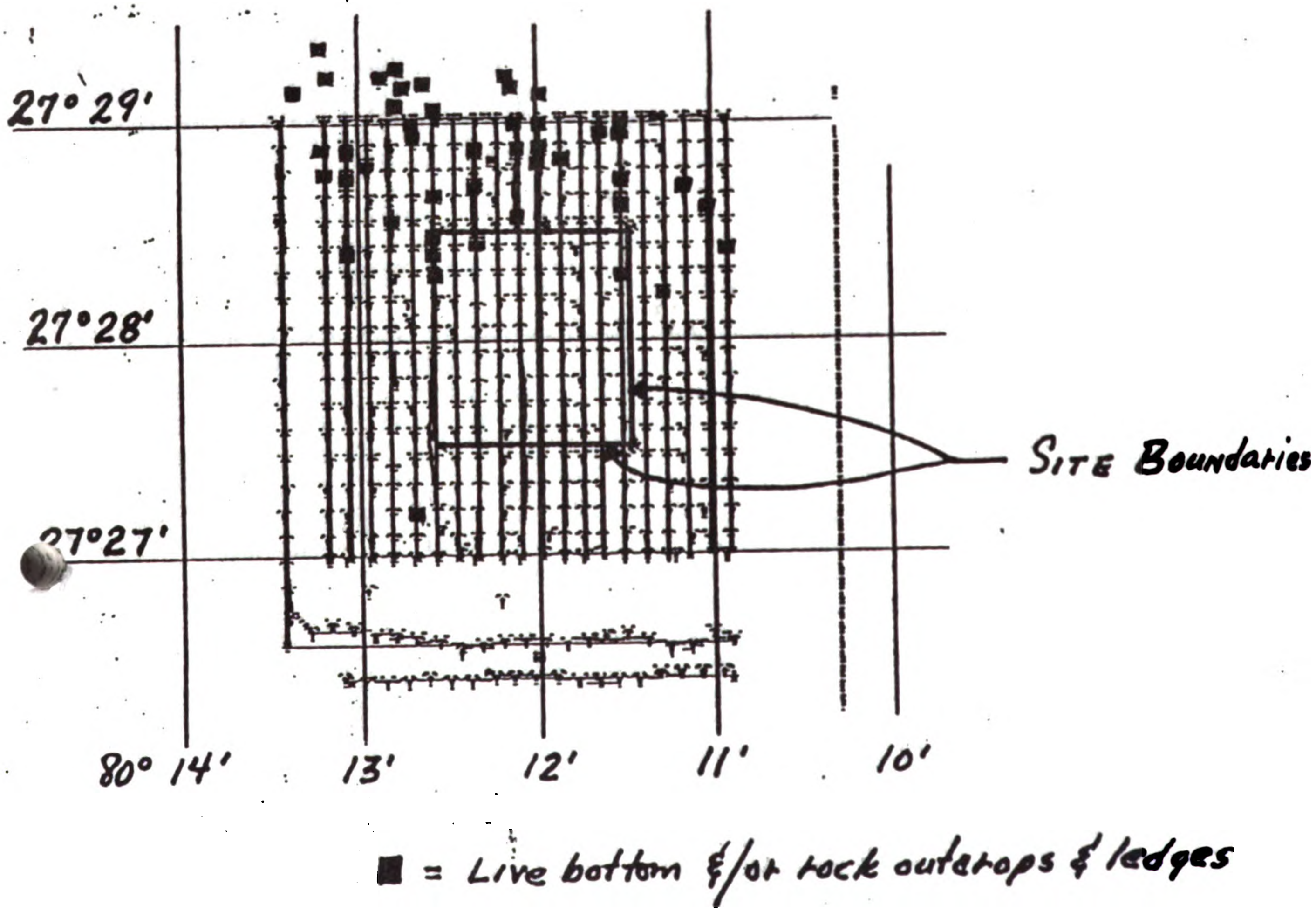
Beginning in April of this year (1991) we have three extensive video and side scan sonar surveys back to back here in Region IV. It will be immensely beneficial to have the vidlog program and video station, with its computer, completed and operational before these surveys begin.

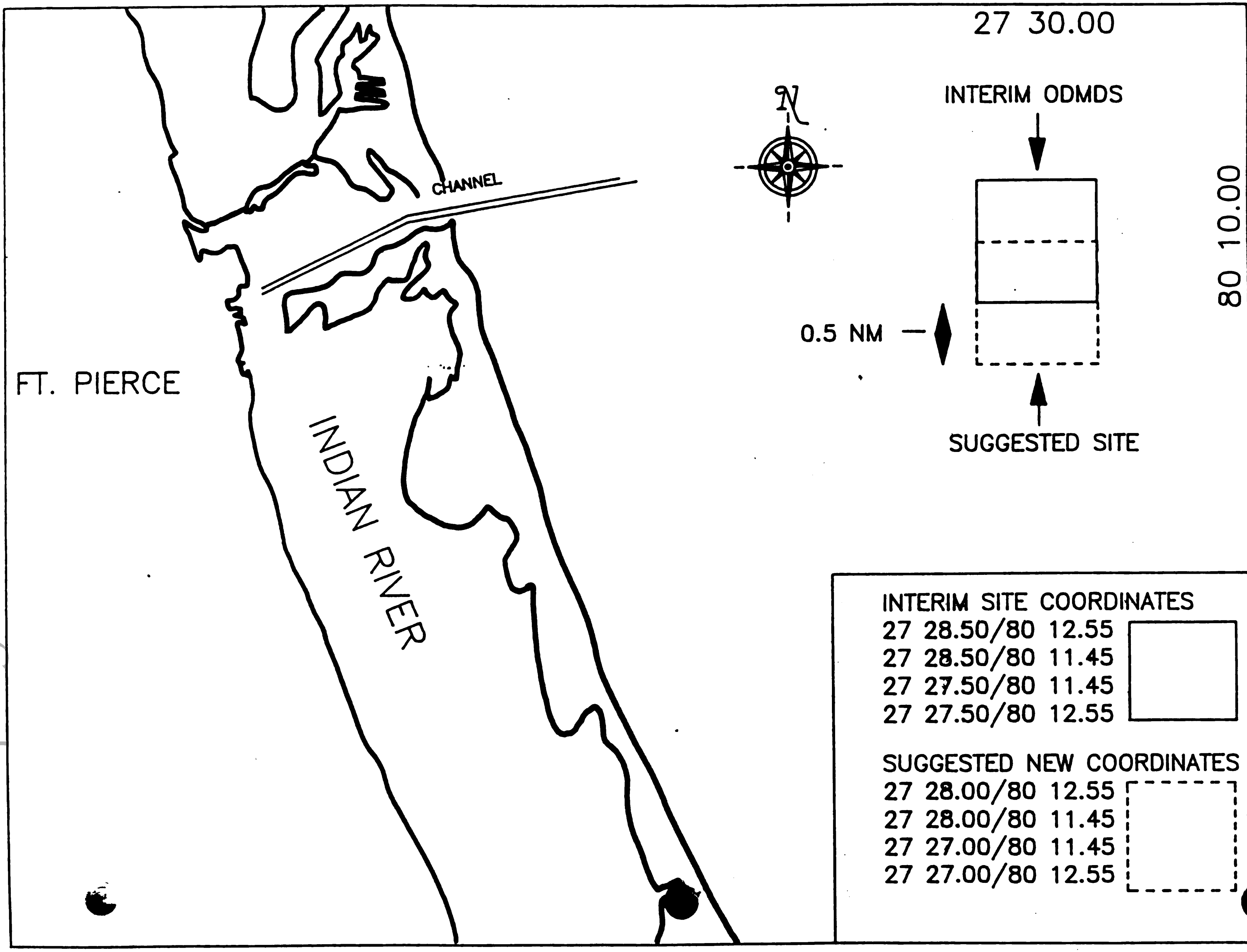
PROJECT PERSONNEL

In addition to the OSV Anderson crew, the scientific crew from EPA, Region IV, included the following personnel:

Philip Murphy - EPA/ESD, Athens, Ga.
Russell Todd - EPA/ESD, Athens, Ga.
Gary Collins - EPA/WD, Atlanta, Ga.
Catherine Fox - EPA/WD, Atlanta, Ga.

FIGURE 1. FT. PIERCE, FLORIDA, ODMDS, VIDEO SURVEY TRANSECTS WITH LIVE BOTTOM LOCATIONS, JANUARY 29-30, 1991.





27 30.00
80 10.00
INTERIM ODMDS
SUGGESTED SITE
0.5 NM
N
CHANNEL
FT. PIERCE
INDIAN RIVER
INTERIM SITE COORDINATES
27 28.50/80 12.55
27 28.50/80 11.45
27 27.50/80 11.45
27 27.50/80 12.55
SUGGESTED NEW COORDINATES
27 28.00/80 12.55
27 28.00/80 11.45
27 27.00/80 11.45
27 27.00/80 12.55

APPENDIX F

Short-Term Modeling

Worst Case Sediment Scenario

Fort Pierce

Ocean Dredged Material Disposal Site

November, 1992

APPENDIX F
Short-Term Modeling
Worst Case Sediment Scenario

Introduction

The U.S. Army Corps of Engineers Waterways Experiment Station (WES) prepared a report, Evaluation of the Dispersion Characteristics of the Miami and Fort Pierce Dredged Material Disposal Sites, for the U.S. Army Engineer Jacksonville District (EIS Appendix C). The report used a two-phase numerical modeling methodology utilizing the Disposal From an Instantaneous Dump (DIFID) model for calculating the short-term fate and a coupled hydrodynamic/sediment transport model for computing the long-term fate of the disposed material. The sediment distribution used in the models was 10 percent silt and clay and 90 percent sand. A more conservative or worst case distribution for the Fort Pierce sediment is 10 percent sand and 90 percent silt and clay. This report presents EPA Region IV's results using an updated DIFID model (version 4.10) with the conservative sediment distribution. A description of the model can be found in the WES report in Appendix C.

Model Parameters

The selected composition of the disposal load used by WES for the Fort Pierce site is shown in Table F-1.

Table F-1
Original Characterization of Dredged Material for Fort Pierce

Description	Density g/cc	Volume ratio	Fall Vel. ft/sec	Voids Ratio	Cohesive
Sand	2.65	0.63	0.04660	0.00	No
Silt-Clay	2.65	0.07	0.00256	1.00	Yes
Water	1.023	0.30			

The revised conservative composition of the disposed load for the Fort Pierce site is shown in Table F-2.

Table F-2
Revised Characterization of Dredged Material for Fort Pierce

Description	Density g/cc	Volume ratio	Fall Vel. ft/sec	Voids Ratio	Cohesive
Sand	2.65	0.03	0.04660	0.00	No
Silt-Clay	2.65	0.27	0.00256	1.00	Yes
Water	1.023	0.70			

These values were obtained from the Corps of Engineers Jacksonville District. The volume of solids was reduced to 30 percent to reflect the high percentage of fine grain materials. All other parameters and coefficients in the simulation were maintained at the values reported in the WES report.

Results

Results presented here are in a similar format as those presented in the WES report for easy comparison. The results of the concentration computation are used to produce a concentration (in ppm or mg/l above ambient conditions) versus distance relationship along the axis of the grid (direction of prevailing current) at five discrete depths of 10, 20, 30, 40 and 50 feet for four specified time periods. These results are shown in Figure F-1. The dump in this simulation occurs at approximately 0.4 nmiles from the origin. Maximum concentrations are found at depths of 30 feet and do not exceed 5 mg/l beyond 2 nmiles from the dump site. A concentration summary is given in Table F-3. The concentration values in this report differ from those in the WES report by orders of magnitude. The WES values were reported in units of mg/l, but were actually unitless and represenative of a solids volumentric ratio. The WES values should therefore be multiplied by the density of the solids to obtain concentration values in units of mg/l.

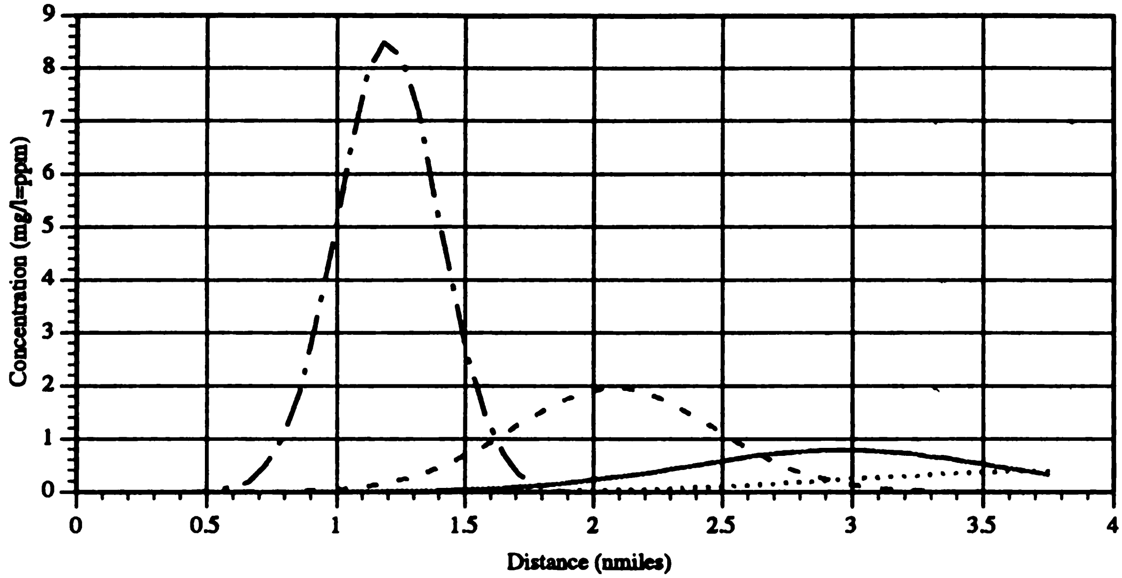
Table F-3
Summary of Computed Maximum Suspended Sediment Concentration
(Concentration in mg/l or ppm above ambient)

Time(sec)/Approximate Distance from Dredge Dump(nmiles)

Depth (ft)	2700 0.85	5400 1.78	8100 2.64	10800 3.42
10	8.48	1.96	0.81	0.41
20	22.3	5.04	2.11	1.07
30	34.6	7.96	3.19	1.67
40	29.2	6.89	2.93	1.48
50	16.7	3.70	1.56	0.78

A plot of the total deposition in feet versus distance along the axis of the disposal grid is shown in Figure F-2. Again, the dump location occurs at approximately 0.4 nmiles from the origin. Accumulation does not exceed 0.10 feet per dump at distances greater than approximately 650 feet from the disposal site.

Fort Pierce Suspended Sediment
Estimated Concentration at 10 Ft Depth



Fort Pierce Suspended Sediment
Estimated Concentration at 20 Ft Depth

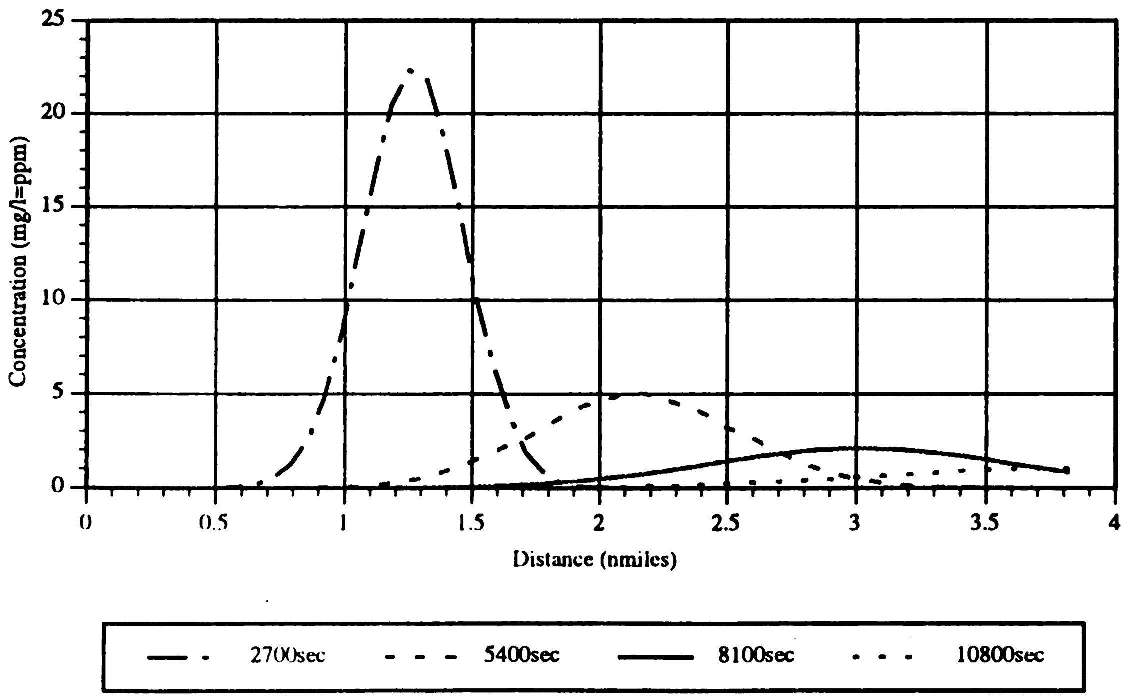
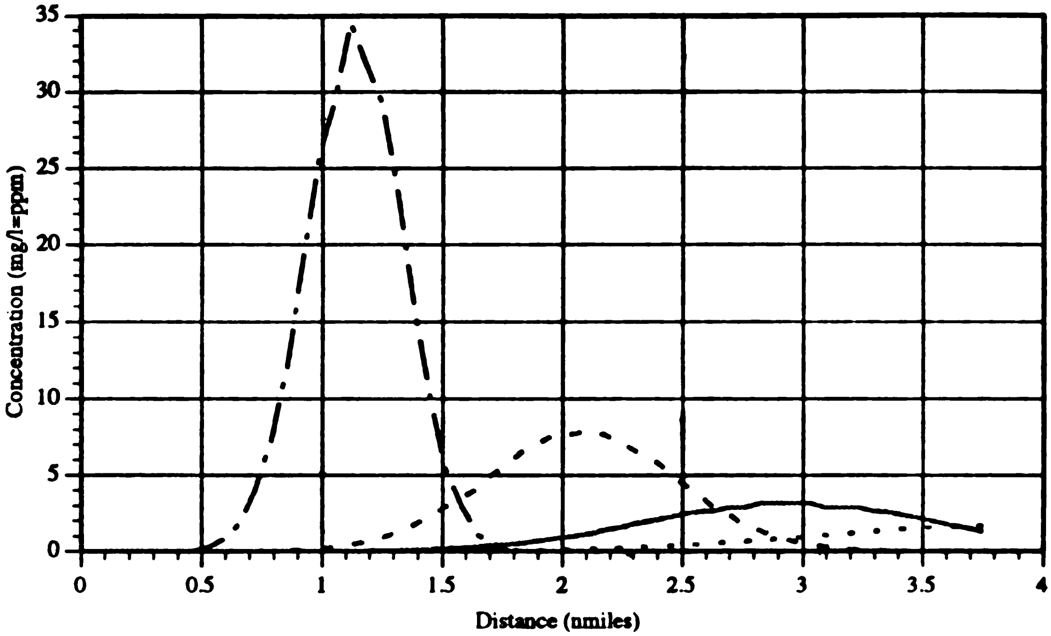


Fig. F-1

Fort Pierce Suspended Sediment
Estimated Concentration at 30 Ft Depth



Fort Pierce Suspended Sediment
Estimated Concentration at 40 Ft Depth

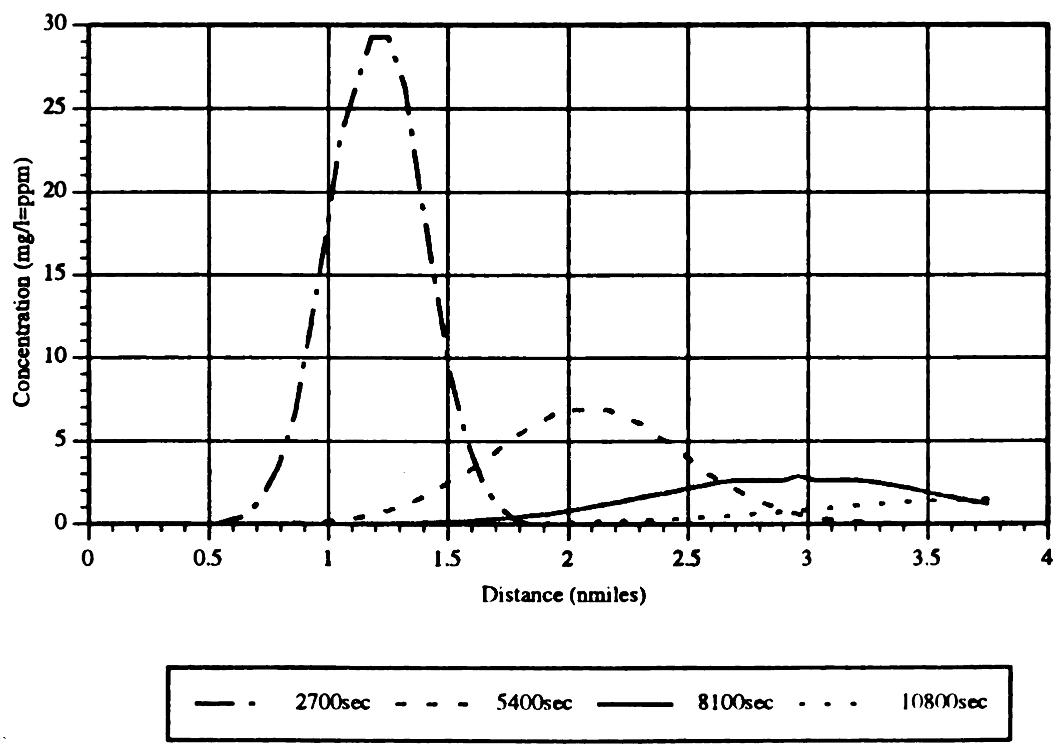


Fig. F-1
Continued

Fort Pierce Suspended Sediment
Estimated Concentration at 50 Ft Depth

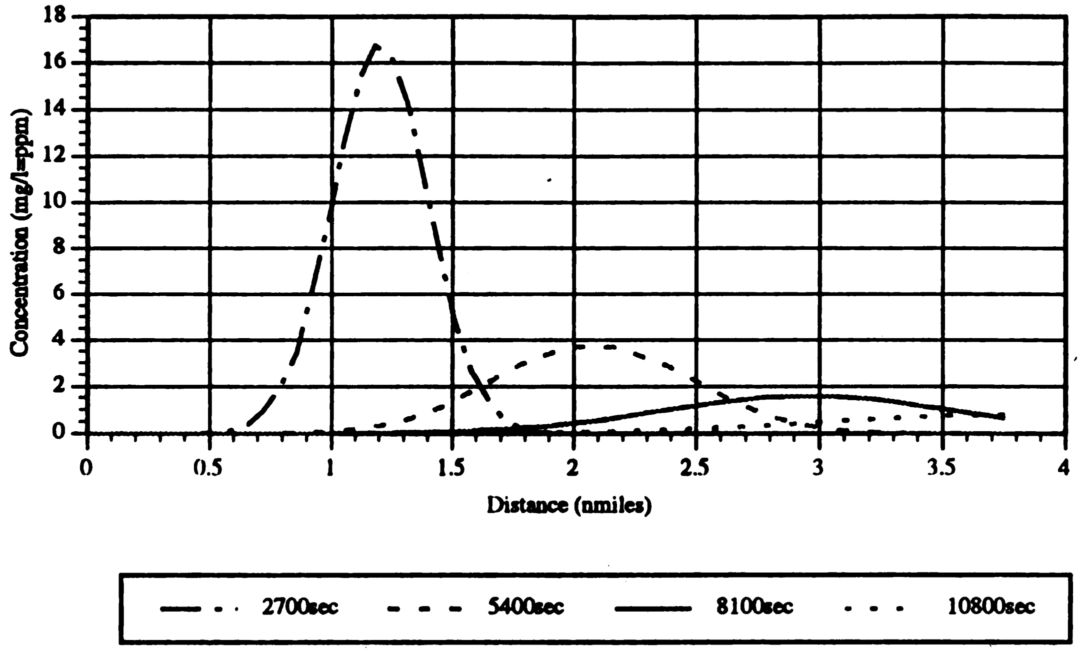


Fig F-1
Continued

Fort Pierce Accumulation on Bttom per Dump
Estimated by ADDAMS Model

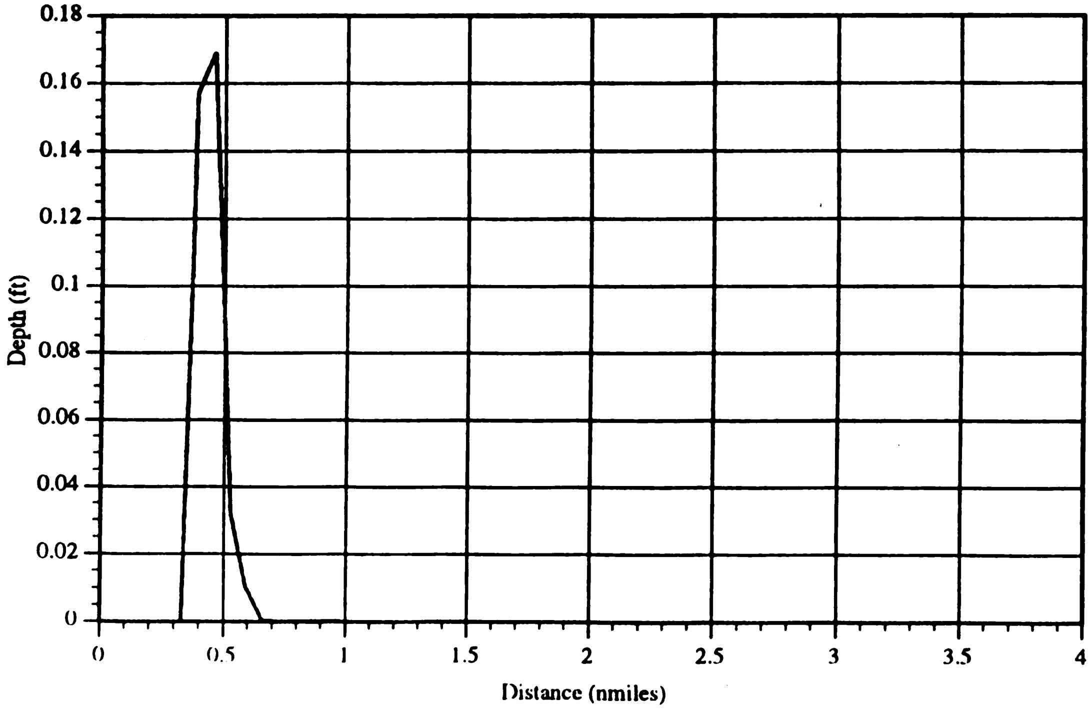


Fig F-2

In addition, suspended sediment concentration above ambient versus time has been plotted for four specific locations of concern in Figure F-3. The four areas correspond to: the live bottom areas found in the northern portion of the interim site, the natural reef described as flat bottom with heavy coral growth, and two artificial reefs. These areas are discussed in the Fort Pierce DEIS in paragraphs 4.43 to 4.46. Depths of 50 feet were used in the model for the live bottom area, the natural reef and the nearest artificial reef. A depth of 30 feet was used for the furthest artificial reef. Distances to the four areas were based on material dumping occurring within the portion of the ODMDS designated for fines (see Appendix D).

The results shown in Figure F-3, are based on three hour cycle periods for dumping. According to the COE Jacksonville District, three hour cycle periods would be typical for material consisting mostly of fines and could continue 24 hours a day. Figure F-3 shows just the first six hours of a dredging operation, but the general trend can be discerned.

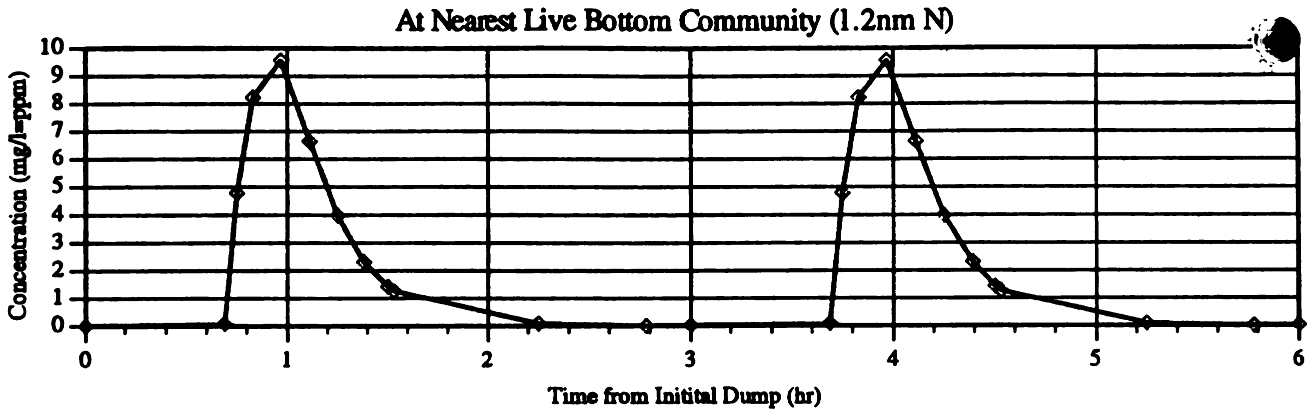
For all four locations, a current of 1.97 feet/sec was assumed in the direction of the amenity. This is highly conservative for the reef community east of the ODMDS and the artificial reef community southeast of the ODMDS. According to the WES report, current meter data for all gages was in a northerly or slightly northwesterly direction. This value was used for these two locations for simplicity and for conservativeness.

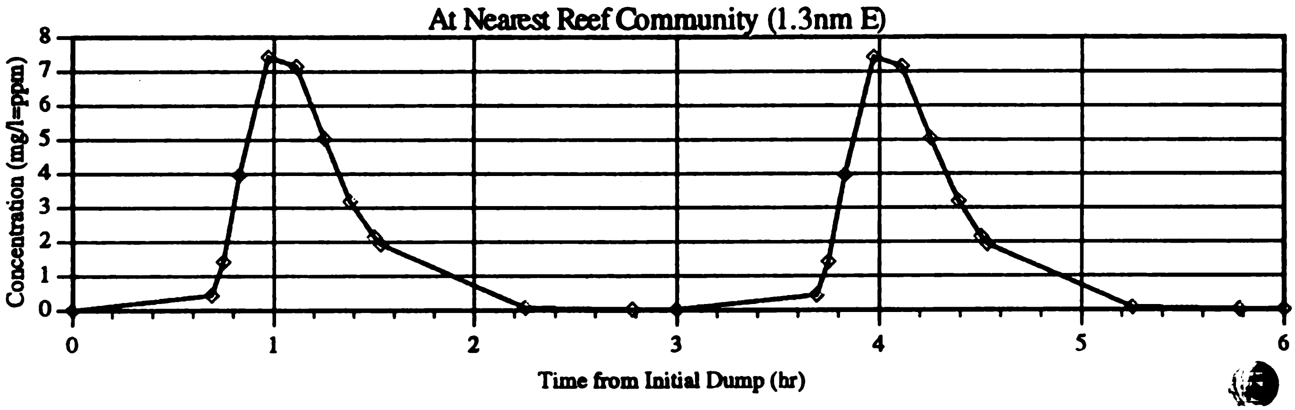
<u>Conclusions</u>

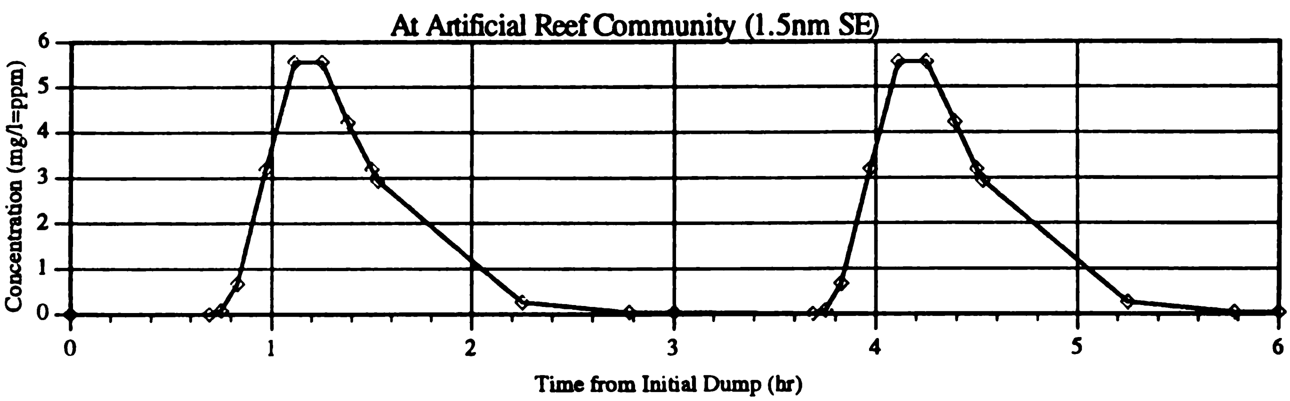
For the first three locations, the above ambient sediment concentrations drop below detectable limits between dumps. For the northwest reef community, concentrations remain above detectable limits after the first dump due to the dispersiveness of the sediment clouds at that distance. However, peak concentrations at this location are low.

In 1985, total suspended solids concentrations and turbidity levels were taken at nine stations in the vicinity of the interim disposal site (Fort Pierce DEIS Appendix A). This data represents only one sample event and is not representative of a seasonal or annual average. However, although the data is limited, it indicates that background suspended sediment concentrations are significantly higher than the short term fluctuations due to the dredge material plume. The background concentrations ranged from five to 24 mg/l with a mean value of 12 mg/l. At the amenity location nearest the ODMDS, concentrations are predicted to exceed 4 mg/l (33% of the recorded mean ambient level) one half hour every three hours. At the furthest location, concentrations will exceed 0.5 mg/l (10% of the recorded low and 4% of the mean ambient level)

Fort Pierce Predicted Suspended Sediment Concentration Above Ambient







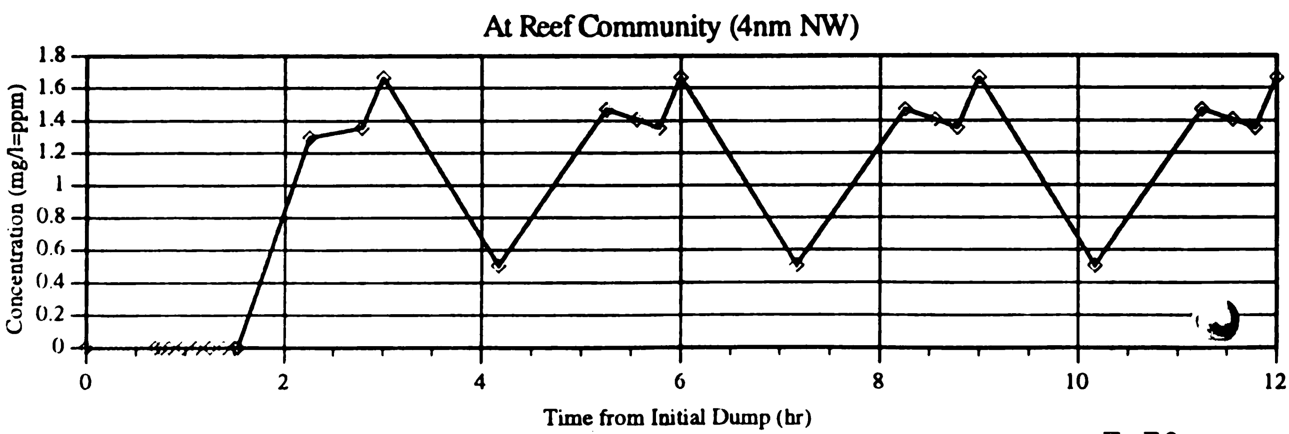


Fig. F-3

continually, but remain below 1.7 mg/l, during operation based on a three hour cycle.

The natural and artificial reefs referred to in paragraphs 4.43 to 4.46 are not scleractinian coral reefs and therefore are not dependent upon the same water quality conditions commonly associated with tropical reef building corals, i.e. clear, low nutrient, warm waters. Most of the organisms comprising the communities found nearby the proposed ODMDS are not likely to be adversely affected by such low predicted suspended sediment loadings.

APPENDIX.G

FORT PIERCE OCEAN DREDGED MATERIAL DISPOSAL SITE DESIGNATION

FLORIDA COASTAL ZONE MANAGEMENT PROGRAM

CONSISTENCY EVALUATION

Submitted by:

U.S. Environmental Protection Agency

Region IV

November 1992

I. INTRODUCTION

The U.S. Environmental Protection Agency (EPA), in cooperation with the U.S. Army Corps of Engineers (COE), has prepared a Draft Environmental Impact statement (DEIS) titled "Draft Environmental Impact Statement For Designation of a Fort Pierce, Florida Ocean Dredged Material Disposal Site." This DEIS evaluates the environmental conditions relevant to the designation of an ocean disposal site offshore Fort Pierce, Florida. Additionally, the DEIS evaluates the proposed Fort Pierce site according to the eleven environmental criteria required for site designations under 40 CFR 228.6 (Ocean Dumping Regulations).

The site proposed for final designation is 0.5 nautical miles south of the Fort Pierce interim site. The total area of the proposed site is 1 square nautical mile (nmi). The coordinates of the site are:

27°28'00"N, and 80°12'55"W;
27°28'00"N, and 80°11'45"W;
27°27'00"N, and 80°11'45"W;
27°27'00"N, and 80°12'55"W

Since September 1949, approximately 900,000 cubic yards of dredged material have been disposed at the interim site.

The site designation is needed in this area to provide an ocean disposal option for dredging projects in the Fort Pierce vicinity. It should be emphasized that final designation of the Fort Pierce site does not by itself authorize any dredging or on-site disposal of dredged material. EPA and the COE must conduct an environmental review of each proposed ocean disposal project. That review ensures that there is a demonstrated need for ocean disposal and that the material proposed for disposal meets the requirements for dredged material given in the Ocean Dumping Regulations.

II. THE FLORIDA COASTAL ZONE MANAGEMENT PROGRAM (CZMP)

There are eight Florida statutes relating to ocean disposal site designations. This assessment discusses how the referenced DEIS for the Fort Pierce site designation will meet the CZMP objectives to protect coastal resources while allowing multiple use of coastal areas. Consult the DEIS for further data and information.

Although the EIS serves a dual role of NEPA documentation for site designation and COE permitting under Section 103 of the Marine Protection, Research, and Sanctuaries Act (MPRSA) of 1972, as amended (see Section 2.01 of DEIS), this CZMP consistency evaluation is only relevant for site designation. Therefore, COE permitting actions will need a separate CZMP consistency evaluation.

A. Chapter 161: Beach and Shore Preservation

The intent of Chapter 161 is the protection of thousands of miles of Florida's coastline by regulating construction activities near and within these areas. The Fort Pierce site designation will, by itself, require no new construction and therefore no related support activities will be subject to the construction regulations in this chapter.

Sediment transport in the vicinity of the site is driven mainly by weather events. Because of this, dispersion of the material can be in any direction. Modelling has indicated that no significant transport of dredged material toward any amenity should occur (Appendix C and F of Fort Pierce EIS). In the event that significant accumulation of the dredged material towards any amenity is evident, use of the site can be modified or terminated by EPA.

B. Chapter 253: State Lands

This chapter addresses the responsibilities of the State Board of Trustees in managing the State sovereign lands by issuing leases, easements, rights of way, or other forms of consent for those wishing to use State lands, including State submerged lands.

Since the Fort Pierce site is not within State waters, Chapter 253 is not relevant.

C. Chapter 258: State Parks and Preserves

Figure 4 in the DEIS locates the Parks and Preserves in the vicinity of the proposed Fort Pierce site. As similarly discussed in Section A above, the distance from these areas to the proposed site should prevent any impacts to these areas from use of the site.

D. Chapter 267: Historic Preservation

There are no known features of historical importance in the vicinity of the proposed site, and therefore it is unlikely that the proposed site designation will result in any impact to these areas. The bottom video survey of the ODMDS did not reveal any new such areas.

E. Chapter 288: Commercial Development and Capital Improvements: Industrial Siting Act

The final designation of the Fort Pierce site provides an environmentally acceptable ocean location for the disposal of dredged material that meets the Ocean Dumping Criteria. If ocean disposal is selected as the most feasible option for a dredged material disposal project, this site designation ensures that an ocean disposal option is available in the area. Therefore, the designation removes one barrier to free and advantageous flow of commerce in the area in that dredging projects and their associated navigational benefits cannot be halted due to the lack of an acceptable ocean disposal site.

The Industrial Siting Act is not applicable to this proposed site designation.

F. Chapter 370: Saltwater Fisheries

Chapter 370 ensures the preservation, management and protection of saltwater fisheries and other marine life. Most commercial and recreational fishing activity in the Fort Pierce vicinity is concentrated in inshore and nearshore waters. The nearest fisheries area is located about 1.3 nmi from the site. In short, the Fort Pierce site does not represent a unique habitat for any of the important commercial or recreational fisheries. Use of the site will smother the non-motile or slow moving benthic organisms at the site. However, the ability of these organisms to recolonize in similar sediments renders this impact short-term and insignificant. Should the disposed material differ in grain-size, other benthic organisms would likely colonize the area. The DEIS will serve as the Biological Assessment from which the National Marine Fisheries Service (NMFS) and, as appropriate, the U.S. Fish and Wildlife Service (FWS) can determine any adverse impacts of the proposed EIS action on threatened and endangered species under their purview.

G. Chapter 376: Pollutant Discharge Prevention and Removal

Possible effects associated with the use of this site are local mounding, temporary increases in turbidity and the smothering of benthic organisms. The effect on the benthos should be minor as discussed in Section F above. The great depths at the site will ensure that any mounding does not become a hazard to navigation. Turbidities resulting from use of the site will be temporary. Any suspended sediments remaining in the water column will be diluted and dispersed so that the long term effect would not be greater than ambient suspended solids concentrations. This is supported by the results of dispersion modelling, which will be followed-up by surveys at the site.

Any material proposed for ocean disposal must meet the criteria given in 40 CFR Part 227 (Ocean Dumping Criteria). EPA and the COE will continue to monitor the site as long as it is used to detect movement of the material and any associated impacts. The Site Management and Monitoring Plan (SMMP) for the Fort Pierce ODMDS is included in the DEIS (see Appendix D).

H. Chapter 403: Environmental Control

The principle concerns raised in this chapter are similar to those addressed in many of the chapters discussed above: pollution control, waste disposal and dredging.

The COE and EPA will evaluate all federal dredged material disposal projects in accordance with the EPA criteria given in the Ocean Dumping Regulations (40 CFR Sections 220-229), the COE regulations (33 CFR 209.120 and 209.145), and any state requirements. The COE will also issue permits to private dredged material disposal projects after review under the same regulations. EPA has the right to disapprove any ocean disposal project if, in its judgement, all provisions of the MPRSA and associated implementing regulations have not been met.

III. CONCLUSIONS

Based on the information presented in the DEIS and the above summary, EPA concludes that the proposed designation of the Fort Pierce ODMDS is consistent with the Florida CZMP to the extent feasible.

APPENDIX H

NON-OCEAN DISPOSAL ALTERNATIVES

A discussion of non-ocean disposal alternatives was presented on the Fort Pierce Harbor General Reevaluation Report. Alternatives considered were beach disposal, Indian River disposal, Offshore disposal and upland disposal. A discussion of these alternatives, as taken from the Fort Pierce Harbor Report, is presented below.

DISPOSAL ALTERNATIVES

The identification of potential disposal alternatives in the feasibility study and report included uplands, inner bay, beach, nearshore, and offshore areas. The nearshore area for the disposal of sand was not acceptable in the feasibility study as it offered too great a potential for severe adverse impact on extensive reef systems paralleling the shoreline. For that reason, the authorized plan did not provide for the placement of dredged material in a nearshore area south of the inlet. That alternative received no further consideration during the reevaluation study of the project. The remaining alternatives were a part of the reevaluation effort.

BEACH DISPOSAL ALTERNATIVE

Suitable material for beach nourishment from construction and maintenance of the authorized project will go on the beaches south of the inlet. The Florida Department of Natural Resources supports this part of the authorized plan as it helps mitigate the adverse impact of the project navigation features which collect sand in the littoral drift movement. Mitigation for that impact is to place sand either directly on the beaches to the south of the inlet or in a nearshore area paralleling the beach for nourishment. As the nearshore area has a potentially greater adverse impact on the reefs in the area, that alternative was not a consideration for further analysis. The reevaluation analysis considers the possible impact of the beach disposal of material on the offshore reefs.

INDIAN RIVER DISPOSAL ALTERNATIVE

The Indian River disposal alternative was a U.S. Fish and Wildlife Service proposal for mitigation. The idea was to use excavated material from deepening and widening to fill a deep hole in the Indian River and make it a more productive habitat for marine species. Excavated material to go into the hole would include primarily rock and sand from the project deepening and widening. Reevaluation of that alternative considers the significant and adverse impacts on organisms discovered in the hole as well as the problems with turbidity on surrounding seagrass beds. This alternative has been dismissed due to State concerns over excessive turbidity caused by placing dredged material into open water.

OFFSHORE DISPOSAL ALTERNATIVE

The material to be dredged from Fort Pierce Harbor will be evaluated further to determine if it is suitable for ocean disposal. Based on existing test results, the material would be suitable, and the cost for ocean disposal would be an estimated $4.29 a cubic yard. That cost includes the dredging operation to remove the material from the channel with mechanical equipment, such as a clam shell and barge. The dredging operation involves the placement of the material into an ocean-going barge for transport about 5 statue miles to the designated offshore disposal site. The expense for transporting the material to the disposal site is included the unit cost but not the costs for mobilization and demobilization of equipment to and from the job site nor any contingency costs associated with the dredging and disposal operation.

UPLAND DISPOSAL ALTERNATIVES

In the feasibility study, the evaluation involved four upland areas for the disposal of the predominately silty materials from excavation work on the authorized project. Three of the four areas were sanitary landfills in need of cover material. The fourth area was a wooded area with potential wildlife impacts as well as being near adjoining residential development and in close proximity to proposed well fields at the time of the feasibility report. The reevaluation effort on upland disposal alternatives again considered those areas as potential upland sites as well as other, undeveloped lands in the area for a total of seven. The location of sites in the reevaluation study is shown on figure D-1. Subsequent paragraphs provide the results of the reevaluation analysis on those areas. Three sites were eliminated from further study, with sites A1, D, E and F retained for more detailed evaluation.

SITE "A" NORTH OF THE AIRPORT

In the feasibility report, Site A was one of the sanitary landfill areas needing cover material and located mostly in the southern half of Section 20, Township 34 South, Range 40 East, in St. Lucie County. A small portion of the site did extend into the southeast quadrant of Section 19. The larger of two parcels of land is about 317 acres and belongs to the St. Lucie County Port and Airport Authority. That parcel covered all the southwest quadrant and a portion of the southeast quadrant in Section 20.

Operation of the landfill involved the old trench and fill technique with no liner to protect the ground water. Today, most of the area designated as Site A is now a golf course in which the County has invested about $4 million to develop. One of the main purposes for that development was to cleanup the ground water contamination. The county operates and maintains the golf course and uses a system of wells to obtain ground water which is run through a treatment system before using it for irrigation on the course. That process helps clean up the ground water contamination. Use of that site for disposal of material is no longer a reasonable alternative considering the development in the area. More reasonable alternatives exist in using other undeveloped sites in the vicinity of the airport.

SITE "A1' WEST OF SITE "A"

To the west of Site A in Section 19 are 5 parcels of land with the largest being approximately 248 acres and undeveloped at this time. That parcel belongs to the St. Lucie County Port and Airport Authority. It is located to the west and north of the existing airport runways (see figure D-1). That area has only trees and low growing vegetation presently growing on the land. To use the area for disposal of material, clearing and grubbing would have to precede the construction of dikes. The clearing operation could have environmental impacts and result in some mitigation actions. In the development of the golf course property on Site A, the county had to reconcile environmental impacts to various species such as the scrub jay, eagle, and gopher tortoise in the project area. Similar problems could exist in other areas adjacent to the airport and require mitigation action if this area was developed as a disposal site.

There is contamination from other landfill sites around the airport. Since the airport's water is supplied by city, the level of contaminants from those landfill operations may not be a significant factor. However, to the south of the airport, there are several trailer parks that could have wells. The various sources of contamination in the area may provide more of a risk than any excavated material from the project modifications. To avoid further problems with contamination, a liner would probably be required for the disposal of material in the area. The site has potential as a disposal area for further evaluation under cost considerations.

SITE "B" WEST OF AIRPORT

In the feasibility report Site B was another sanitary landfill that needed cover material. The site is entirely within one parcel of land about 71 acres in size which is located adjacent to the west side of the airport property. That one parcel is in the lower half of the northwest quadrant in Section 30 (see figure D-1). The landfill operation again involved the old trench and fill technique with no liner for ground water protection. Some of the contamination at the site may be from hazardous and toxic wastes. The Florida Department of Environmental Regulation has a site assessment underway to identify the amount and source of contamination. The county sold the site with the stipulation that any contamination would need to undergo cleanup efforts. The cleanup effort is under litigation.

Considering the existing contamination problems, use of the site is very questionable as a disposal area. To acquire the site for disposal would likely include the acceptance of existing contamination problems and require a costly cleanup effort prior to using the area for disposal. In addition to cost, the cleanup would require considerable time and effort to make the site acceptable. A liner would most likely be required to prevent water seepage in the disposal area from leaching down into the old landfill and causing further problems. Based on the potential problems, Site B is not a good potential alternative for a timely and cost efficient solution. As there are other sites in the vicinity of the airport with less potential problems and more cost efficient to utilize, no further consideration is given to Site B.

SITE "C"

The feasibility report identified Site C as a sanitary landfill that needed cover material. The site has similar contamination problems as those discussed for Site B. Assuming the liability for a cleanup effort before using the landfill as a disposal area would be an expensive process in addition to the other costs to prepare the area for disposal. Based on the prospect of contamination problems, use of that site was not a consideration for further analysis as other undeveloped land in the area of the airport would be more cost efficient for upland disposal.

SITE "D"

Site D in the feasibility report was an undeveloped area in the southern half of Section 32, Township 34 South, Range 40 East, in St. Lucie County (see figure D-1). The site now is broken into 11 parcels with the largest being about 56 acres of undeveloped land covered with trees and low vegetation. An adjacent parcel to the south has about 9 acres of undeveloped land which could be combined with the 56 acres for a total of about 65 acres. The combined acreage is potentially a low cost subdivision development of 5 to 9 units per acres. The area is sufficient for the disposal of material but the surrounding neighborhood influences would make utilization somewhat risky.

The remaining parcels are small in acreage with development on two of them. The location of the two developed parcels is such that a usable combination of the other areas is difficult without including the developed areas. A paved road extends from east to west across the middle of the quadrant to further separate the parcels. Adjacent residential developments also exist on both the east and west sides of the 64 acre site. The close proximity of residential areas would also impact use as a permanent disposal area. Disregarding potential problems associated with locating the disposal site near residential areas, the 64 acre site is included as a possible disposal alternative for further evaluation.

SITE "E"

This site was not in the feasibility report and comprises one parcel of land that is in the north half of Section 32, Township 34, Range 40 East, in St. Lucie County (see figure D-1). That parcel contains about 79 acres of vacant land and is zoned for light industrial use. Vegetation on the parcel is mainly scrub, dry prairie, and mesic flatwoods. Previous uses may have been related to livestock based on the presence of a wooden loading chute on the property and woven-wire fencing around the property. Some of the ground cover was missing as if it was recently scraped leaving sandy material exposed in many areas. The acreage would be sufficient for a disposal area. As it is a marketable industrial tract in close proximity to the airport, use of the site will be evaluated further for both temporary and permanent disposal of dredged material.

SITE "F"

This is the 80-acre site referred to by Florida DER. The feasibility report did not include this site for analysis. The land belongs to the MacArthur Foundation and consist of about 118 acres on the causeway island to the south of the port. The single parcel of land is located in Section 2 of Township 35 South, Range 40 East, in St. Lucie County (see figure D-1). Current zoning on the site is for residential development. The parcel is bordered on the south by the Indian River and to the north by State Road A1A. Portions of the property have already been used for disposal of sandy material from dredging of the City Marina. The county has an agreement with the MacArthur Foundation to allow the beach quality sand to be removed for beach nourishment.

Interior dirt roads provide access to the diked areas. Land outside the diked areas and roads have natural vegetation including palms, Australian pines, and scrub grasses. The site has been vacant for years and there are no current plans for residential development. Considering the location, the site has a very good potential for residential development and adjacent neighborhood influences make disposal over a long term somewhat doubtful. Use of the site will be evaluated further for both temporary and permanent disposal of dredged material.

DESIGN CONSIDERATIONS

The undeveloped, upland sites under consideration would require clearing and diking in preparation for disposal. To hold approximately 535,000 cubic yards of material from channel and turning basin excavation, an area of 65 acres would require diking to a height of 8 to 10 feet. Dike construction would involve the excavation and placement of about 65,000 cubic yards of material from within the disposal site. If the material at the disposal site is not suitable for dike construction, a borrow source would have to be located for the dike material. The expense of excavating, loading, and transporting the dike material to the disposal site would be an additional cost. At this time, the material within the potential disposal sites is assumed to be suitable for dike construction.

Excavation of the bottom materials from the Ft. Pierce Harbor project and transport to the potential disposal sites involved the use of a hydraulic dredge with booster pumps, as required to move the material through a submerged pipeline. At this time, that type of equipment is considered to be the most efficient means to dredge and transport the material to the upland disposal sites under consideration. In estimating costs two size dredges were considered in determining the most efficient costs.

In the situation where the upland area would be leased for use as a temporary disposal site, a secondary site would be necessary for final disposal. In discussions with county officials operating the sanitary landfill, use of that area would be a possibility, if the material is suitable. Assuming the dredged material is suitable, the material would need to be moved to the landfill after it has had time to dewater. From the disposal areas near the port, the sanitary landfill is 8 to 10 miles away. To move that material overland, trucking is considered the most efficient means of conveyance when compared to pumping the material through a pipeline. The costs for the truck haul are shown in table D-1 along with other dredging and transport costs related to the alternative upland sites.

DREDGING AND TRANSPORT COSTS

In estimating the costs for initial excavation and material transport, the hydraulic pipeline dredge is considered to be the most efficient equipment for placing material in a upland area near the job site. Other means of accomplishing the excavation are to use a hopper dredge with pumpout capability, a clamshell bucket, or dragline with the latter two requiring a crane and barges to operate. That equipment would need a vessel berth with landside access to unload the excavated material. The hopper dredge could either pump the material to an interim disposal area for eventual movement to a permanent disposal site or directly to the permanent site, if located nearby. The clamshell or dragline would place excavated material into a barge for transport to the shoreline where a dock would be necessary for unloading. The unloading process would depend on the distance to the disposal area. If the permanent disposal site is not more than 2 miles from the berth, the material could be pumped to the site from the barge. More distant areas may require an interim disposal site close to the berth which would be used for the material to dewater before truck hauling to the distant disposal site. The costs for those operations involve rehandling operations that are considered excessive in comparison to using a pipeline dredge.

In determining the size of the pipeline dredge for the work, consideration was given to an 18 inch and 27 inch diameter pipeline. The amount of material for the dredges to handle remained constant at an estimated 535,000 cubic yards. For the more distant disposal sites (A1, D, and E), the 27 inch pipeline dredge provides a more cost efficient means to excavate and transport the material which is shown in table D-1. For disposal site F, which is closer to the dredging area, the smaller 18 inch pipeline dredge provides a more cost efficient means to excavate and transport the material cost.

TABLE D-1

Estimated Excavation and Transport Costs

Disposal Site	Transport Mode	Unit Distance	Combined Costs	Dredge and Transport Costs[1]
A1	18" Pipeline	30,000'	$6.50	$3,478,000
	27" Pipeline	30,000'	5.00	2,675,000
D	18" Pipeline	18,000'	3.90	2,087,000
	27" Pipeline	18,000'	3.40	1,819,000
E	18" Pipeline	18,000'	3.90	2,087,000
	27" Pipeline	18,000'	3.40	1,819,000
F	18" Pipeline	5,000'	1.70	910,000
	27" Pipeline	5,000'	1.80	963,000
Sanitary Landfill	12 c.y. Truck	47,500'[2]	3.07	1,643,000
Offshore Site	Barge	26,400'	4.29	2,295,000

1. Combined dredge and transport cost except for sanitary landfill site.

2. Approximate distance from port area to sanitary landfill.

The cost estimates in table D-1 include no mobilization or demobilization expense necessary to move the equipment to and from the project nor any contingency costs associated with the dredging and disposal operation. The trucking cost for disposal in the sanitary landfill is only for the trucking operation and does not include any dredging costs to get material into an interim site for drying or the cost for obtaining and preparing the site.

UPLAND AREA PREPARATION COSTS

Preparation of the upland disposal site alternatives would involve diking, clearing, and grubbing about 65 acres as well as weir construction. The only exceptions would be the sanitary landfill, Site E, and Site F. The sanitary landfill has sufficient area reportedly available for the storage of 535,000 cubic yards of material without the need for any site preparations. Site E has some cleared area with an estimated 80 percent needing to be cleared and grubbed before use. Site F has some diked areas which will need expanding for more acreage and possibly some additional work to raise the existing dikes to a higher elevation. The quantity of material estimated for dike construction was reduced by 30 percent to account for the existing dikes at the site. The estimated cost for preparing the disposal areas to receive the dredged material is in table D-2.

TABLE D-2

Estimated Upland Disposal Area Preparation Costs [1]

Disposal Site	Item Description	Unit Quantity	Total Costs	Costs
A1	Dike construction	65,000 c.y.	$3.25	$211,000
	Clearing & grubbing	65 acres	1,400	91,000
	Weir construction	2	80,000	160,000
	TOTAL			$462,000
D	Dike construction	65,000 c.y.	$3.25	$211,000
	Clearing & grubbing	65 acres	1,400	91,000
	Weir construction	2	80,000	160,000
	TOTAL			$462,000
E	Dike construction	65,000 c.y.	$3.25	$211,000
	Clearing & grubbing	52 acres	1,400	73,000
	Weir construction	2	80,000	160,000
	TOTAL			$444,000
F	Dike construction	45,500 c.y.	$3.25	$148,000
	Clearing & grubbing	65 acres	1,400	91,000
	Weir construction	2	80,000	160,000
	TOTAL			$399,000

1. No cost included for mobilization or demobilization of equipment to do the site preparation work.

Infaunal abundance, often related to the productivity of the benthos, was reported as the total number of individuals per station and as the number of individuals per square meter. Species richness was reported as both the total number of taxa represented in a given station collection and by Margalef's Index D (Margalef, 1958). This is estimated as $D = (S-1)/\ln N$, where S is the number of taxa and N is the number of individuals in the sample.

Species diversity, which is often related to the ecological stability and environmental "quality" of the benthos, was estimated by the Shannon-Weaver Index (Shannon and Weaver, 1963). The following formula has been applied:

$$H' = -\sum_{i=1}^{S} p_i(\ln p_i)$$

where S is the number of species in the sample, i is the ith species in the sample, and p_i is the number of individuals of the ith species divided by the total number of individuals of all species in the sample.

Species diversity within a given community is dependent on both the number of taxa present (species richness) and the distribution of all individuals among those species (equitability or evenness). To quantify and compare the equitability in the fauna to the species diversity for a given area, Pielou's Index J' (Pielou, 1966) was calculated as $J' = H'/\ln S$, where H' is the Shannon-Weaver Index of diversity (as calculated above) and S is the number of taxa in the sample.

3.2 FAUNAL SIMILARITIES

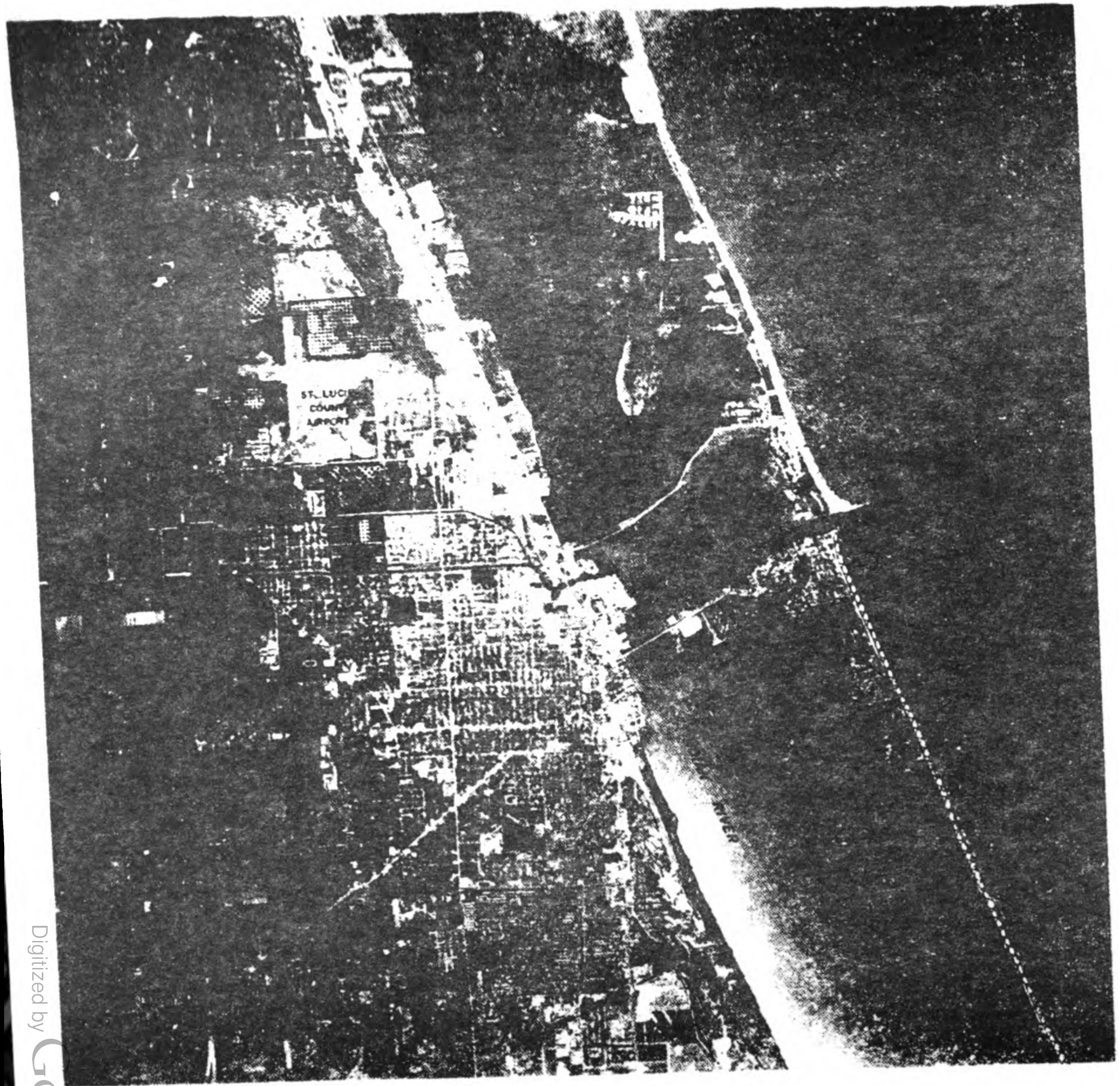
Numerical classification analysis (Boesch, 1977) was performed on the faunal data to examine between-station differences at the Ft. Pierce Harbor site and to compare faunal composition at each station within the site. Classification analysis by both station (normal analysis) and species (inverse analysis) was performed by using the Czekanowski quantitative index of faunal similarity (Field and MacFarlane, 1968). This index considers both the number of species in common and the difference in number of individuals among stations. Although it is weight

The summary in table D-4 provides the estimated costs for representative upland areas in different locations with potential for use in the disposal of excavated material. The cost for offshore disposal of 535,000 cubic yards of material is an estimated $2,295,000 as shown in table D-1. A comparison of the offshore disposal costs with the different upland sites considerations in table D-4 shows that offshore disposal is less expensive by $636,000 than the least cost upland alternative of using Site D for permanent disposal of the material. Based on the results of the analysis, the conclusions is that distant areas around the airport would be too costly for use as would closer areas around the port and nearby inland properties. The offshore disposal site would be the preferred means of disposal.

TABLE D-4

Summary of Estimated Disposal Area Costs

Disposal Site	Estimated use	Cost items	Estimated Costs
D	Permanent disposal	Excavation & transport	$1,819,000
	Preparation		462,000
	Real estate		650,000
	TOTAL		$2,931,000
	Temporary disposal	Excavation & transport	$1,819,000
	Preparation		462,000
	Real estate		260,000
	Truck to landfill		1,643,000
	TOTAL		$4,184,000
E	Permanent disposal	Excavation & transport	$1,819,000
	Preparation		444,000
	Real estate		1,300,000
	TOTAL		$3,563,000
F	Temporary disposal	Excavation & transport	$1,819,000
	Preparation		444,000
	Real Estate		520,000
	Truck to landfill		1,643,000
	TOTAL		$4,426,000
	Permanent disposal	Excavation & transport	$ 910,000
	Preparation		399,000
	Real Estate		3,250,000
	TOTAL		$4,559,000
	Temporary disposal	Excavation & transport	$ 910,000
	Preparation		399,000
	Real Estate		1,300,000
	Truck to landfill		1,643,000
	TOTAL		$4,252,000



LEGEND

- DISPOSAL AREA ENVIRONMENTAL MITIGATION
- DISPOSAL AREA BEACH NOURISHMENT
- DISPOSAL AREA OFFSHORE
- DISPOSAL AREA UPLAND

OFFSHORE DISPOSAL AREA

GRAPHIC SCALE
2400' 0 2400' 4800' 7200'

HARBOR, FLORIDA

ALTERNATIVE DISPOSAL AREAS

DEPARTMENT OF THE ARMY
CORPS OF ENGINEERS
FLORIDA

FIG. D-1

APPENDIX I

ODMDS BENTHIC COMMUNITIES

FINAL REPORT

FT. PIERCE HARBOR, FLORIDA, ODMDS BENTHIC COMMUNITIES

to

U.S. ENVIRONMENTAL PROTECTION AGENCY
Office of Wetlands, Oceans, and Watersheds
February 1993

Prepared by

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for

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1.0 INTRODUCTION

The Ft. Pierce Harbor, Florida Ocean Dredged Material Disposal Site (ODMDS) was investigated by the U. S. Environmental Protection Agency (EPA) during March 1992 as part of a monitoring study of disposal at that site. One aspect of this evaluation was benthic community characterization, which was accomplished via sample collection by EPA personnel and via laboratory and data analysis by Barry A. Vittor & Associates, Inc. (BVA).

The Ft. Pierce Harbor ODMDS is centered approximately at coordinates 27°28.0′ and 80°12.0′W (Figure 1). Four benthic monitoring stations were located within the disposal area and seven stations were located just outside this area, which measures approximately 1.1 nmi wide and 1.1 nmi long (Figure 1). Station coordinates and approximate water depths are provided in Table 1.

2.0 METHODS

2.1 SAMPLE COLLECTION AND HANDLING

Divers used handheld cylindrical corers to collect bottom samples with a diameter of 10 cm, or a surface area of 0.0079 m^2. Fifteen replicate cores were obtained at each of nine stations, and 30 replicates were collected at each of two other stations. Macroinfaunal samples were sieved through a 0.5-mm mesh screen and preserved with 10% formalin on the ship. Macroinfaunal samples were transported to the BVA laboratory in Mobile, Alabama.

The larger number of replicate cores was collected to establish the number of replicates needed to adequately represent the numbers of species in benthic assemblages in the study area. Sampling representativeness was evaluated on the basis of species-area curves, and via the method of Dennison and Hay (1967), for each of the two stations. As shown in Figure 2, the number of replicates needed to represent the total infaunal assemblage at each site was estimated to be in the range from 15 to 16. The former (15) was selected as the most appropriate number of replicates to be analyzed for the remaining nine stations.

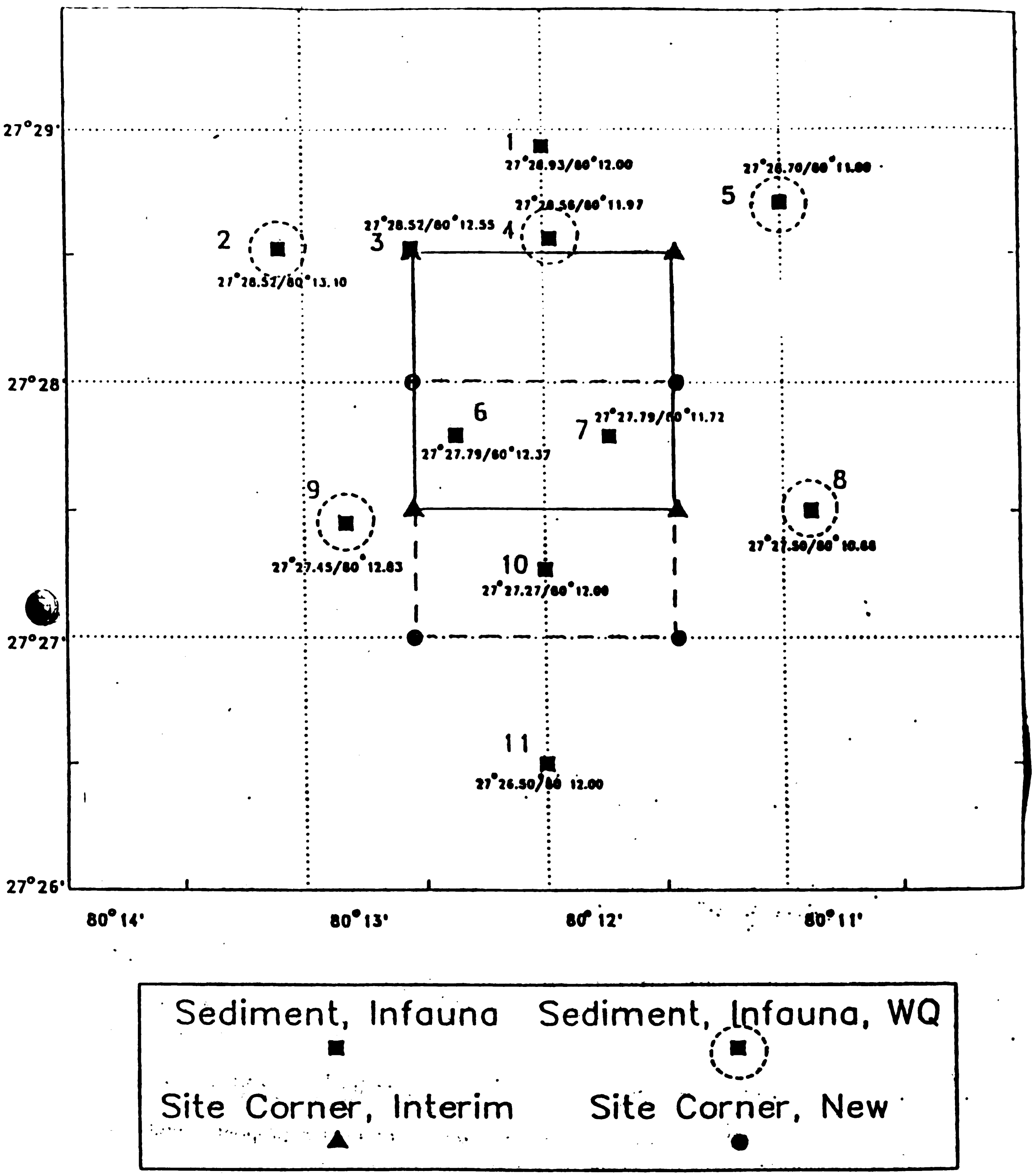

Figure 1. Locations of benthic and sediment sampling stations at the Ft. Pierce, Florida ODMDS.

Table 1. Ft. Pierce Harbor, Florida ODMDS benthic sample station coordinates and approximate water depths.

STATION	DEPTH (m)	LATITUDE (N)	LONGITUDE (W)
1	—	27°28.93′	80°12.00′
2	14.0	27°28.52′	80°13.10′
3	—	27°28.52′	80°12.55′
4	15.0	27°28.56′	80°11.97′
5	14.5	27°28.70′	80°11.00′
6	—	27°27.79′	80°12.37′
7	—	27°27.79′	80°11.72′
8	14.0	27°27.50′	80°10.88′
9	12.0	27°27.45′	80°12.83′
10	13.0	27°27.27′	80°12.00′
11	—	27°26.50′	80°12.00′

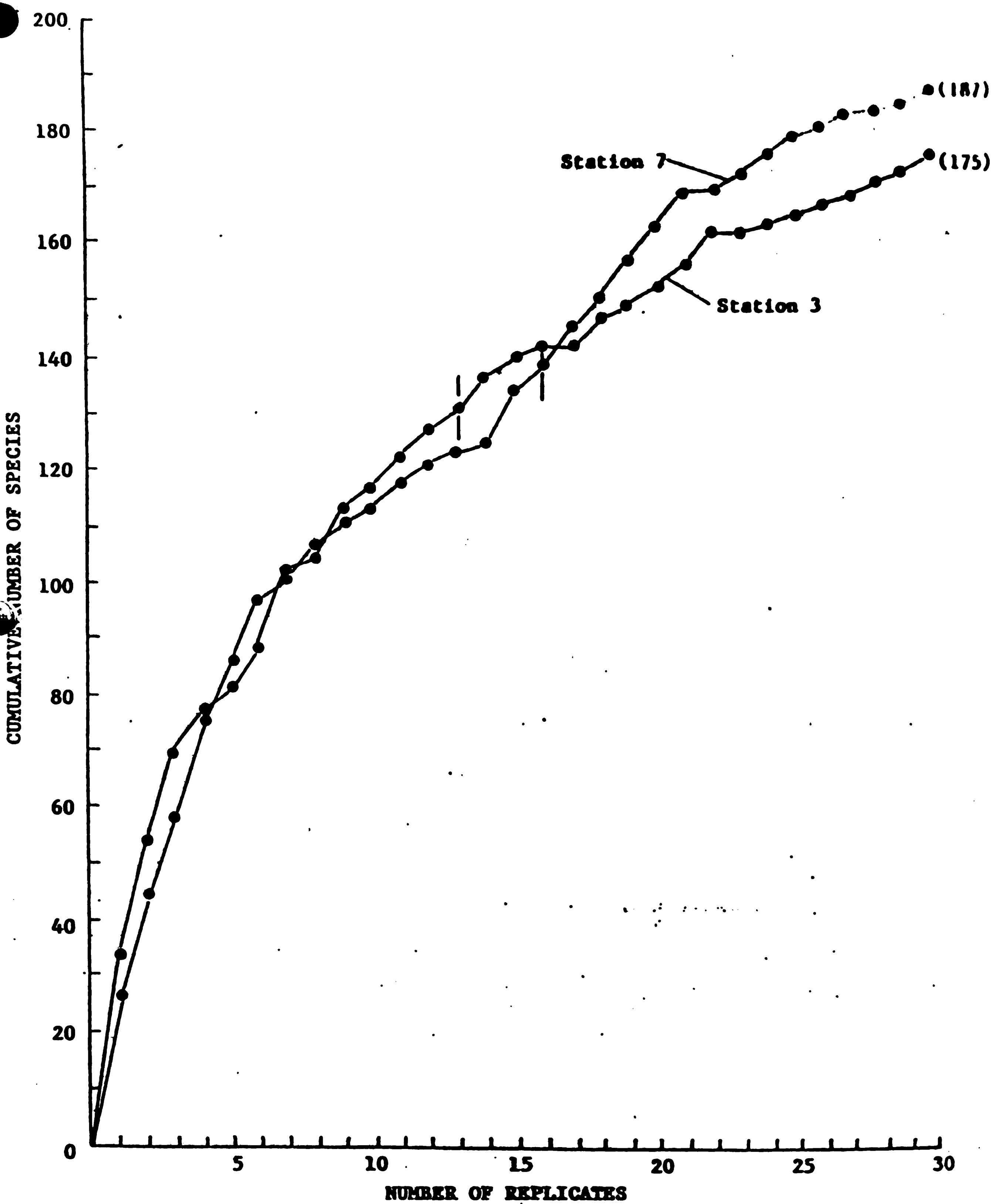

Figure 2. Species saturation curves for benthic macroinfauna sampling at the Ft. Pierce, Florida ODMDS in March 1992.

Two additional handheld cores were collected at each station for sediment texture analysis. Sediment samples were placed in plastic bags and frozen onboard the ship.

2.2 SEDIMENT ANALYSIS

Sediment texture was determined at half-phi intervals, using the hydrometer technique for fractions smaller than 44 µm and nested sieves for larger fractions.

Texture parameters that were computed included percent gravel, sand, silt, and clay. In addition, textural descriptions were generated, based on the Wentworth Scale. Organic content was measured as ash-free dry weight, expressed as percent.

2.3 MACROINFAUNAL SAMPLE ANALYSIS

Upon arrival at the BVA laboratory, samples were inventoried, then rinsed gently through a 0.5-mm mesh sieve to remove preservatives and silt, and than stored in 70% isopropanol solution until processed.

Sample material (consisting of sediment, detritus, and organisms) was placed in a white enamel tray for examination under a Wild M-5A dissecting microscope. All macroinvertebrates found were carefully removed with forceps and placed in appropriate glass vials containing 70% isopropanol, according to major taxonomic groups (i.e., Polychaeta, Mollusca, Crustacea, Echinodermata, and Others).

All macroinfauna recovered during sample rough-sorting were identified down to the lowest practical identification level (LPIL) (species level, except for juveniles, damaged, or otherwise unidentifiable animals). The numbers of individuals of each taxon, excluding fragments, were recorded.

A voucher collection was prepared, composed of representative individuals of each species not previously encountered in samples from the Ft. Pierce ODMDS area. Specimens were placed in stoppered vials, with the appropriate preservative, and labeled. The label, written in India ink, contained the species name, project location, station and replicate, collection date, taxonomist's name or initials, identification date, and the number of specimens present in the vial. Individual vials were placed inside museum jars with preservative, cataloged, and added to the project voucher collection.

Wet-weight biomass of major taxonomic groups (i.e., Polychaeta, Mollusca, Crustacea, Echinodermata, Miscellaneous) was measured for each macroinfaunal sample, after identification/enumeration. Each set of organisms was removed from its sample vial, blot-dried on filter paper, and then weighed on a Mettler balance accurate to ±0.1 mg.

3.0 DATA ANALYSIS METHODS

The analytic strategies and methods used for this study are currently incorporated in similar benthic community characterization reports prepared for EPA ODMDS surveys in the Gulf of Mexico (e.g., Vittor & Associates, 1991). Through the use of various univariate and multivariate statistical analyses, large data sets can be reduced and synthesized to reveal important trends and ecological relationships in the benthic community. Benthic community analysis generally includes habitat characterization and characterization of macroinfaunal assemblages.

Macroinfaunal characterization involves an evaluation of several biological community structure parameters (e.g., species composition, species diversity indices, biomass measurements) during initial data reduction, followed by pattern and classification analysis for delineation of species assemblages. Because species are distributed along environmental gradients, there are generally no distinct boundaries between communities. However, the relationships between habitats and species assemblages reflect the interactions of physical and biological factors and express the major ecological trends.

3.1 COMMUNITY STRUCTURE

Various types of numerical indices were chosen for analysis and interpretation of the macroinfaunal database. Selection was based primarily on the ability of the indices to provide a meaningful summary of data, as well as on their usefulness in the characterization of benthic communities.

Infaunal abundance, often related to the productivity of the benthos, was reported as the total number of individuals per station and as the number of individuals per square meter. Species richness was reported as both the total number of taxa represented in a given station collection and by Margalef's Index D (Margalef, 1958). This is estimated as $D = (S-1)/\ln N$, where S is the number of taxa and N is the number of individuals in the sample.

Species diversity, which is often related to the ecological stability and environmental "quality" of the benthos, was estimated by the Shannon-Weaver Index (Shannon and Weaver, 1963). The following formula has been applied:

$$H' = -\sum_{i=1}^{S} p_i(\ln p_i)$$

where S is the number of species in the sample, i is the ith species in the sample, and p_i is the number of individuals of the ith species divided by the total number of individuals of all species in the sample.

Species diversity within a given community is dependent on both the number of taxa present (species richness) and the distribution of all individuals among those species (equitability or evenness). To quantify and compare the equitability in the fauna to the species diversity for a given area, Pielou's Index J' (Pielou, 1966) was calculated as $J' = H'/\ln S$, where H' is the Shannon-Weaver Index of diversity (as calculated above) and S is the number of taxa in the sample.

3.2 FAUNAL SIMILARITIES

Numerical classification analysis (Boesch, 1977) was performed on the faunal data to examine between-station differences at the Ft. Pierce Harbor site and to compare faunal composition at each station within the site. Classification analysis by both station (normal analysis) and species (inverse analysis) was performed by using the Czekanowski quantitative index of faunal similarity (Field and MacFarlane, 1968). This index considers both the number of species in common and the difference in number of individuals among stations. Although it is weighted toward the occurrence of dominant (i.e., abundant) species, preliminary selection of species based on their percent abundance by station and percent frequency of occurrence for the study area can reduce the weighted bias.

The value of the similarity index is 1.0 when the two samples are identical and 0 when no species are in common. Hierarchical clustering of similarity values is achieved by using the group-average sorting strategy (Lance and Williams, 1967), displayed in the form of dendrograms (cluster graphs).

Both similarity classification and cluster analyses were performed with the aid of a "Package of Computer Programs for Benthic Community Analysis" (Bloom *et al.*, 1977) as modified for use in BVA's benthic data management program. Species selected for these analyses were those that comprised at least 0.20% of all individuals collected during the survey. Total densities for each of the selected species at a given station collection were log-transformed [$x = \ln(x+1)$] for the analysis.

Classification of selected taxa results in the grouping of taxa based on their overall distribution patterns. The relationship of taxa or taxonomic groups to habitats delineated by the classification of station groups is presented as a data matrix in a two-way contingency table. By using nodal analysis to further simplify measures of frequency occurrence and degree of restriction of taxa to habitats (station groups), species group constancy, fidelity, and abundance are assessed for coincidental classifications. Constancy is a measure of the extent to which a species group may be expected to occur in similar habitats (Boesch, 1977). Fidelity is a measure of the degree to which species are restricted or faithful to a particular station group (or habitat). Abundance defines the concentration of species within station groups. Diagrams were prepared to assist in the interpretation of pattern analysis.

4.0 HABITAT CHARACTERISTICS

Sediments ranged from clayey sand to gravelly sand at the 11 stations. Clay and volatile organic fractions ranged from 0.8% to 1.5% and 0.8% to 2.2%, respectively (Table 2).

Table 2. Sediment characteristics at benthic stations sampled at the Ft. Pierce, Florida ODMDS in March 1992.

STATION	PERCENT COMPOSITION				
	GRAVEL	SAND	SILT	CLAY	ORGANICS
1	1.5	96.1	0.1	1.5	0.8
2	36.2	60.4	0.4	1.4	1.6
3	9.9	86.6	0.4	1.4	1.8
4	10.9	86.2	0.2	0.8	1.9
5	34.6	61.9	0.2	1.1	2.2
6	21.7	71.9	3.1	1.8	2.1
7	14.8	82.0	0.2	1.1	1.9
8	16.1	80.6	0.1	1.2	2.0
9	32.9	63.9	0.3	0.9	1.9
10	29.2	67.8	0.2	0.9	2.0
11	30.1	66.8	0.2	0.9	2.0

Stations 2, 5, 9, and 11 were characterized by at least 30% gravel (probably shell hash). Highest percent clay was found at Station 10, where gravel was only 1.5%. The largest silt fraction (3.1%) occurred at Station 6, which was located in the northwest corner of the new disposal area. Lowest percent silt plus clay was observed at Station 1, which was located north of the disposal site. Highest organic content was found at Stations 5 and 6. Station 5 was located northeast of the disposal site.

5.0 BENTHIC COMMUNITY CHARACTERIZATION

5.1 FAUNAL COMPOSITION, ABUNDANCE, AND COMMUNITY STRUCTURE

Species enumeration at each of the survey stations was presented as Data Summary Reports, which are provided separately to EPA. Each report includes a phylogenetic listing, by station, of species count data and percent representation of each taxon, plus number of species, individual density, and basic community statistics (i.e., species diversity, species evenness, and species richness). Appendix A provides a complete phylogenetic species list for all survey stations combined.

A total of 11,256 individuals, representing 417 taxa, was identified from 165 samples (Table 3). Annelids contributed the largest number of taxa (164, or 39.3%), and largest number of individuals (6,006, or 53.4%) censused. Five of the top 10 taxa were polychaetes. Dominant polychaetes included *Goniadides carolinae*, which was the second most-abundant taxon, Serpulidae (LPIL), *Schistomeringos pectinata*, *Dendatisyllis carolinae*, and *Spiophanes bombyx*. Most of these taxa are associated primarily with gravelly sand sediments. (*S. bombyx* is more typical of sandy silt sediments).

Arthropods contributed the second-highest number of species (117, or 28.1%) and the third-highest number of individuals sampled (1,211, or 10.8%). The most abundant arthropod was the cumacean *Cyclaspis varians*, which ranked seventeenth in overall abundance. Other numerically important species included the amphipod *Erichthonius brasiliensis* and the cumaceans *Cyclaspis pustulata* and *Oxyurostylis* (LPIL).

Table 3. Taxonomic listing and abundance of phyla and numerically dominant taxa from EPA - Ft. Pierce survey, March 1992.

PHYLUM	NO. INDIVIDUALS	% TOTAL	% TAXA	% TOTAL
ANNELIDA	6006	53.3582	164	39.33
MOLLUSCA	1192	10.5899	105	25.18
ARTHROPODA	1211	10.7587	117	28.06
ECHINODERMATA	1781	15.8227	10	2.40
OTHER PHYLA	1066	9.4705	21	5.04
	========		========	
TOTALS	11256		417	

NUMERICALLY DOMINANT SPECIES

SPECIES		NO. INDIVIDUALS	% TOTAL	CUMULATIVE %	STATION OCCURRENCE	% STATION OCCURRENCE
OPHIUROIDEA (LPIL)	(E)	1430	12.7043	12.7043	11	100.00
GONIADIDES CAROLINAE	(P)	975	8.6620	21.3663	11	100.00
OLIGOCHAETA (LPIL)	(O)	888	7.8891	29.2554	11	100.00
SERPULIDAE (LPIL)	(P)	837	7.4360	36.6914	11	100.00
SCHISTOMERINGOS PECTINATA	(P)	591	5.2505	41.9419	11	100.00
RHYNCHOCOELA (LPIL)	(R)	387	3.4382	45.3801	11	100.00
HOLOTHURIA SP.A	(E)	258	2.2921	47.6722	10	90.91
CAECUM SP.A	(M)	211	1.8746	49.5468	10	90.91
DENTATISYLLIS CAROLINAE	(P)	177	1.5725	51.1193	11	100.00
SPIOPHANES BOMBYX	(P)	143	1.2704	52.3897	11	100.00
ASPIDOSIPHON ALBUS	(S)	130	1.1549	53.5446	10	90.91
HETEROPODARKE FORMALIS	(P)	109	0.9684	54.5130	10	90.91
ACTINIARIA (LPIL)	(Cn)	100	0.8884	55.4014	10	90.91
LUMBRINERIDES ACUTA	(P)	97	0.8618	56.2632	11	100.00
BHAWANIA HETEROSETA	(P)	95	0.8440	57.1072	11	100.00
ANCISTROSYLLIS HARTMANAE	(P)	89	0.7907	57.8979	11	100.00
CYCLASPIS VARIANS	(C)	88	0.7818	58.6797	11	100.00
EUNICE VITTATA	(P)	86	0.7640	59.4437	8	72.73
MALDANIDAE (LPIL)	(P)	0	0.7640	60.2077	11	100.00
MEDIOMASTUS (LPIL)	(P)	84	0.7463	60.9540	10	90.91
PRIONOSPIO CRISTATA	(P)	77	0.6841	61.6381	11	100.00
CAECUM COOPERI	(M)	76	0.6752	62.3133	11	100.00
OPISTHODONTA SP.B	(P)	72	0.6397	62.9530	10	90.91
POLYGORDIUS (LPIL)	(P)	72	0.6397	63.5927	11	100.00
ECHINOIDEA (LPIL)	(E)	72	0.6397	64.2324	10	90.91
PRIONOSPIO (LPIL)	(P)	71	0.6308	64.8632	10	90.91
EXOGONE LOUREI	(P)	69	0.6130	65.4762	11	100.00
PHASCOLION SP.B	(S)	68	0.6041	66.0803	10	90.91
ERICHTHONIUS BRASILIENSIS	(C)	63	0.5597	66.6400	11	100.00
CYCLASPIS PUSTULATA	(C)	63	0.5597	67.1997	7	63.64
OXYUROSTYLIS (LPIL)	(C)	59	0.5242	67.7239	11	100.00
MAGELONA SP.C	(P)	58	0.5153	68.2392	9	81.82
TURBELLARIA (LPIL)	(Pl)	53	0.4709	68.7101	11	100.00
ISCHNOCHITON SP.C	(M)	52	0.4620	69.1721	10	90.91
CRASSINELLA LUNULATA	(M)	51	0.4531	69.6252	8	72.73
ERVILIA CONCENTRICA	(M)	50	0.4442	70.0694	10	90.91
BRANCHIOSTOMA FLORIDAE	(Ce)	49	0.4353	70.5047	9	81.82
PIONOSYLLIS GESAE	(P)	48	0.4264	70.9311	10	90.91
CYCLASPIS SP.D	(C)	47	0.4176	71.3487	5	45.45
HEMIPODUS ROSEUS	(P)	46	0.4087	71.7574	10	90.91
PHYLLODOCIDAE (LPIL)	(P)	44	0.3909	72.1483	9	81.82
LILJEBORGIA SP.A	(C)	42	0.3731	72.5214	10	90.91
OPHELIA DENTICULATA	(P)	41	0.3643	72.8857	5	45.45
PARAPIONOSYLLIS UEBELACKERAE	(P)	41	0.3643	73.2500	7	63.64
TYPOSYLLIS AMICA	(P)	41	0.3643	73.6143	9	81.82
BOWMANIELLA PORTORICENSIS	(C)	39	0.3465	73.9608	9	81.82
SCHISTOMERINGOS CF. RUDOLPHI	(P)	38	0.3376	74.2984	7	63.64
ARENE TRICARINATA	(M)	38	0.3376	74.6360	9	81.82
PLAKOSYLLIS QUADRIOCULATA	(P)	35	0.3109	74.9469	9	81.82
SABELLARIA SP.A	(P)	35	0.3109	75.2578	7	63.64
STROMBIFORMIS AURICINCTUS	(M)	33	0.2932	75.5510	9	81.82
CRASSINELLA MARTINICENSIS	(M)	32	0.2843	75.8353	10	90.91
MELANELLA SP.E	(M)	31	0.2754	76.1107	4	36.36
CIRRATULIDAE (LPIL)	(P)	30	0.2665	76.3772	9	81.82
AONIDES MAYAGUEZENSIS	(P)	30	0.2665	76.6437	9	81.82
PAGURIDAE (LPIL)	(C)	30	0.2665	76.9102	10	90.91

(C) = Crustacea, (Ce) = Cephalochordata, (Cn) = Cnidaria, (E) = Echinodermata, (M) = Mollusca, (O) = Oligochaeta, (P) = Polychaeta, (Pl) = Platyhelminthes, (R) = Rhynchocoela, (S) = Sipuncula

Molluscs ranked third in species abundance (105, or 25.2%) and fourth in individual abundance (1,192, or 10.6%). *Caecum* sp. A was the most abundant mollusc taxon present, and eighth most abundant overall. Other dominant molluscan taxa were *Caecum cooperi* and *Ischnochiton* sp. C.

Echinoderms were represented by only 10 taxa (2.4%), but ranked second in individual abundance (1,781 or 15.8%). An unidentified ophiuroid was the most abundant taxon and comprised 15.8% of all organisms censused.

Other phyla comprised approximately 9% of individuals and 5% of taxa. The most abundant miscellaneous taxon was Rhynchocoela (LPIL), which ranked sixth in abundance. Thirteen phyla were represented among the infaunal community (Appendix A).

Community statistics by station (Table 4) reflect very high similarity among stations. Species abundance ranged from 134 to 184 while individual abundance ranged from 6,439 to 11,139/m^2. Mean densities were very uniform with respect to intra-station variability, and coefficients of variation ranged from 25.8% (Station 7) to 61.3% (Station 8). Station 11, which was located furthest from (south of) the disposal site had a moderate number of taxa (138), while Station 10, which was located in the south portion of the old disposal site had 134 taxa and the lowest individual abundance. Extremely high individual abundance at Station 5 was attributed to several dominant taxa, including the polychaete Serpulidae (LPIL), the echinoderm Holothuria sp. A, and the mollusc *Caecum* sp. A. Station 6 also had very high individual abundance, and was dominated by Ophiuroidea (LPIL).

Shannon-Weaver species diversity *H'* ranged from 3.20 (Station 6) to 4.32 (Station 8), and was very high at all sample stations. As stated earlier, Station 6 infauna were dominated by the echinoderm Ophiuroidea (LPIL) which comprised 33.5% of the organisms present at that station. This taxon was also the numerical dominant at Station 8, but comprised less than 14% of total individuals.

Table 4. Benthic community statistics for monitoring performed at the Ft. Pierce, Florida ODMDS in March 1992.

STATION NUMBER	TOTAL TAXA	MEAN TAXA PER REPL.	TOTAL NO. INDIVIDUALS	MEAN DENSITY	STANDARD DEVIATION	H'	J'	D
1	152	29.7	990	8354	3594	3.97	0.79	21.89
2	153	29.4	872	7359	2672	4.09	0.81	22.45
3	139	27.4	1005	8481	3211	3.60	0.73	19.96
4	135	26.2	772	6515	2578	3.89	0.79	20.15
5	175	26.0	1320	11139	3317	3.84	0.74	24.22
6	141	19.0	1224	10329	3919	3.20	0.65	19.69
7	141	31.9	1131	9544	2461	3.62	0.73	19.91
8	184	36.3	1134	9570	5869	4.32	0.83	26.02
9	158	36.0	1033	8718	4137	3.84	0.76	22.62
10	134	25.3	763	6439	3448	3.84	0.78	20.04
11	138	26.0	1012	8541	4355	3.46	0.70	19.80

Pielou's evenness index J' was moderately high and varied from 0.65 at Station 6 to 0.83 at Station 8, primarily in relation to the degree of numerical dominance by major taxa (as described above with respect to species diversity).

Margalef's species richness D reflected uniformly high taxa abundances, and values of this index were very high (up to 26.02 at Station 8). Lowest richness (19.69) occurred at Station 6, although this station did not have the lowest number of species (141).

Infaunal wet-weight biomass data showed some correspondence to individual abundances of the phyla. Echinoderms comprised the highest biomass at Stations 6, 9, and 10 (Table 5) and had the highest total biomass among all stations combined. Molluscs comprised the highest biomass at Stations 1, 2, 5 and 7. Station 9 had the greatest total infaunal standing crop, as a result of unusually high echinoderm biomass in Replicates F and M. Station 5 also had very high biomass, due to unusually large molluscs in Replicate D.

5.2 NUMERICAL CLASSIFICATION ANALYSIS

Both normal (station) and inverse (species) classification analyses were performed on the Ft. Pierce Harbor data set and displayed as dendrograms (Figures 3 and 4). Selection of the 56 species included in the analyses was based on a minimum representation of 0.25% of total individuals. Count data for the taxa selected for analysis (30 annelids, 8 crustaceans, 9 molluscs, 3 echinoderms, 2 sipunculids, 1 platyhelminth, 1 rhynchocoel, 1 cnidarian, and 1 cephalochordate) were included in a matrix of station and species groups (Table 6). These taxa accounted for nearly 77% of the macroinfaunal individuals collected.

Numerical classification of the 11 stations was interpreted at a three-group level (Figure 3). Groups were delineated at a degree of similarity of 72%, indicating high homogeneity among the stations that comprised these groups, and between groups. Groups A and C consisted of 6 and 3 stations, respectively. Group C stations were located in or above the northern part of the interim disposal site, and contained relatively low percent gravel. Group B (Station 8) occurred east of the disposal site and was characterized by sandy sediments that contained minimal amounts of silt, clay, and organic material. Group C stations contained gravelly sand sediments with low

Table 5. Benthic macroinfauna wet weight biomass for the Ft. Pierce Harbor, Florida ODMDS in March 1992. Replicate data are gm/0.0079m^2.

STATION	TAXON	REP A	REP B	REP C	REP D	REP E	REP F	REP G	REP H	REP I	REP J	REP K	REP L	REP M	REP N	REP O	TOTALS
001	ANNELIDA	0.027	0.050	0.013	0.018	0.038	0.092	0.015	0.071	0.012	0.013	0.039	0.021	0.011	0.024	0.008	0.452
001	ARTHROPODA	0.002	0.007	0.007	0.005	0.003	0.001	0.002	0.002	0.005	0.003	0.001	0.002	0.001	0.007	0.011	0.059
001	MOLLUSCA	0.007	0.015	0.001	0.002	0.055	0.001	0.014	0.014	0.222	0.022	0.071	0.014	0.030	0.065	0.010	0.543
001	ECHINODERMATA	0.005	0.027	0.006	0.018	0.014	0.011	0.002	0.005	0.054	0.004	0.003	0.004	0.024	0.049	0.005	0.231
001	MISCELLANEOUS	0.006	0.013	0.003	0.026	0.013	0.000	0.002	0.002	0.016	0.005	0.002	0.009	0.002	0.022	0.003	0.124
002	ANNELIDA	0.131	0.050	0.018	0.073	0.250	0.061	0.022	0.040	0.051	0.090	0.017	0.084	0.075	0.014	0.137	1.113
002	ARTHROPODA	0.029	0.004	0.006	0.001	0.002	0.001	0.004	0.002	0.001	0.006	0.010	0.007	0.004	0.001	0.002	0.080
002	MOLLUSCA	0.031	0.049	0.026	0.551	0.073	0.010	0.019	0.127	0.004	0.038	0.006	0.029	0.646	0.013	0.013	1.635
002	ECHINODERMATA	0.002	0.013	0.002	0.001	0.008	0.002	0.003	1.176	0.000	0.002	0.014	0.357	0.001	0.003	0.003	1.587
002	MISCELLANEOUS	0.000	0.022	0.002	0.001	0.133	0.035	0.014	0.004	0.077	0.011	0.015	0.001	0.012	0.025	0.031	0.383
003	ANNELIDA	0.030	0.005	0.010	0.012	0.013	0.012	0.091	0.010	0.019	0.017	0.033	0.007	0.005	0.015	0.035	0.314
003	ARTHROPODA	0.011	0.006	0.012	0.001	0.005	0.001	0.011	0.005	0.057	0.006	0.021	0.006	0.011	0.002	0.006	0.161
003	MOLLUSCA	0.017	0.003	0.001	0.002	0.008	0.018	0.005	0.000	0.020	0.003	0.002	0.002	0.003	0.056	0.014	0.154
003	ECHINODERMATA	0.006	0.025	0.015	0.002	0.065	0.001	0.021	0.028	0.037	0.081	0.002	0.002	0.017	0.033	0.002	0.337
003	MISCELLANEOUS	0.003	0.023	0.147	0.026	0.005	0.005	0.073	0.013	0.018	0.002	0.063	0.004	0.022	0.036	0.016	0.456
004	ANNELIDA	0.023	0.007	0.033	0.006	0.007	0.004	0.019	0.173	0.021	0.026	0.008	0.005	0.002	0.018	0.053	0.405
004	ARTHROPODA	0.012	0.003	0.013	0.013	0.007	0.001	0.005	0.003	0.003	0.003	0.007	0.003	0.006	0.009	0.007	0.095
004	MOLLUSCA	0.192	0.002	0.006	0.001	0.004	0.004	0.001	0.000	0.001	0.000	0.004	0.064	0.003	0.189	0.009	0.480
004	ECHINODERMATA	0.023	0.018	0.002	0.041	0.008	0.024	0.003	0.002	0.002	0.006	0.015	0.007	0.003	0.028	0.052	0.234
004	MISCELLANEOUS	0.022	0.022	0.001	0.024	0.017	0.056	0.003	0.043	0.040	0.063	0.042	0.003	0.044	0.014	0.052	0.446
005	ANNELIDA	0.063	0.045	0.060	0.081	0.045	0.007	0.071	0.048	0.116	0.055	0.038	0.084	0.060	0.066	0.108	0.947
005	ARTHROPODA	0.003	0.011	0.062	0.006	0.002	0.004	0.003	0.005	0.010	0.003	0.006	0.005	0.015	0.003	0.009	0.147
005	MOLLUSCA	0.130	0.018	0.002	4.456	0.012	0.116	0.058	0.011	0.016	0.002	0.021	0.018	0.122	0.013	0.040	5.035
005	ECHINODERMATA	0.000	0.051	0.001	0.010	0.002	0.001	0.026	0.005	0.006	0.001	0.002	0.001	0.023	0.003	0.001	0.133
005	MISCELLANEOUS	0.032	0.003	0.158	0.241	0.050	0.010	0.001	0.021	0.001	0.004	0.012	0.008	0.001	0.157	0.004	0.703
006	ANNELIDA	0.327	0.017	0.011	0.018	0.019	0.009	0.052	0.018	0.035	0.020	0.021	0.096	0.062	0.028	0.081	0.814
006	ARTHROPODA	0.002	0.003	0.007	0.001	0.001	0.004	0.001	0.006	0.001	0.005	0.006	0.001	0.002	0.001	0.004	0.045
006	MOLLUSCA	0.010	0.025	0.004	0.051	0.001	0.034	0.031	0.063	0.203	0.163	0.292	0.245	0.005	0.001	0.007	1.135
006	ECHINODERMATA	0.941	0.075	0.018	0.065	0.042	0.004	0.065	0.171	0.018	0.012	0.015	0.003	0.027	0.005	0.011	1.472
006	MISCELLANEOUS	0.002	0.011	0.029	0.011	0.001	0.004	0.002	0.008	0.002	0.003	0.069	0.233	0.018	0.007	0.008	0.408
007	ANNELIDA	0.152	0.011	0.007	0.042	0.047	0.046	0.014	0.024	0.031	0.013	0.030	0.015	0.028	0.019	0.031	0.510
007	ARTHROPODA	0.001	0.008	0.003	0.001	0.004	0.008	0.003	0.002	0.007	0.016	0.006	0.001	0.001	0.002	0.001	0.064
007	MOLLUSCA	0.021	0.008	0.033	0.009	0.043	0.079	0.016	0.243	0.009	0.021	0.055	0.022	0.015	0.004	0.111	0.689
007	ECHINODERMATA	0.051	0.047	0.031	0.022	0.014	0.087	0.030	0.006	0.020	0.032	0.102	0.049	0.010	0.047	0.064	0.612
007	MISCELLANEOUS	0.095	0.097	0.001	0.014	0.019	0.015	0.035	0.007	0.009	0.013	0.202	0.002	0.005	0.003	0.167	0.684
008	ANNELIDA	0.003	0.008	0.011	0.004	0.008	0.183	0.013	0.012	0.043	0.005	0.214	0.008	0.004	0.070	0.016	0.602
008	ARTHROPODA	0.003	0.016	0.002	0.008	0.005	0.002	0.011	0.003	0.003	0.006	0.002	0.006	0.004	0.007	0.006	0.084
008	MOLLUSCA	0.006	0.061	0.007	0.030	0.004	0.040	0.003	0.008	0.002	0.016	0.002	0.021	0.082	0.052	0.014	0.348
008	ECHINODERMATA	0.006	0.037	0.001	0.053	0.020	0.021	0.021	0.014	0.011	0.001	0.035	0.002	0.009	0.140	0.019	0.390
008	MISCELLANEOUS	0.001	0.079	0.027	0.022	0.084	0.011	0.038	0.028	0.047	0.004	0.007	0.001	0.008	0.076	0.161	0.594
009	ANNELIDA	0.050	0.017	0.011	0.002	0.051	0.021	0.019	0.006	0.116	0.031	0.092	0.104	0.008	0.066	0.043	0.637
009	ARTHROPODA	0.010	0.003	0.001	0.001	0.001	0.002	0.001	0.002	0.000	0.001	0.001	0.002	0.004	0.008	0.003	0.040
009	MOLLUSCA	0.055	0.007	0.005	0.004	0.003	0.003	0.001	0.015	0.020	0.005	0.037	0.048	0.027	0.028	0.007	0.265
009	ECHINODERMATA	0.493	0.948	0.004	0.003	0.014	7.025	0.003	0.011	0.019	0.016	0.215	0.009	3.427	0.011	0.079	12.277
009	MISCELLANEOUS	0.018	0.002	0.003	0.003	0.001	0.165	0.019	0.044	0.002	0.014	0.002	0.011	0.018	0.005	0.009	0.316
010	ANNELIDA	0.009	0.006	0.005	0.006	0.026	0.013	0.014	0.006	0.055	0.030	0.019	0.014	0.007	0.002	0.004	0.216
010	ARTHROPODA	0.001	0.006	0.003	0.002	0.003	0.002	0.003	0.005	0.002	0.007	0.002	0.001	0.002	0.006	0.002	0.047
010	MOLLUSCA	0.000	0.024	0.014	0.002	0.020	0.003	0.001	0.006	0.008	0.022	0.008	0.001	0.031	0.001	0.001	0.142
010	ECHINODERMATA	0.019	0.076	0.060	0.022	0.081	1.054	0.001	0.121	0.028	0.032	0.051	0.007	0.059	0.005	0.006	1.622
010	MISCELLANEOUS	0.001	0.001	0.001	0.002	0.003	0.065	0.001	0.013	0.005	0.001	0.004	0.001	0.005	0.001	0.043	0.147
011	ANNELIDA	0.134	0.026	0.047	0.008	0.184	0.063	0.040	0.034	0.061	0.020	0.006	0.018	0.018	0.024	0.008	0.691
011	ARTHROPODA	0.000	0.001	0.001	0.002	0.003	0.001	0.001	0.006	0.000	0.003	0.003	0.004	0.002	0.001	0.002	0.030
011	MOLLUSCA	0.027	0.005	0.084	0.001	0.005	0.002	0.012	0.029	0.003	0.001	0.003	0.013	0.010	0.001	0.003	0.199
011	ECHINODERMATA	0.003	0.002	0.008	0.004	0.005	0.001	0.002	0.009	0.004	0.001	0.002	0.002	0.002	0.032	0.027	0.104
011	MISCELLANEOUS	0.005	0.079	0.041	0.204	0.005	0.002	0.039	0.181	0.024	0.055	0.013	0.415	0.001	0.005	0.001	1.070

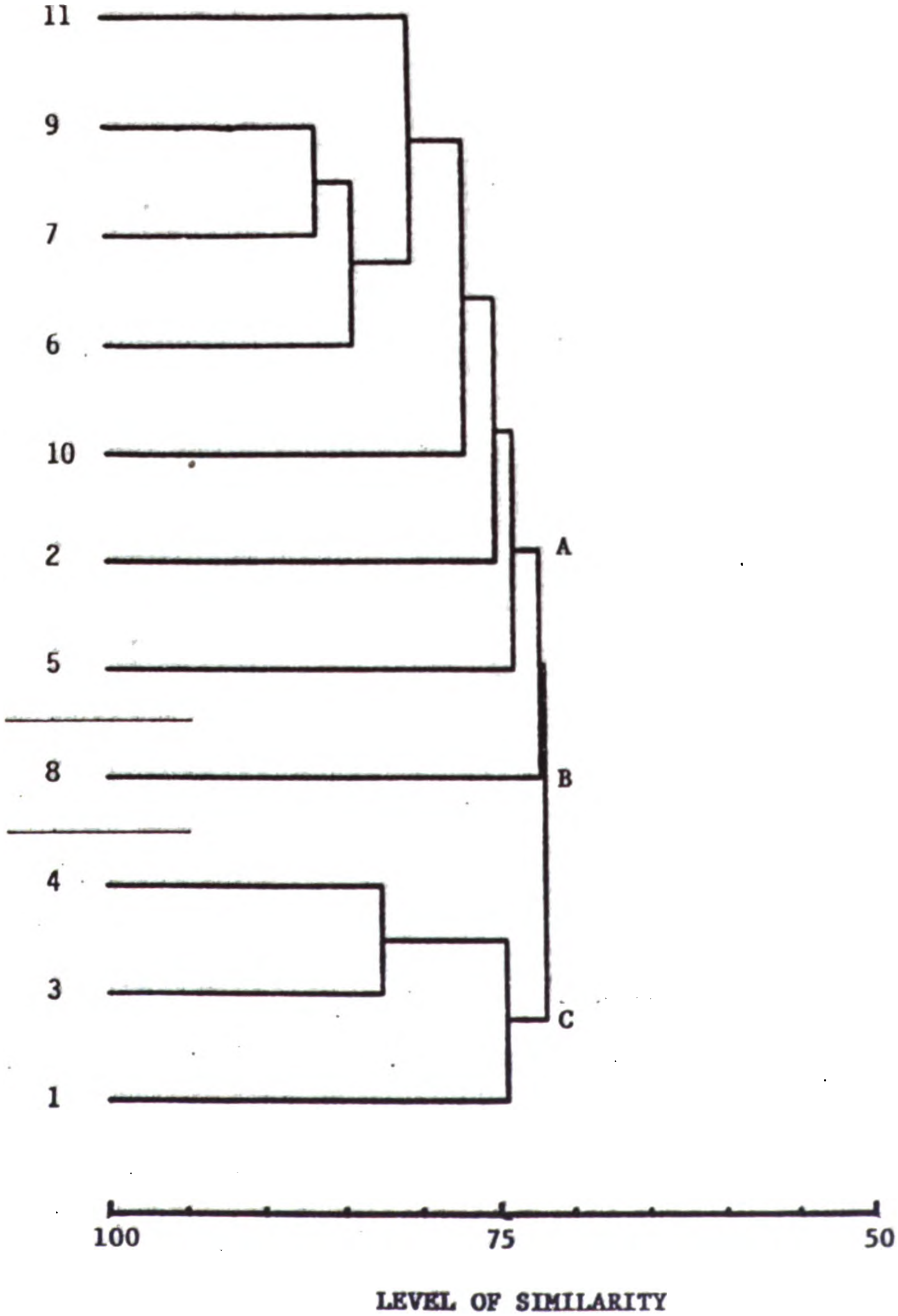

Figure 3. Normal (station) classification analysis dendrogram for infauna sampled at the Ft. Pierce, Florida ODMDS in March 1992.

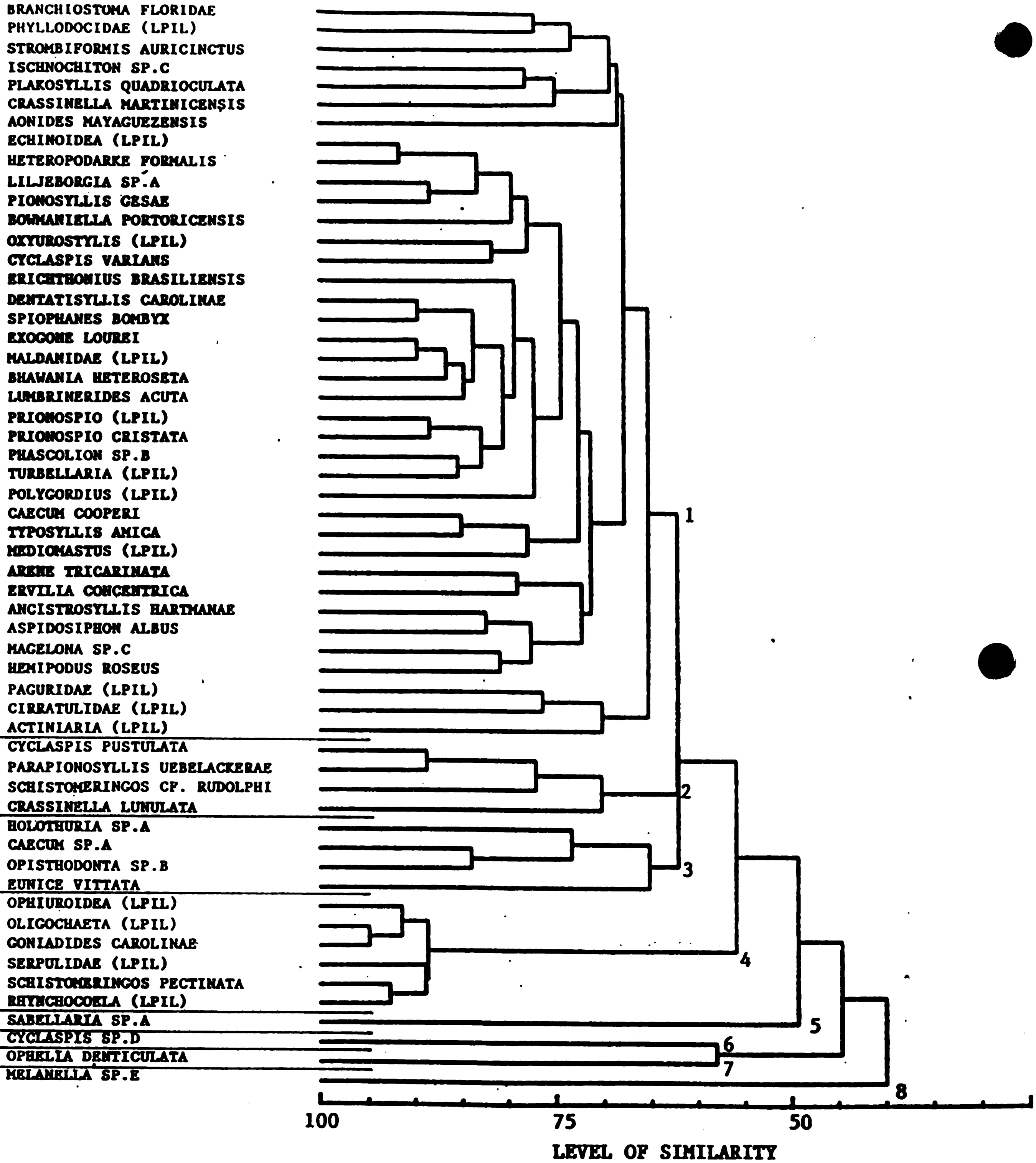

Figure 4. Inverse (species) classification analysis dendrogram for infauna sampled at the Ft. Pierce, Florida ODMDS in March 1992.

Table 6. Data matrix of station and species groups compiled from classification analysis dendrograms for EPA Fort Pierce Harbor, Florida ODMDS benthic survey, March 1992.

NUMBER INDIVIDUALS/STATION

		A							B	C		
		11	9	7	6	10	2	5	8	4	3	1
	BRANCHIOSTOMA FLORIDAE	9	4	6	3	0	6	10	4	5	2	0
	PHYLLODOCIDAE (LPIL)	3	4	7	3	3	4	8	0	11	0	1
	STROMBIFORMIS AURICINCTUS	9	5	1	7	1	4	1	0	4	1	0
	ISCHNOCHITON SP.C	1	5	13	4	1	4	6	3	1	0	14
	PLAKOSYLLIS QUADRIOCULATA	6	5	7	3	2	4	2	5	0	0	1
	CRASSINELLA MARTINICENSIS	2	5	4	0	1	9	1	5	1	1	3
	AONIDES MAYAGUEZENSIS	2	2	6	3	8	5	1	1	0	2	0
	ECHINOIDEA (LPIL)	2	5	9	2	16	0	1	7	10	10	10
	HETEROPODARKE FORMALIS	4	6	20	2	18	0	2	15	17	15	10
	LILJEBORGIA SP.A	2	3	2	2	7	0	4	5	10	5	2
	PIONOSYLLIS GESAE	2	5	3	4	11	0	1	6	9	3	4
	BOWMANIELLA PORTORICENSIS	2	1	4	2	4	0	3	7	6	10	0
	OXYUROSTYLIS (LPIL)	3	2	3	8	14	2	1	14	4	6	2
	CYCLASPIS VARIANS	3	4	1	2	19	10	5	25	3	7	9
	ERICHTHONIUS BRASILIENSIS	1	5	3	3	5	10	4	9	18	1	4
	DENTATISYLLIS CAROLINAE	7	15	17	6	9	13	15	47	12	22	14
	SPIOPHANES BOMBYX	5	13	17	19	15	9	17	12	22	6	8
	EXOGONE LOUREI	5	8	5	6	5	7	10	14	5	1	3
	MALDANIDAE (LPIL)	8	14	8	6	8	6	12	10	2	2	10
	BHAWANIA HETEROSETA	14	19	11	10	10	13	5	4	2	1	6
	LUMBRINERIDES ACUTA	15	2	14	15	5	11	11	3	5	3	13
	PRIONOSPIO (LPIL)	3	3	6	10	2	10	8	9	9	11	8
1	PRIONOSPIO CRISTATA	2	6	11	13	6	3	8	7	11	9	1
	PHASCOLION SP.B	6	6	6	15	6	0	7	11	7	2	2
	TURBELLARIA (LPIL)	2	7	4	9	6	2	5	6	3	3	6
	POLYGORDIUS (LPIL)	2	9	4	14	1	14	18	1	2	5	2
	CAECUM COOPERI	1	8	12	7	1	3	1	7	6	7	23
	TYPOSYLLIS AMICA	0	4	5	6	0	3	1	7	3	8	4
	MEDIOMASTUS (LPIL)	0	10	40	5	2	8	1	12	1	3	2
	ARENE TRICARINATA	0	7	7	1	3	4	7	0	1	3	5
	ERVILIA CONCENTRICA	2	6	3	2	4	4	2	0	8	14	5
	ANCISTROSYLLIS HARTMANAE	11	16	8	11	5	11	2	2	5	16	2
	ASPIDOSIPHON ALBUS	25	8	6	11	1	3	3	0	49	22	2
	MAGELONA SP.C	9	13	10	8	1	2	0	0	5	2	8
	HEMIPODUS ROSEUS	10	3	6	6	3	4	0	1	2	7	4
	PAGURIDAE (LPIL)	1	1	2	1	0	3	6	5	3	2	6
	CIRRATULIDAE (LPIL)	4	3	2	1	0	1	0	3	3	8	5
	ACTINIARIA (LPIL)	6	1	1	0	3	3	12	60	2	7	5
	CYCLASPIS PUSTULATA	5	5	10	13	5	0	11	14	0	0	0
	PARAPIONOSYLLIS UEBELACKERAE	3	2	8	2	5	0	9	12	0	0	0
2	SCHISTOMERINGOS CF. RUDOLPHI	0	11	7	1	3	1	6	9	0	0	0
	CRASSINELLA LUNULATA	9	5	6	12	6	0	10	0	0	1	2
	HOLOTHURIA SP.A	1	21	0	12	10	36	138	4	1	1	34
	CAECUM SP.A	12	20	16	5	2	22	116	9	0	1	8
3	OPISTHODONTA SP.B	11	12	4	1	1	19	15	5	0	1	3
	EUNICE VITTATA	1	3	0	3	1	2	63	12	0	0	1
	OPHIUROIDEA (LPIL)	87	177	181	410	89	35	18	150	73	129	81
	OLIGOCHAETA (LPIL)	187	89	144	81	88	72	25	16	51	26	109
	GONIADIDES CAROLINAE	173	76	127	145	66	114	40	24	53	110	47
4	SERPULIDAE (LPIL)	55	89	82	46	7	42	261	48	33	66	108
	SCHISTOMERINGOS PECTINATA	22	47	39	42	54	25	20	50	71	168	53
	RHYNCHOCOELA (LPIL)	44	23	26	44	43	30	37	30	43	44	23
5	SABELLARIA SP.A	3	0	1	0	1	0	4	22	1	0	3
6	CYCLASPIS SP.D	0	0	0	0	0	5	5	0	13	4	20
7	OPHELIA DENTICULATA	0	0	0	0	4	0	0	10	4	5	18
8	MELANELLA SP.B	11	4	0	0	3	13	0	0	0	0	0

amounts of silt, and low percent organics. Group C stations were located both within and outside the disposal site.

Classification of the 56 taxa at the 11 stations was interpreted at a five-group level (Figure 4). This classification based the grouping of species on their overall distribution patterns. Species groups were relatively homogeneous and were delineated at a 40% or higher level of similarity. The relationship of species or species groups to the probable habitat types identified through classification of stations was best represented by a two-way coincidence table in which a data matrix was arranged by station and species groups (Table 6). Quantitative interpretation of the degree of coincidence between station groups and species was then examined via nodal analysis of constancy, fidelity, and abundance. Nodal diagrams (Figure 5) are discussed below.

Species Group 1 contained 38 of the 56 taxa considered, and represented a diverse assemblage typical of both shelly sand and silty sand habitats. Species Group 1 contained moderately dominant taxa, including *Spiophanes bombyx*, *Caecum cooperi*, and *Dendatisyllis carolinae*. Group 1 species showed high constancy, fidelity, and abundance at Group A stations. These taxa showed moderate association with station Group C (those with lower percent gravel).

Species Group 2 contained 4 taxa, most of which are generally characteristic of silty sand habitats. The species in this group were moderately abundant, but were not among the most dominant taxa. Group 2 showed high constancy and fidelity at Group A stations, but had generally low affinity for this group with respect to abundance. Species Group 2 had low affinity for station Groups A and B.

Species Group 3 also contained 4 taxa, generally associated with silty sand substrates (e.g., the echinoderm Holothuria sp. A; the gastropods *Caecum* sp. A and *Opisthodonta* sp. B; and the polychaete *Eunice vittata*. These species were locally abundant, and had high constancy and fidelity at Group A stations, despite the presence of coarser substrate at Group A stations.

Species Group 4 contained 5 of the 56 taxa. These taxa generally associated with both silty sand and shell-hash sediments, and were the most abundant taxa censused. Group 4 species

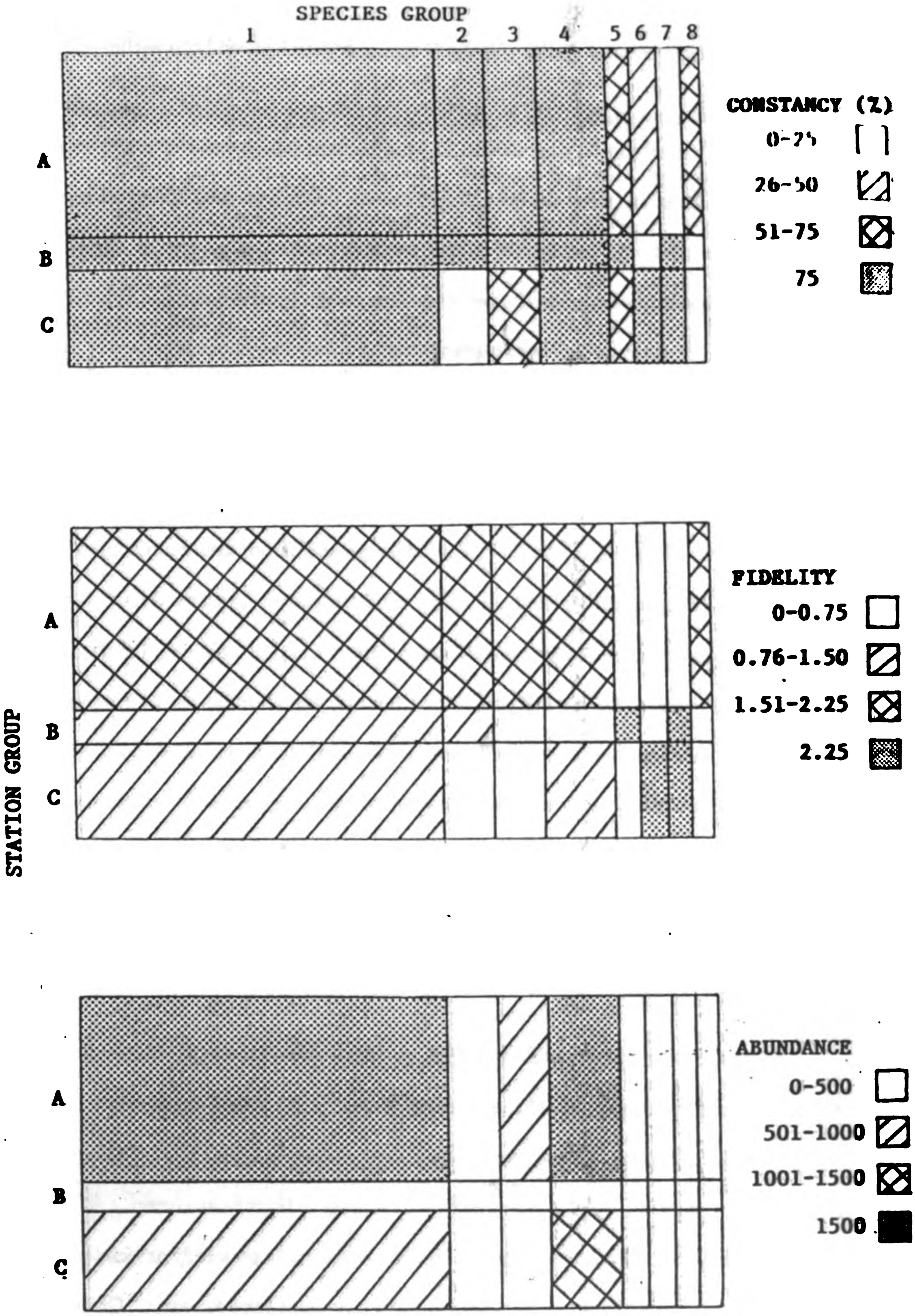

Figure 5. Nodal analysis diagrams of groups based on numerical classification analysis for the Ft. Pierce, Florida ODMDS benthic survey, March 1992.

showed high constancy, fidelity, and abundance at Group A stations, and high constancy and abundance at Group C stations.

Species Groups 5, 6, 7, and 8 each contained only one species. These taxa occurred in low numbers at most stations.

5.3 SPECIES ASSEMBLAGES

The above analyses of the Ft. Pierce Harbor infaunal data indicated the presence of two main species assemblages, based on apparent habitat type. Representative taxa are listed below.

Gravelly Sand assemblage (Stations 2, 5, 6, 7, 9, 10, 11)

Bhawania heteroseta	(P)
Lumbrinerides acuta	(P)
Polygordius (LPIL)	(P)
Schistomeringos cf. *rudolphi*	(P)
Eunice vittata	(P)
Holothuria sp. A	(E)
Caecum sp. A	(M)
Opisthodonta sp. B	(M)

Silty sand assemblage (Stations 1, 3, 4, 8)

Aspidosiphon albus	(S)
Ervilia concentrica	(M)
Ophelia denticulata	(P)
Cyclaspis sp. D	(C)
Caecum cooperi	(M)

These assemblages were not clearly distinguished at the Ft. Pierce ODMDS, due to the generally high similarity among stations.

6.0 SUMMARY

The results of the benthic survey of the Ft. Pierce Harbor ODMDS may be summarized as follows.

1. Coarsest (gravelly sand) bottoms occurred in the southern portion of the study area, and silty sand stations occurred in the northern part of the disposal site. Percent silt, clay, a[illegible] organic was very low throughout the study area.

2. Annelids, arthropods, and molluscs contributed the majority of taxa censused during the survey, while annelids, echinoderms, and arthropods accounted for the greatest proportion of individuals.

3. Species abundance was very high at all stations, with greatest numbers of taxa at stations characterized by sand sediments with high gravel content. Somewhat lower species abundance occurred at stations that exhibited low to high percent gravel.

4. Individual abundance was moderately high and was generally uniform throughout the study area, and did not appear to be related consistently to sediment texture.

5. Species diversity, evenness, and richness were very high throughout the study area. Highest diversities were not consistently related to elevated percent gravel.

6. Community classification analyses indicated the presence of two major station groups and four major species groups. Station groups were related primarily to location and percent gravel. Species groups also showed correspondence to these parameters.

7. Nodal analyses identified constancy, fidelity, and abundance of species groups in relation to station groups, and showed two infaunal species assemblages based on habitat type: gravelly sand and silty sand species assemblages.

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APPENDIX A

Phylogenetic List of Infaunal Taxa for the Ft. Pierce Harbor ODMDS Survey in March 1992

ANNELIDA

OLIGOCHAETA

OLIGOCHAETA (LPIL)

POLYCHAETA

ACROCIRRIDAE

MACROCHAETA SP.A

AMPHARETIDAE

AMPHARETE (LPIL)
AMPHARETE SP.A
AMPHARETIDAE (LPIL)
ISOLDA PULCHELLA

AMPHINOMIDAE

EURYTHOE SP.B
PARAMPHINOME SP.B

ARABELLIDAE

ARABELLA MUTANS
ARABELLIDAE (LPIL)
DRILONEREIS SP.E
LABROROSTRATUS (LPIL)

CAPITELLIDAE

CAPITELLIDAE (LPIL)
DASYBRANCHUS SP.C
MEDIOMASTUS (LPIL)
MEDIOMASTUS CALIFORNIENSIS
NOTOMASTUS (LPIL)

CHAETOPTERIDAE

MESOCHAETOPTERUS (LPIL)
MESOCHAETOPTERUS CAPENSIS
SPIOCHAETOPTERUS OCULATUS

CHRYSOPETALIDAE

BHAWANIA HETEROSETA
PALEANOTUS SP.A

CIRRATULIDAE

CAULLERIELLA (LPIL)
CAULLERIELLA CF. ALATA
CAULLERIELLA SP.B
CIRRATULIDAE (LPIL)
DODECACERIA SP.A
THARYX CF. ANNULOSUS

DORVILLEIDAE

PETTIBONEIA DUOFURCA
SCHISTOMERINGOS CF. RUDOLPHI
SCHISTOMERINGOS PECTINATA

EUNICIDAE

EUNICE SP.B
EUNICE SP.C
EUNICE VITTATA
EUNICIDAE (LPIL)

LYSIDICE SP.G

MARPHYSA (LPIL)
NEMATONEREIS HEBES
GLYCERIDAE
GLYCERA (LPIL)
GLYCERA SP.F
GLYCERIDAE (LPIL)
HEMIPODUS ROSEUS
GONIADIDAE
GONIADIDES CAROLINAE
HESIONIDAE
HESIONIDAE (LPIL)
HETEROPODARKE FORMALIS
HETEROPODARKE LYONSI
MICROPHTHALMUS HARTMANAE
PODARKE SP.D
PODARKEOPSIS LEVIFUSCINA
LUMBRINERIDAE
LUMBRINERIDAE (LPIL)
LUMBRINERIDES (LPIL)
LUMBRINERIDES ACUTA
LUMBRINERIS LATREILLI
LUMBRINERIS VERRILLI
MAGELONIDAE
MAGELONA (LPIL)
MAGELONA SP.B
MAGELONA SP.C
MAGELONA SP.I
MALDANIDAE
AXIOTHELLA MUCOSA
AXIOTHELLA SP.A
MALDANIDAE (LPIL)
PETALOPROCTUS SP.A
PETALOPROCTUS SP.B
NEPHTYIDAE
NEPHTYIDAE (LPIL)
NEPHTYS SIMONI
NEPHTYS SQUAMOSA
NEREIDAE
CERATONEREIS LONGICIRRATA
NEREIDAE (LPIL)
NEREIS (LPIL)
ONUPHIDAE
DIOPATRA CUPREA
MOOREONUPHIS CF. NEBULOSA
MOOREONUPHIS PALLIDULA
ONUPHIDAE (LPIL)
OPHELIIDAE
ARMANDIA MACULATA

OPHELIA DENTICULATA

ORBINIIDAE
- ORBINIIDAE (LPIL)
- SCOLOPLOS RUBRA

OWENIIDAE
- GALATHOWENIA OCULATA
- OWENIA SP.A
- OWENIIDAE (LPIL)

PARAONIDAE
- ARICIDEA CF. CERRUTII
- ARICIDEA SP.A
- CIRROPHORUS (LPIL)
- CIRROPHORUS BRANCHIATUS
- PARAONIDAE (LPIL)

PHYLLODOCIDAE
- ANAITIDES MADERIENSIS
- ANAITIDES MUCOSA
- EUMIDA SANGUINEA
- NEREIPHYLLA FRAGILIS
- PARANAITIS SPECIOSA
- PHYLLODOCIDAE (LPIL)

PILARGIDAE
- ANCISTROSYLLIS (LPIL)
- ANCISTROSYLLIS CAROLINENSIS
- ANCISTROSYLLIS HARTMANAE
- ANCISTROSYLLIS JONESI
- LITOCORSA ANTENNATA
- PILARGIDAE (LPIL)
- PILARGIS BERKELEYAE
- SIGAMBRA BASSI
- SYNELMIS CF. ALBINI
- SYNELMIS EWINGI

PISIONIDAE
- PISIONE REMOTA

POECILOCHAETIDAE
- POECILOCHAETUS (LPIL)

POLYGORDIIDAE
- POLYGORDIUS (LPIL)

POLYNOIDAE
- HARMOTHOE SP.B
- HARMOTHOE SP.C
- POLYNOIDAE (LPIL)

SABELLARIIDAE
- SABELLARIA SP.A

SABELLIDAE
- CHONE (LPIL)
- HYPSICOMUS PHAETOENIA
- POTASPINA SP.A
- SABELLIDAE (LPIL)

SACCOCIRRIDAE
- SACCOCIRRUS SP.A

SERPULIDAE
- PSEUDOVERMILIA OCCIDENTALIS
- SERPULIDAE (LPIL)

SIGALIONIDAE
- PSAMMOLYCE CTENIDOPHORA
- SIGALION SP.A
- SIGALIONIDAE (LPIL)

SPIONIDAE
- AONIDES MAYAGUEZENSIS
- LAONICE CIRRATA
- MICROSPIO PIGMENTATA
- PARAPRIONOSPIO PINNATA
- POLYDORA SOCIALIS
- PRIONOSPIO (LPIL)
- PRIONOSPIO CIRRIFERA
- PRIONOSPIO CRISTATA
- SCOLELEPIS SQUAMATA
- SPIO PETTIBONEAE
- SPIONIDAE (LPIL)
- SPIOPHANES BOMBYX

SYLLIDAE
- AUTOLYTUS DENTALIUS
- BENTATISYLLIS CAROLINAE
- EHLERSIA CORNUTA
- EHLERSIA SP.A
- EXOGONE ATLANTICA
- EXOGONE DISPAR
- EXOGONE LOUREI
- GRUBEOSYLLIS CLAVATA
- OPISTHODONTA SP.B
- PARAPIONOSYLLIS LONGICIRRATA
- PARAPIONOSYLLIS UEBELACKERAE
- PIONOSYLLIS GESAE
- PIONOSYLLIS SP.M
- PLAKOSYLLIS QUADRIOCULATA
- SPHAEROSYLLIS BILOBATA
- SPHAEROSYLLIS CENTROAMERICANA
- SPHAEROSYLLIS GLANDULATA
- SPHAEROSYLLIS PIRIFEROPSIS
- SPHAEROSYLLIS TAYLORI
- STREPTOSYLLIS PETTIBONEAE
- STREPTOSYLLIS SP.C
- SYLLIDAE (LPIL)
- SYLLIDAE GENUS F
- SYLLIDES BANSEI
- SYLLIDES FLORIDANUS
- SYLLIS GRACILIS
- TRYPANOSYLLIS COELIACA

- TYPOSYLLIS AMICA

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TYPOSYLLIS SP.B
TEREBELLIDAE
HAUCHIELLA SP.A
LOIMIA MEDUSA
LYSILLA SP.B
POLYCIRRUS (LPIL)
TEREBELLIDAE (LPIL)
ARTHROPODA (ARACHNIDA)
HYDRACARINA
SPERCHONTIDAE
SPERCHON (LPIL)
ARTHROPODA (CRUSTACEA)
AMPHIPODA
AMPHIPODA (LPIL)
AEGINELLIDAE
AEGINELLIDAE (LPIL)
DEUTELLA (LPIL)
DEUTELLA INCERTA
AMPELISCIDAE
AMPELISCA AGASSIZI
AMPHILOCHIDAE
AMPHILOCHUS (LPIL)
GITANOPSIS SP.D
AMPITHOIDAE
AMPITHOE SP.A
AORIDAE
AORIDAE (LPIL)
MICRODEUTOPUS MYERSI
RILDARDANUS LAMINOSA
ARIGISSIDAE
ARGISSIDAE (LPIL)
CAPRELLIDAE
CAPRELLA (LPIL)
CAPRELLA SP.A
CAPRELLIDAE (LPIL)
COROPHIIDAE
COROPHIIDAE (LPIL)
GAMMARIDAE
GAMMARIDAE (LPIL)
GIBBEROSUS (LPIL)
GIBBEROSUS MYERSI
HAUSTORIIDAE
ACANTHOHAUSTORIUS SP.P
ISAEIDAE
ISAEIDAE (LPIL)
MEGAMPHOPUS (LPIL)
PHOTIS (LPIL)
ISCHYROCERIDAE

CERAPUS (LPIL)

CERAPUS SP.B
CERAPUS SP.E
ERICHTHONIUS (LPIL)
ERICHTHONIUS BRASILIENSIS
ISCHYROCERIDAE (LPIL)
LILJEBORGIIDAE
LILJEBORGIA (LPIL)
LILJEBORGIA SP.A
LILJEBORGIIDAE (LPIL)
MELITIDAE
ELASMOPUS (LPIL)
MAERA (LPIL)
MAERA SP.C
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APPENDIX J

MAPPING OF SEDIMENT CHEMISTRY
AT THE
PROPOSED FORT PIERCE, FLORIDA ODMDS
AND
POST DISPOSAL MAPPING AT THE INTERIM ODMDS

Final Report

MAPPING OF SEDIMENT CHEMISTRY AT THE PROPOSED FORT PIERCE, FLORIDA ODMDS AND POSTDISPOSAL MAPPING AT THE INTERIM ODMDS

EPA Contract No. 68-C8-0105
Work Assignment 4-203

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1.0 INTRODUCTION

Ocean disposal of dredged materials can affect the environment of a disposal site by disrupting the benthic community and potentially causing long-term reduction of oxygen in the pore waters of the surficial sediments and the overlying water column. Dredged materials may also be transported by natural ocean processes into habitats adjacent to the disposal site. Because careful selection of a disposal site can minimize impact to sensitive areas, an Environmental Impact Statement is prepared to address these ecological considerations. Once a site is chosen for disposal of dredged materials, the Environmental Protection Agency (EPA), in conjunction with the United States Army Corps of Engineers (USACE), becomes responsible for managing and monitoring the disposal site and associated disposal activities. This responsibility is mandated under Section 102 of the Marine Protection, Research, and Sanctuaries Act of 1972 (MPRSA). EPA Region IV is currently responsible for managing and monitoring 34 ocean dredged-material disposal sites (ODMDS). A critical component of the monitoring programs is the tracking of sediment and sediment movement patterns in and around the ODMDSs. Determining the transport and fate of deposited material is the key to understanding the potential long-term effects of the dredged-material disposal and identifying where the effects may be manifested.

To assist in the designation and future monitoring of the proposed Fort Pierce ODMDS, EPA Region IV used two rapid seafloor sediment-sampling and analysis systems developed by the Center for Applied Isotope Studies (CAIS). One system, the Gamma Isotope Mapping System (GIMS), uses a towed sled with gamma spectroscopy capabilities for determining the seafloor lithology. The second system, the Continuous Sediment Sampling System (CS^3), uses a specially equipped sled that pumps a sediment slurry to a survey vessel where the slurry density is viewed through a sight tube and filtered. The retained particles are later analyzed by x-ray fluorescence (XRF) at the CAIS laboratory. The GIMS and the CS^3 enabled the survey team to acquire real-time mapping of seafloor sediments in and around a disposal site, and permitted *in situ* evaluations of native sediments and dredged material.

Because EPA Region IV has routinely used the GIMS and CS^3 during ODMDS monitoring activities over the past several years, the operation of these two systems and the subsequent analysis of collected samples has become routine. Therefore, the EPA determined that one generic, comprehensive (19-point) Quality Assurance Project Plan (QAPjP) would be applicable to all ODMDS surveys using these systems. This QAPjP (EPA, 1991) should be referenced for detailed descriptions of the technical approaches, quality assurance, and quality control methods for the GIMS and CS^3.

2.0 OBJECTIVE

This was the first sediment mapping survey performed on the proposed Fort Pierce ODMDS. The primary purpose of the survey was to document the sediment lithology within and immediately surrounding the ODMDS. The data collected as a result of the sediment mapping survey will be reviewed as part of the official designation of the site. A secondary objective was to locate and identify dredged material deposited within the interim ODMDS during past dredge disposal activities.

3.0 TECHNICAL APPROACH

The March 1992 survey involved the systematic mapping of the relative elemental composition of sediments at and near the proposed Fort Pierce ODMDS. Two- and three-dimensional maps were generated using the GIMS survey data. The target analytes monitored are presented in Table 1. Box-core samples were collected and analyzed using XRF for elemental content, a Ge(Li) detector for gamma radiation, and standard testing sieves for particle size. Target analytes and particle-size classification measured on the box-core sediment samples are also listed in Table 1. Table 2 lists the technical data for the GIMS and the CS^3.

The survey was conducted using the EPA Ocean Survey Vessel *Peter W. Anderson* (OSV *Anderson*). The Loran navigation system aboard the survey vessel was used as the primary

Table 1. Analytes and Reporting Units According to Analytical Method

Analytical System		Analyte		Reporting Units
GIMS		K-40	Potassium	Counts per minute (cpm)
		Bi-214	Bismuth	
		Tl-208	Thalium	
		Total		
XRF (CS^3 and box cores)		Mg	Magnesium	Weight percent (wt%)
		Al	Aluminum	
		Si	Silicon	
		S	Sulfur	
		Ca	Calcium	
		Fe	Iron	
		P	Phosphorus	
		Sr	Strontium	
		Ti	Titanium	Parts per million (ppm)
		Cr	Chromium	
		Mn	Manganese	
		Ni	Nickel	
		Cu	Copper	
		Zn	Zinc	
		Zr	Zirconium	
		Cd	Cadmium	
		Sn	Tin	
		Sb	Antimony	
		Ba	Barium	
		Pb	Lead	
Radiometric		U	Uranium	Picocuries per kilogram (pCi/kg)
		Th	Thorium	
		K	Potassium	
Particle size	>1.000-mm	very coarse sand		Percent (%) by weight
	1.000-0.500-mm	coarse sand		
	0.500-0.250-mm	medium sand		
	0.250-0.125-mm	fine sand		
	0.125-0.062-mm	very fine sand		
	<0.062-mm	silt		

Table 2. GIMS and CS^3 Technical Data

GIMS

Data results	Counts per minute (cpm)
Listing	Hard-copy printout
Time between stations	60 s
Calibration standard	Monazite sand
Calibration results	Spectrum printout
Navigational method	Loran and Global Positioning System (GPS)
Operating range	
Gamma signal depth	≈25 cm
Reference	Cs-137
Reference channel	55
Resolution	≈ 8%
Gain	0-255
Preferred gain	50-220
Ship speed	2.5 to 3 kn

CS^3

Analytical method	XRF
Data results	Parts per million (ppm) Weight percent (wt%)
Listing	Hard-copy printout
Distance between stations	305 m
Calibration test	NIST standards for XRF
Navigational method	Loran and Global Position System
Operating range	
Penetration (sled)	≈2-10 cm
Ship speed	2.5 to 3 kn
Sample	Sediment pellet or wafer on glass fiber filter
Sample size	≈31 mm
Sample weight	20-200 mg

navigation system. The Loran navigation system and fathometer within the CAIS sampling systems were calibrated to the ship's navigation system.

3.1 Gamma Isotope Mapping System

The first system deployed was the GIMS. This system recorded gamma radiation data in counts per minute for Bi-214, Tl-208, K-40, and the total activity. Bi-214 reflected the uranium content of phosphatic deposits often found along the coast of the southeastern United States. Tl-208 indicated heavy mineral content. K-40 indicated fine clay sediments. Total gamma activity represented the total spectrum of gamma radiation measured in the survey region.

Prior to deployment, the GIMS was tested with a radioactive monazite-sand reference sample to check the calibration of the spectrometer. The gamma sled was lowered to the seafloor and activated. It was towed at speeds of 2.5 to 3 kn along transects predetermined by EPA personnel. The GIMS transects were identified by time and location (latitude and longitude). Data were stored on computer diskette, and a hard copy was produced for review during the survey.

The GIMS recorded the latitude, longitude, and water depth of each station with a Loran navigation system and a fathometer calibrated to the ship's systems. There was a 60-s delay from the time when the coordinates and depth were recorded to the time when the data were retrieved from the spectrometer. This allowed the system to record the actual position of the gamma sled.

A four-color plot showing the ship's transects and Bi-214 gamma intensities was produced while the survey was in progress; blue indicated the lowest level of activity, and green, red, and orange indicated increasing levels of activity. The main purpose of this map was to track the ship's transects during the survey and to provide a visual aid for evaluation of changes in the seafloor lithology. The color map was used only during the survey and was stored in the survey logbook.

Upon completion of the GIMS survey, a postdeployment calibration test was performed with the same monazite-sand reference sample. Once the calibration test had been completed, two- and three-dimensional sediment lithology maps of Bi-214, K-40, Tl-208, water depth, and total gamma activity were generated while onboard the OSV *Anderson* to show the variations of the gamma activity on the seafloor. The dredged sediments were identified through the isotopic differences found as a result of the survey.

3.2 Continuous Sediment Sampling System

The second system deployed was the CS^3. This system used the same shipboard electronics as the GIMS to locate and record the station coordinates. The CS^3 sled was towed at approximately the same speed at which the GIMS was towed (≈ 2.5 to 3 kn) along the same transects recorded by the GIMS. The sled housed a displacement pump made of Delrin plastic. A suspended sediment slurry was pumped through a rubber hose to the shipboard processor, which contained wetted parts that were made entirely of rubber and plastic. The continuous flow of the sediment slurry was monitored through the sight tube during the survey. Due to the absence of fine sediment on the seafloor, no CS^3 samples were acquired.

In addition to recording the station coordinates, a visual description of the approximate density of sediment slurry was recorded in the field notebook. This information was later used to determine possible box-core sampling locations.

3.3 Box-Core Sampling

Upon completion of the CS^3 survey, box-core sample sites were selected based on the GIMS data. The box-cores samples were used to ground truth the GIMS and CS^3 data, and also to provide additional data to identify the sediment particle size at the sites. The survey ship's Loran was used to locate the box-core sampling sites. The box corer was supplied by the OSV *Anderson*. The box core was thoroughly cleaned and inspected before and after each deployment. The top 7.5 cm of the box-core sample were collected. After collection, the samples were stored in plastic bags, labeled according to site number, and immediately refrigerated. The box-core samples were transported, under refrigeration, to the CAIS laboratory for analysis.

3.4 Ge(Li) Gamma Detector (Box Cores Only)

The box-core samples were dried at 50 to 60 °C, homogenized, and separated into two portions. A 1-kg aliquot of the first portion was ground to 0.3-mm or less particle size, packed into a tared 0.5-L Marinelli beaker, and weighed. The dry weight was used for determining the isotope concentrations in the samples. The beaker was sealed with vinyl tape and stored for a minimum of 14 days before analysis. This allowed for the in-growth of the U and Th daughter products. The sample was placed in a Ge(Li) radiation detector and pulse-height analyzer for a counting time of 20,000 s. The results for U, Th, and were recorded in counts per 20,000 s, and were converted to picocuries per kilogram (pCi/kg).

3.5 XRF Analysis (Box Cores)

The second portion of the dried box-core sediment sample was subsampled for XRF analysis. A representative subsample, not exceeding 6 g, was prepared for XRF analysis. Using an acid-washed mortar and pestle, the subsample was ground into coarse, sand-sized particles. It was again ground with an acid-washed ball mill until at least 80% of the subsample passed through a 120-mesh sieve. The ground subsample was mixed with a cellulose binder, and pressed into a standard pellet for XRF analysis.

Box-core pellets were analyzed using standard CAIS procedures for XRF analysis (EPA, 1991). Algorithms were defined and applied to enhance optimum elemental evaluation of the site-specific sediment chemistry. Calibration checks of the system were performed daily using NIST 2704 and NIST 1646 standard reference materials.

3.6 Particle Size

The remainder of the box-core sample was processed in the laboratory for particle-size determinations using U.S. Standard Testing Sieves. The sample was weighed prior to sieving, and after sieving each sieve fraction was reweighed to adjust for material lost during the process. Percentages of each particle-size fraction were calculated and recorded in a laboratory notebook.

4.0 SURVEY

The survey started on March 10, 1992, at 1400 h with the arrival of the CAIS crew at the Indian River Terminal at Fort Pierce, Florida. The equipment was loaded onto the OSV *Anderson*. Installation and calibration of the GIMS was completed by 1650 h. The following morning the ship departed the Indian River Terminal and headed for the proposed offshore disposal site shown in Figure 1.

The GIMS was deployed at 0900 h on March 11. It was on Station 0001 (27°26.81'N and 80°13.12'W) and operating by 0908 h. The system continued to record data from the seafloor until the final station, 464 (27°28.62'N and 80°10.88'W), was reached at 1928 h. The sled was retrieved from the seafloor on March 11 by 1950 h, and postcalibration of the system was performed at 2000 h. The calibration of the system was confirmed by the comparison of the pulse height spectra of the Cs-137 peak as well as the Bi-214, Tl-208, and K-40 peaks. The recorded gamma activity data for all stations are given in Appendix A.

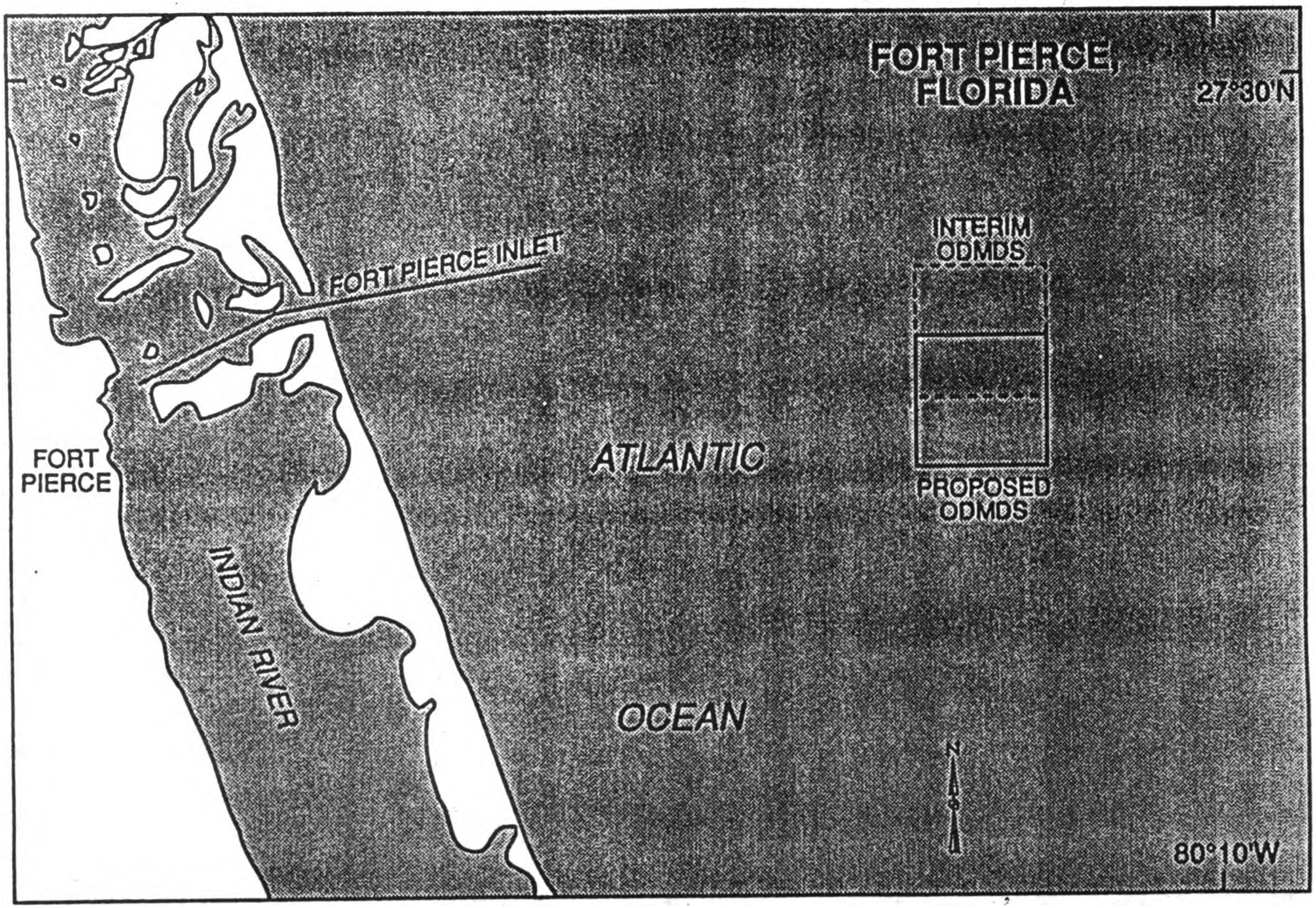


Figure 1. Proposed Fort Pierce ODMDS.

Even though the CS^3 and GIMS transects were approximately the same, the stations were recorded by different methods. The GIMS stations were recorded on a 60-s interval, and the CS^3 stations were fixed approximately 305 m apart. The CS^3 sled was deployed at 2000 h and was on Station 01 (27°26.57'N and 80°13.12'W) by 2110 h. The system encountered several pump failures due to the coarse sand seafloor environment at the site. However, the entire site was surveyed by examining every other GIMS transect. The final station, 87 (27°27.31'N and 80°10.86'W), was reached at 0657 h on March 12. The CS^3 sled was retrieved by 0715 h.

Locations for bulk quantity samples were chosen by CAIS and EPA personnel using the GIMS and CS^3 survey data. The two- and three-dimensional isotopic maps from the GIMS and the absence of sediment density as noted from the CS^3 sight tube were reviewed to determine the actual box-coring locations. A box-core sampler, supplied by the OSV *Anderson*, was used to obtain the samples. Box-core sampling began at Station 6 (27°27.89'N and 80°11.67'W) on March 12 at 0842 h, and ended at 1003 h at Station 2 (27°28.58'N and 80°12.55'W). A total of six box-core stations were sampled during the survey. The OSV *Anderson* returned to the Indian River Terminal by 1050 h. The CAIS crew offloaded the sediment mapping equipment from the OSV *Anderson* and departed Fort Pierce by 1700 h.

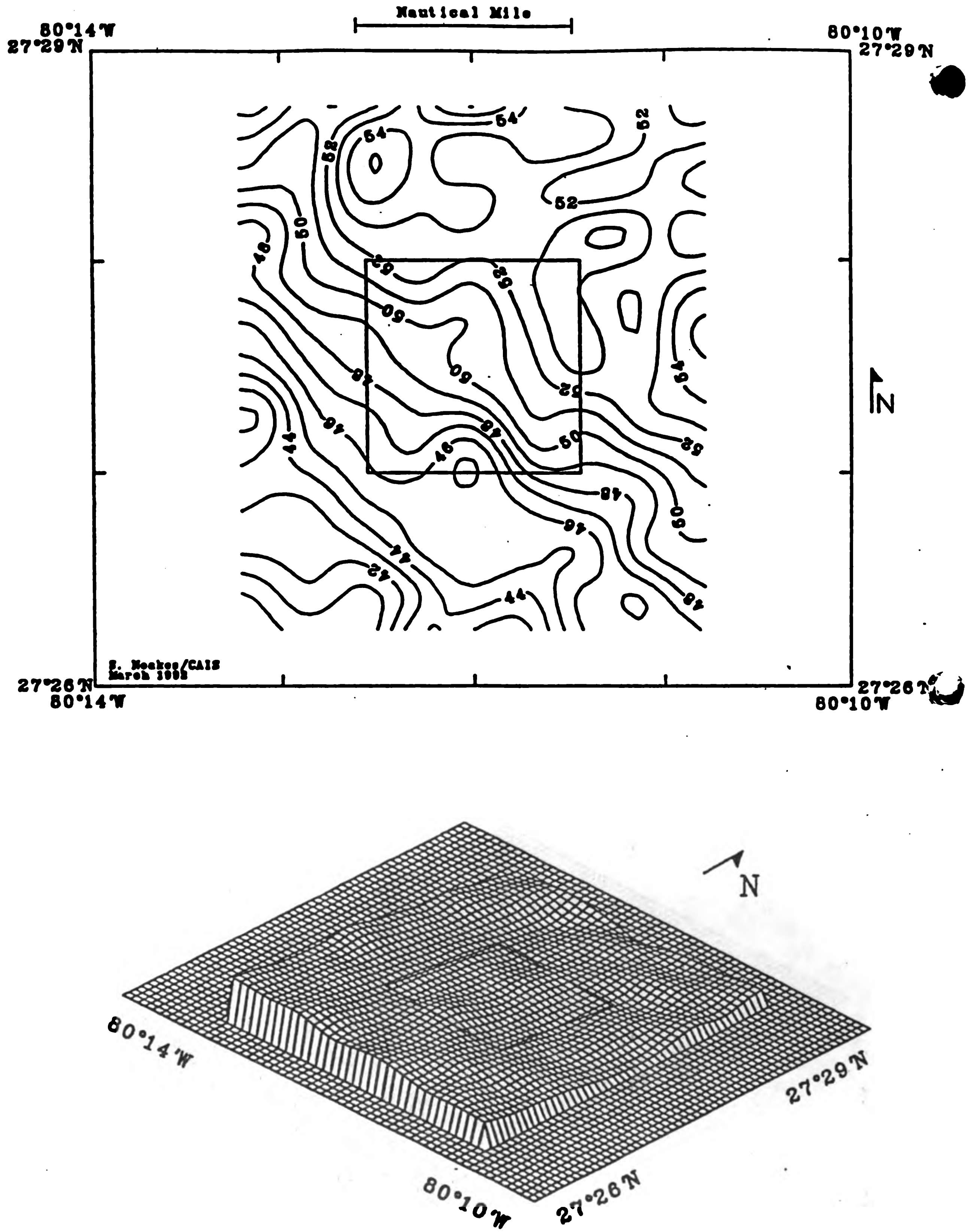


Figure 3. Contour map of water depth (upper illustration) and topographic profile of the seafloor (lower illustration) for the proposed Fort Pierce ODMDS.

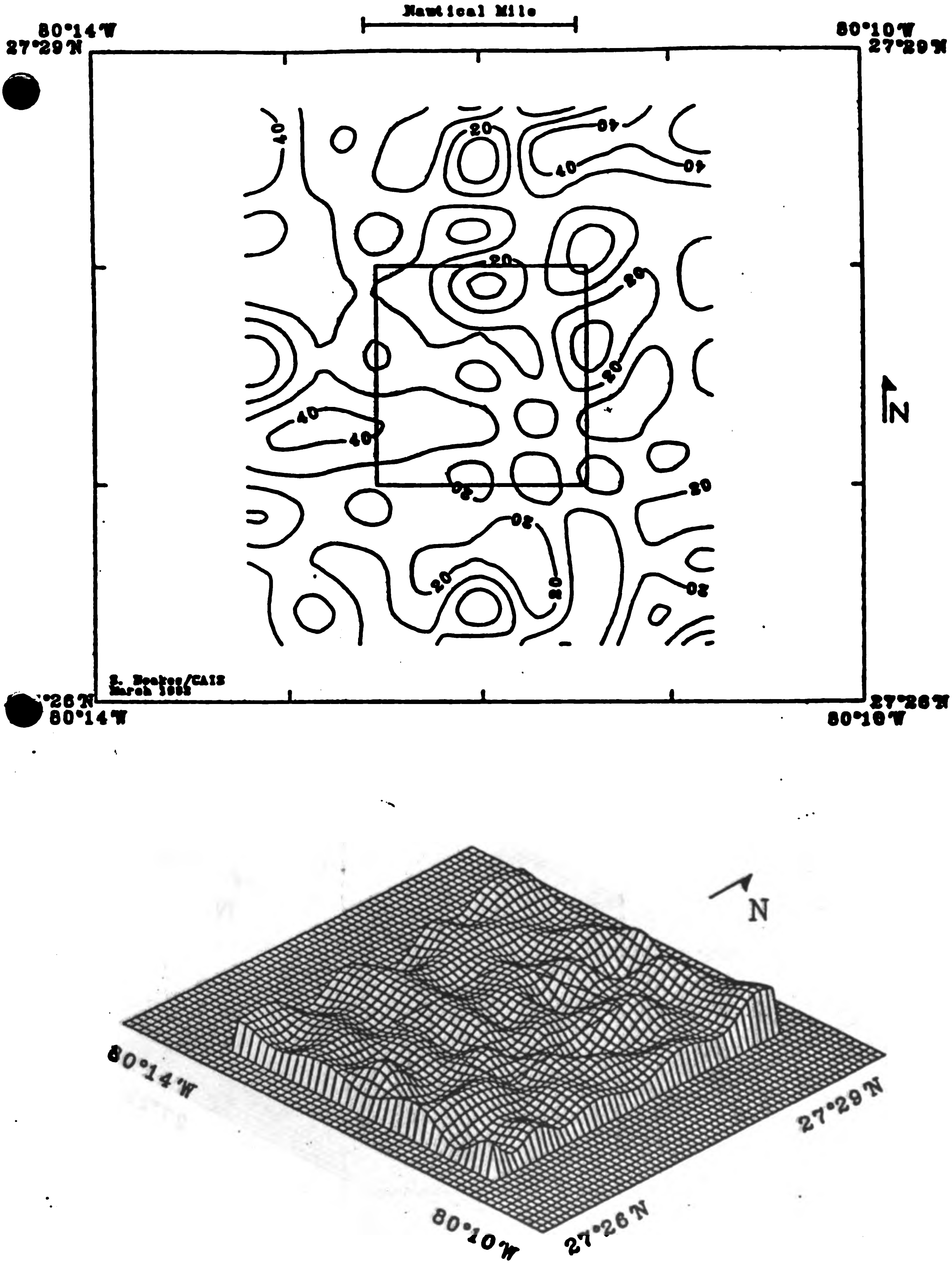


Figure 4. Contour map (upper illustration) and topographic profile (lower illustration) of gamma activity for the proposed Fort Pierce ODMDS.

(a) Bi-214 activity.

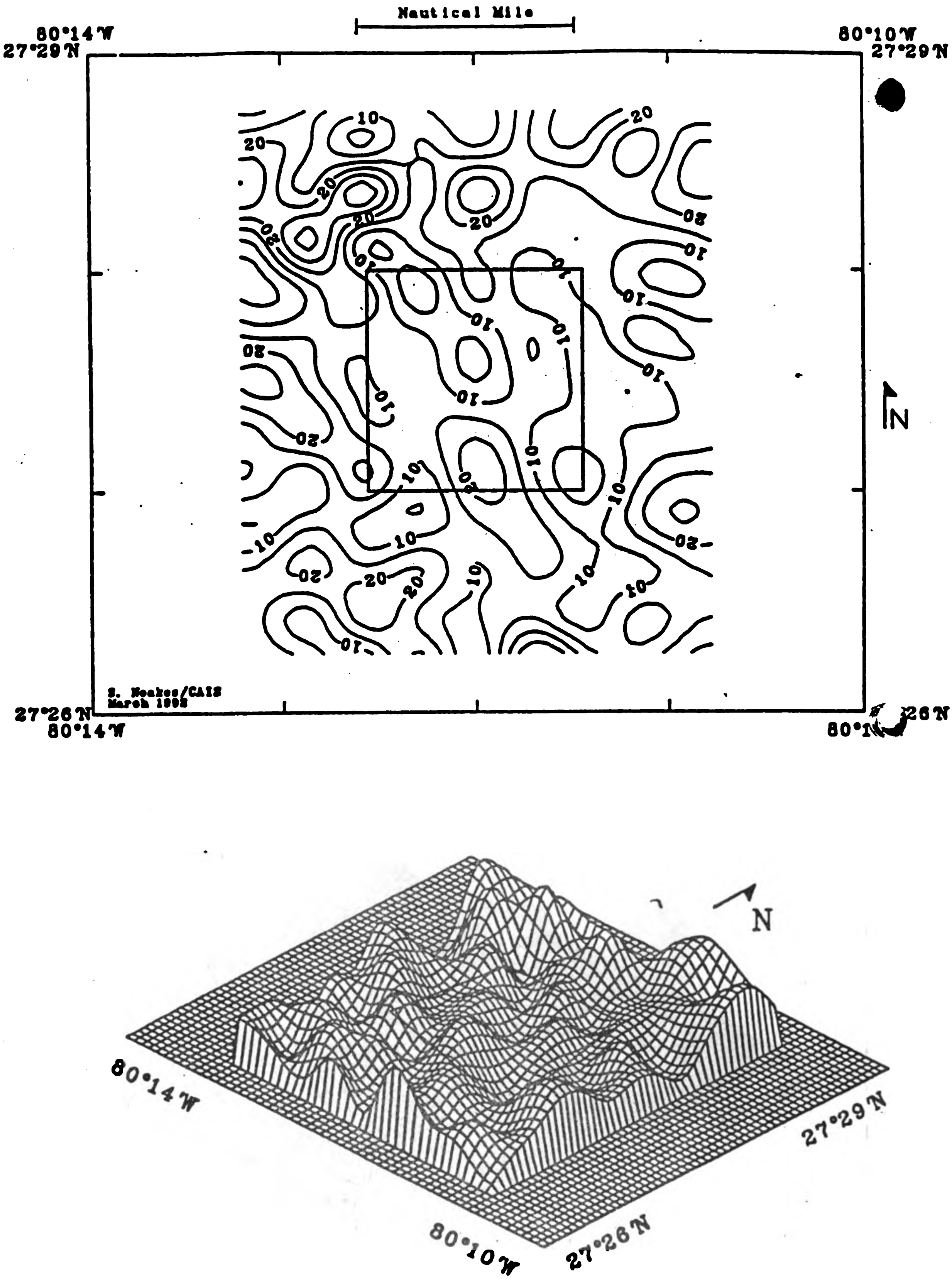
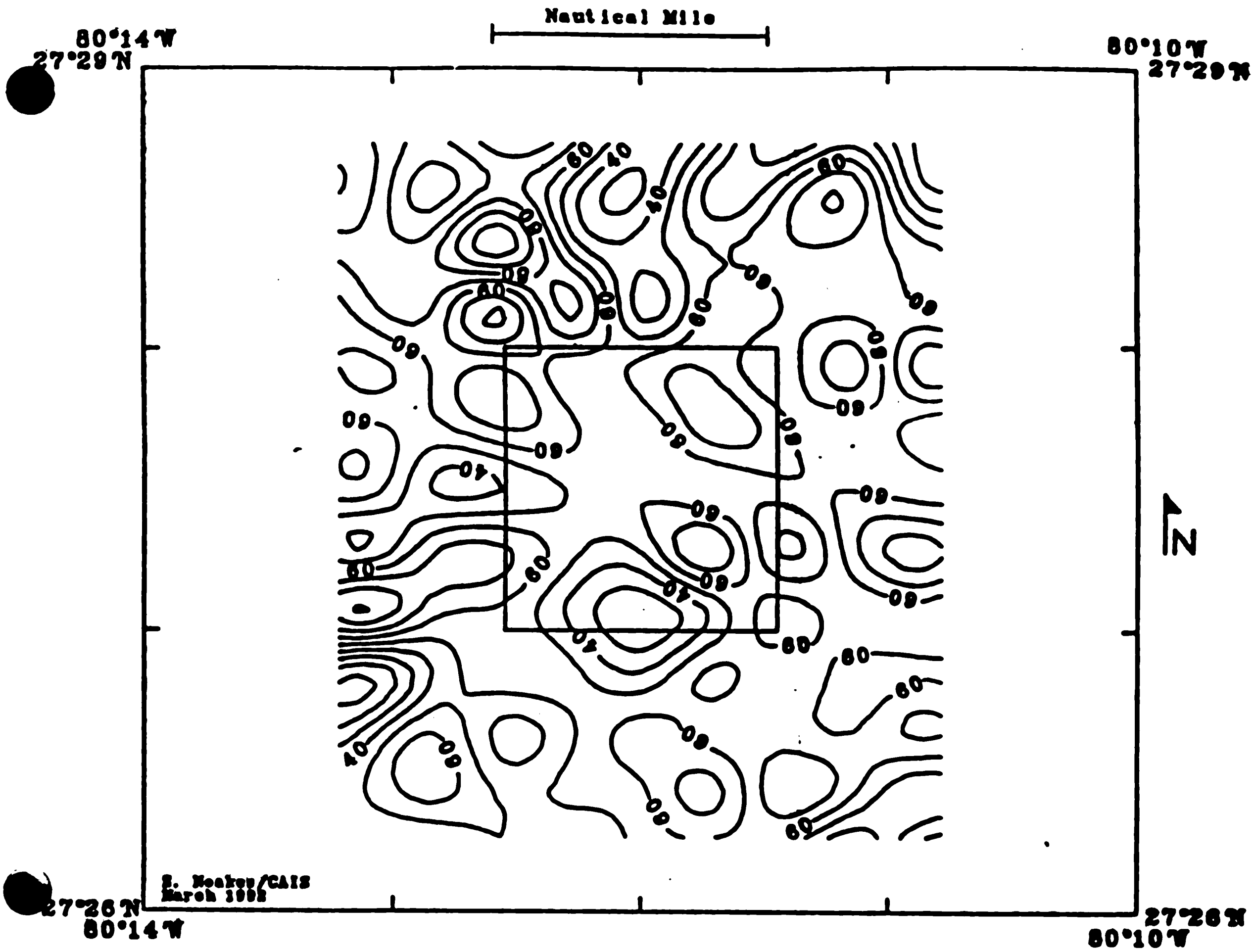


Figure 4. Contour map (upper illustration) and topographic profile (lower illustration) of gamma activity for the proposed Fort Pierce ODMDS.

(b) Tl-208 activity.



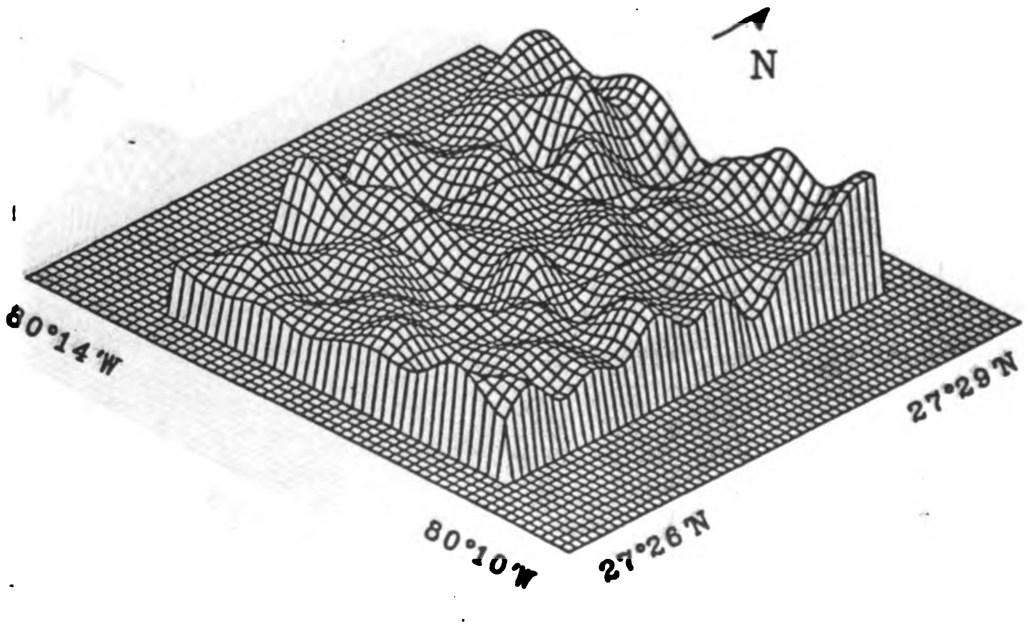


Figure 4. Contour map (upper illustration) and topographic profile (lower illustration) of gamma activity for the proposed Fort Pierce ODMDS.

(c) K-40 activity.

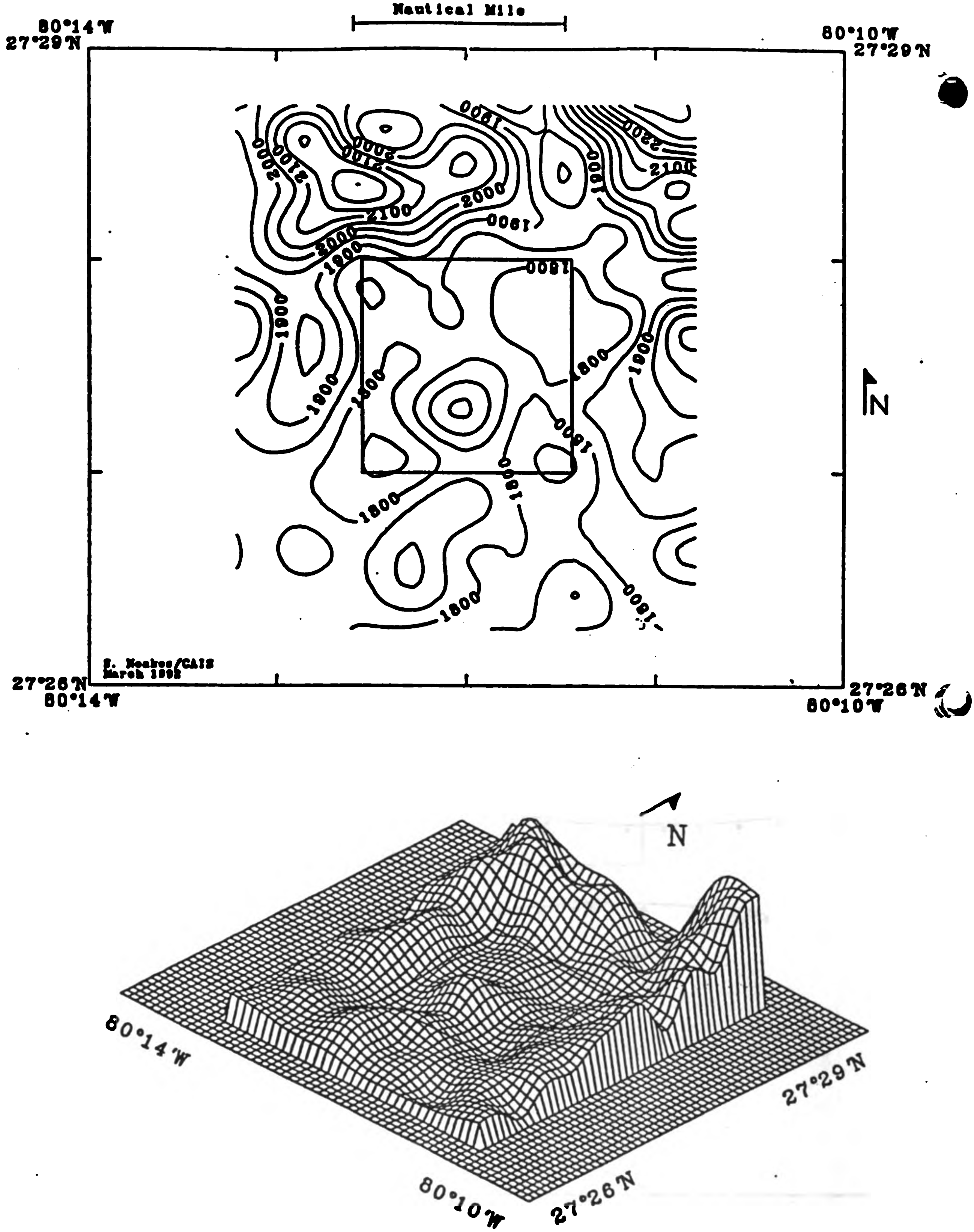


Figure 4. **Contour map (upper illustration) and topographic profile (lower illustration) of gamma activity for the proposed Fort Pierce ODMDS.**

(d) total activity.

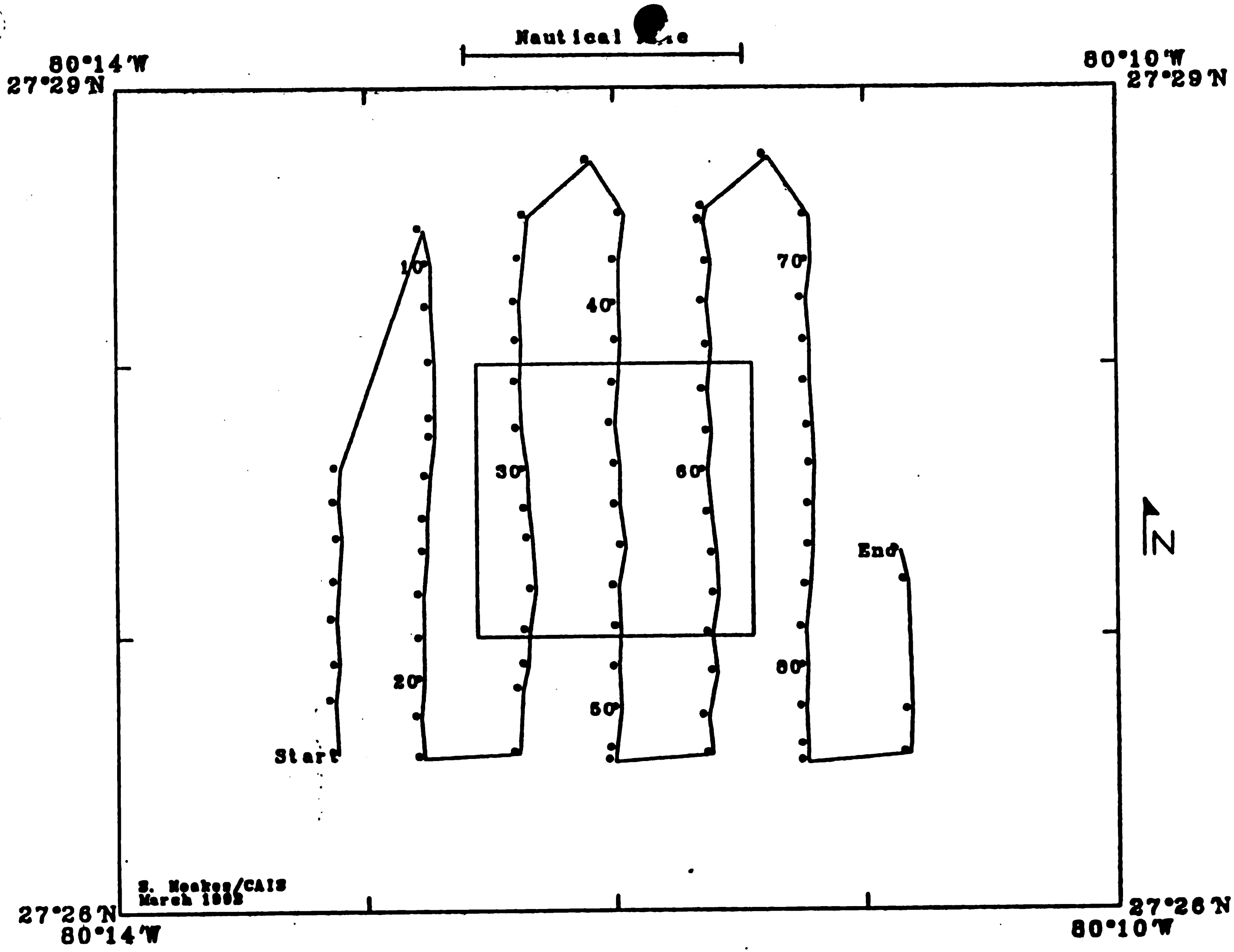


Figure 5. Ship's transects and CS^3 stations for the proposed Fort Pierce ODMDS.

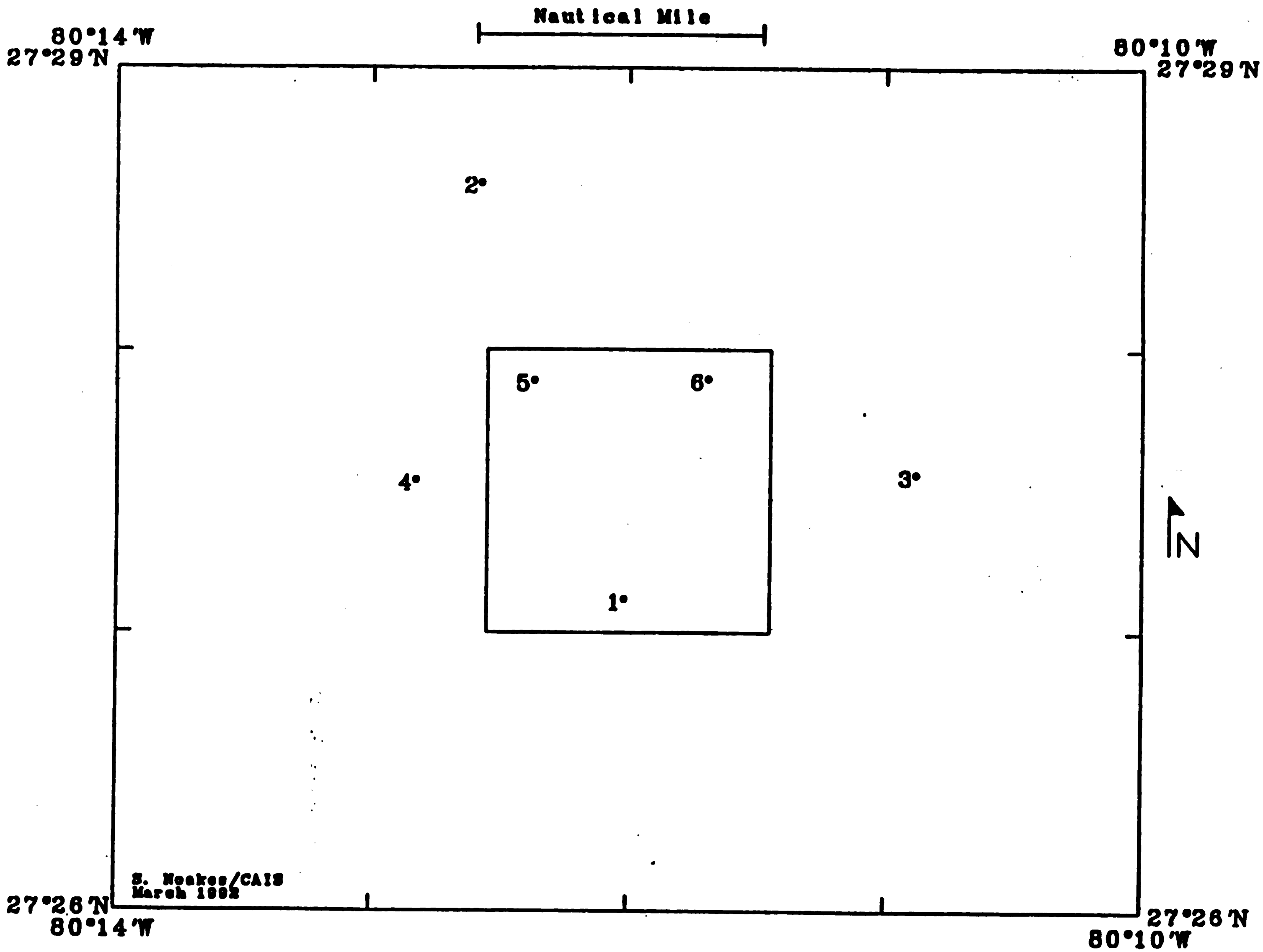


Figure 6. Box-core locations for the proposed Fort Pierce ODMDS.

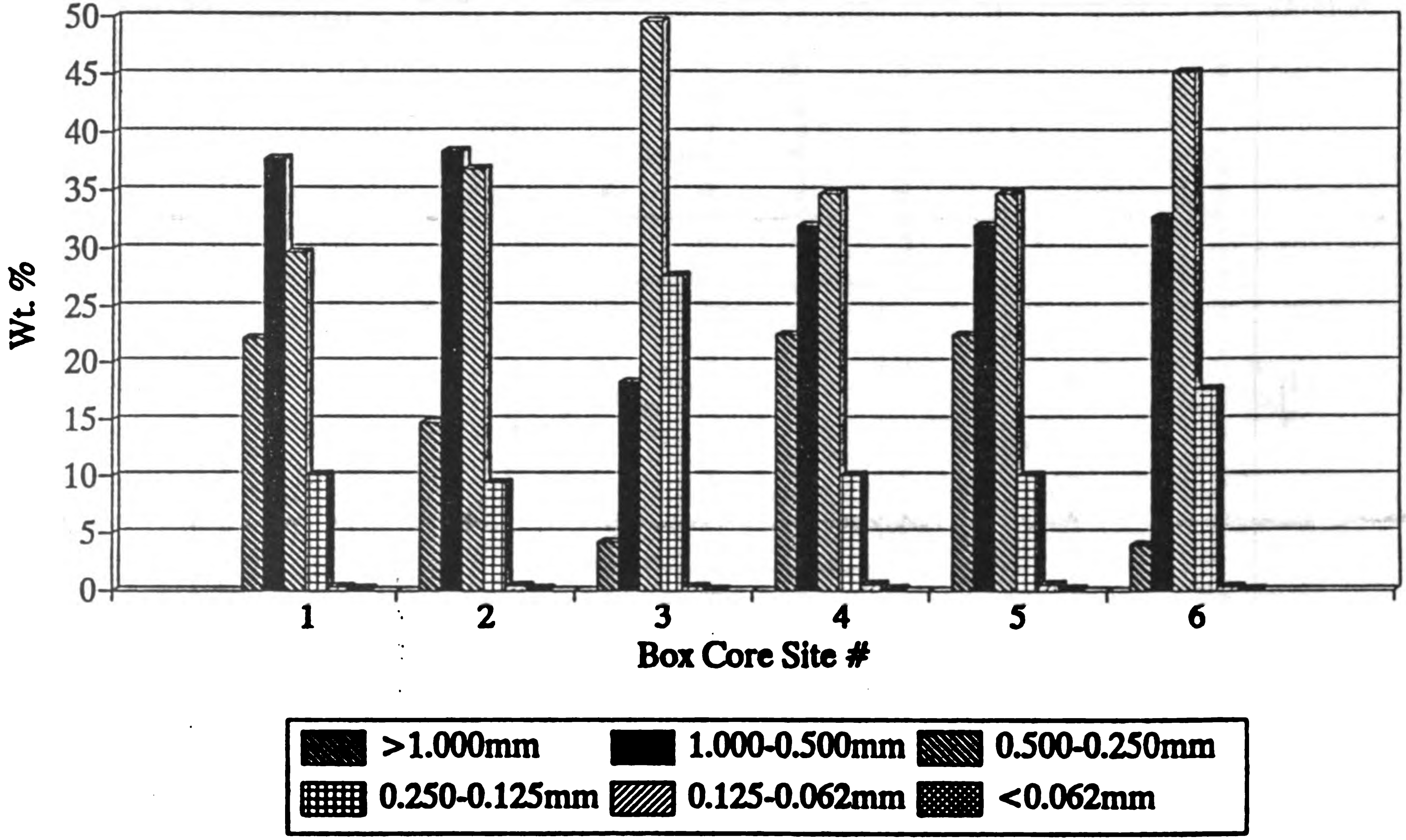


Figure 7. Proposed Fort Pierce ODMDS Particle Size.

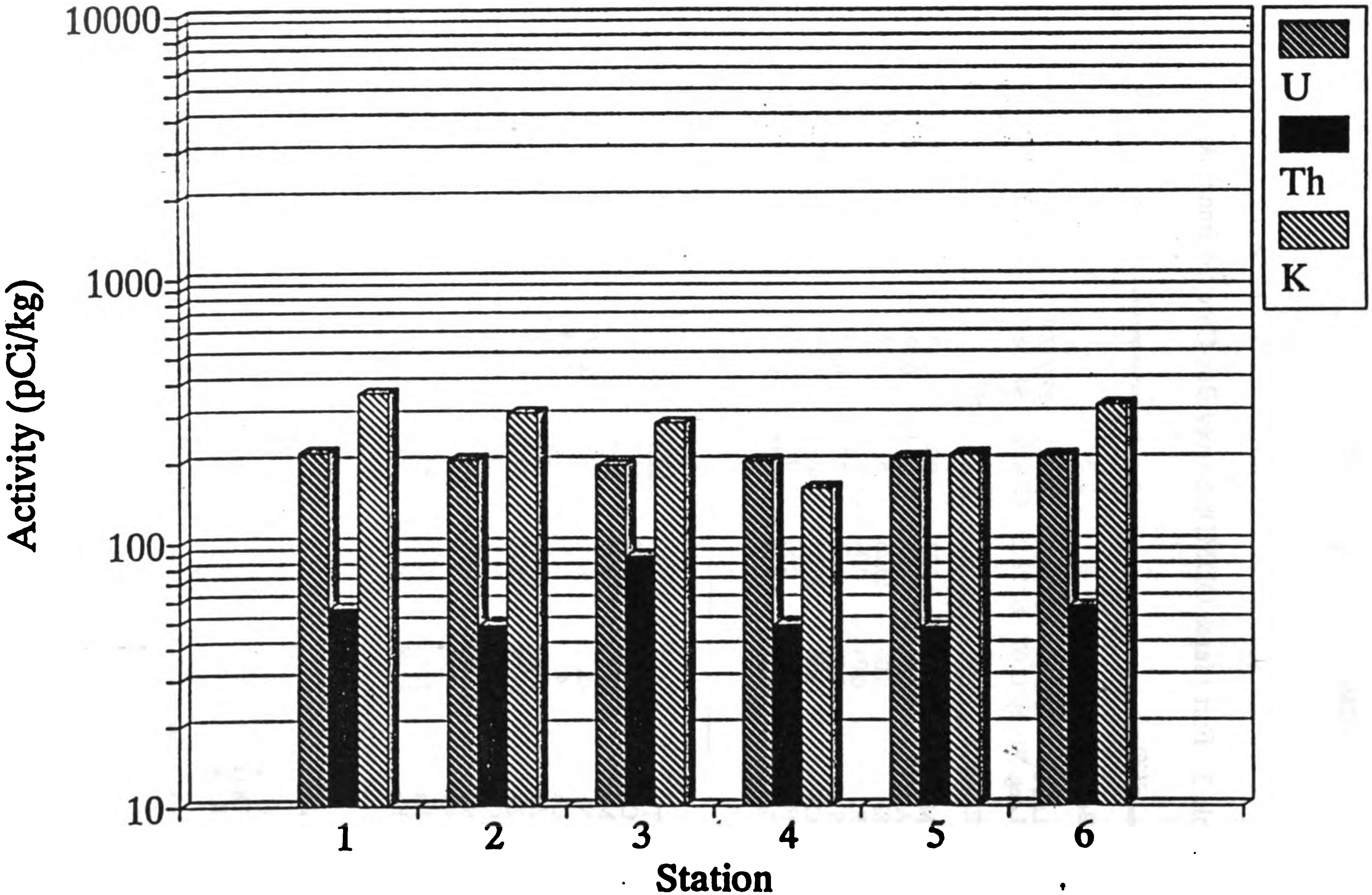


Figure 8. Proposed Fort Pierce ODMDS Laboratory Gamma Analyses.

Table 3. Fort Pierce ODMDS Survey Box-Core Sediment Analyses

Box core:	1	2	3	4	5	6
Lat. N	27°27.11'	27°28.58'	27°27.55'	27°27.53'	27°27.88'	27°27.89'
Long. W	80°12.00'	80°12.55'	80°10.86'	80°12.81'	80°12.35'	80°11.67'
Element			wt%			
Mg	0.42	0.37	0.36	0.37	0.28	0.37
Al	0.38	0.24	0.24	0.19	0.20	0.17
Si	8.06	10.26	8.35	6.02	7.89	5.55
P	0.04	0.06	0.05	0.11	0.02	0.05
S	0.32	0.23	0.27	0.31	0.24	0.24
Ca	28.65	26.71	28.38	30.28	28.72	29.66
Fe	0.58	0.68	0.59	0.51	0.62	0.79
Sr	0.19	0.19	0.17	0.18	0.18	0.20
			ppm			
Ti	260.38	170.04	121.37	158.01	156.00	111.61
Cr	26.42	15.07	14.83	17.19	23.33	19.13
Mn	47.21	43.59	39.99	39.28	51.19	52.39
Ni	25.99	18.43	22.78	26.19	27.78	30.80
Cu	4.91	6.64	7.97	6.03	6.79	5.51
Zn	18.24	20.34	17.52	15.49	19.94	17.55
Zr	22.08	25.08	22.89	8.83	13.75	11.12
Cd	3.37	2.28	3.52	3.36	1.34	1.21
Sn	3.17	2.21	2.68	4.24	2.89	3.93
Sb	2.66	2.61	3.54	2.96	4.22	4.73
Ba	40.61	40.87	33.03	31.43	30.32	38.12
Pb	12.76	20.92	13.80	11.97	22.20	9.80
Radiometric			(pCi/kg)			
U (Bi-214)	219	205	196	203	209	210
Th (Tl-208)	56	49	89	49	48	57
K (K-40)	367	308	282	160	213	329

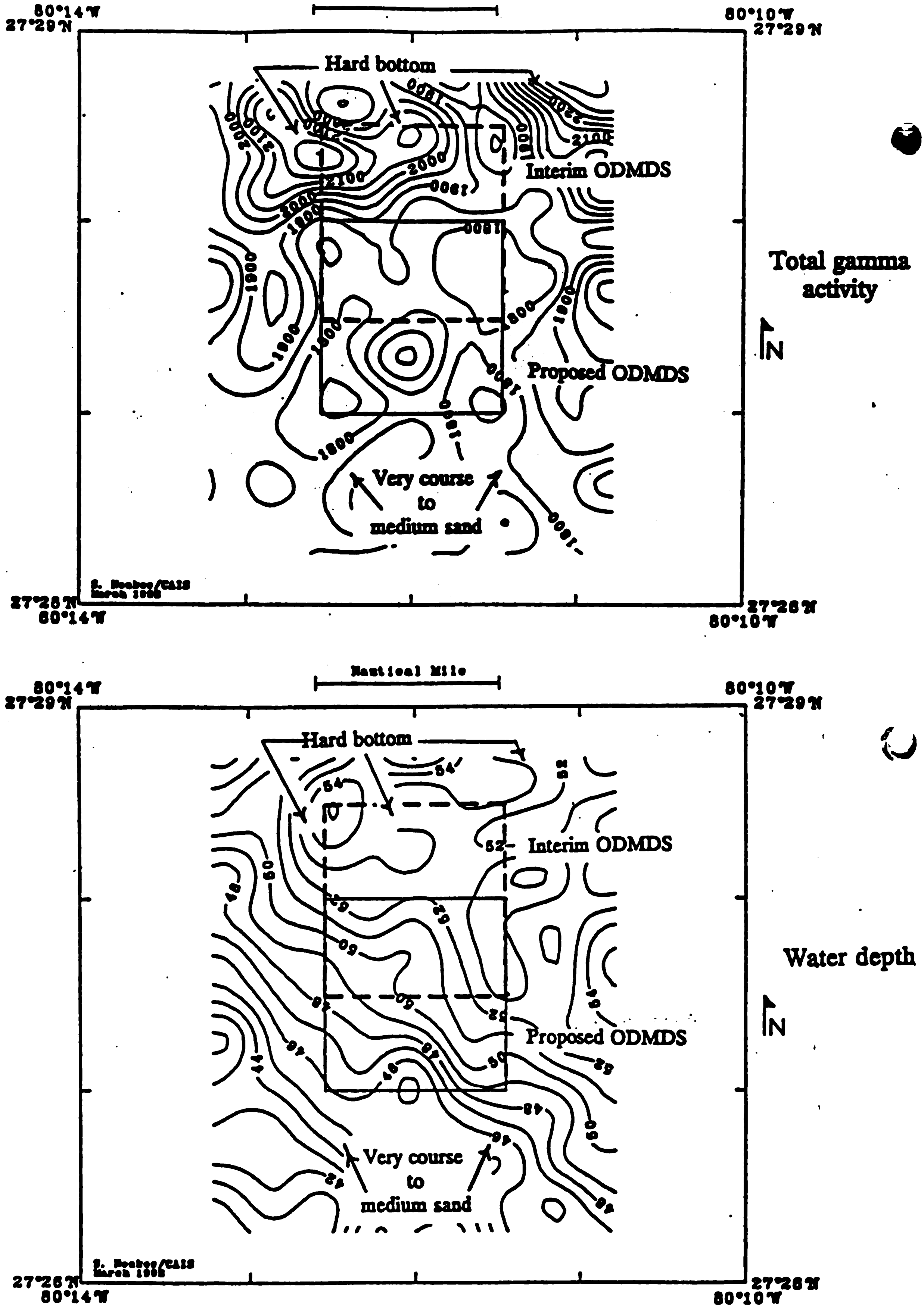


Figure 9. Evaluation of seafloor lithology at the Interim and proposed Fort Pierce ODMDSs.

total gamma activity to the interim and proposed ODMDS. The water depth map for the survey is also shown in this figure. The location of the rock outcrops coincide with higher gamma activity and a depression in the seafloor found near the northwest corner of the interim site.

The box-core sediment XRF analyses proved to be very uniform in elemental content. Ca was the most prominent element at the Fort Pierce area with some Si present. The particle size analysis for these samples was also very uniform with a few exceptions. Sediments from box-core Samples 1 and 2 were nearly identical. Sediments from box-core Samples 4 through 6 were also very similar in particle size distribution. The majority of these samples were composed of medium and coarse sand with a lesser amount of very coarse sand present in the samples. Box-core Sample 3 sediment was the only sample containing fine sand (27 wt%) along with 50 wt% of medium sand. Box-core 3 was located east of the proposed ODMDS by approximately a half mile. Only minute amounts of very fine sand and silt were found in any of the box-core samples. This verified the absence of fine sediment as detected by the CS^3 during survey.

The laboratory gamma analyses performed on the six box-core samples also proved to be very uniform. The only exception was the box-core 3 sample with a slightly higher Th value than the rest of the samples.

7.0 CONCLUSION

A live, hard-bottom environment exists to the north and northwest of the proposed Fort Pierce ODMDS. This area revealed a higher gamma activity than the area to the south encompassing the proposed ODMDS. The proposed ODMDS appeared to be very uniform in gamma activity, elemental, and physical content. Excluding the hard bottom region, the site appears to consist of medium to very coarse calcium carbonate sand. No distinct signs of fine sediment were detected during the sediment mapping survey. Any dredged material deposited within the interim ODMDS must have been similar to the sediment found at the disposal site or has since been removed from the area due to ocean transport.

8.0 SAMPLE CUSTODY AND RECORDS

All samples obtained as a result of the survey are stored at the CAIS building for at least 1 year after completion of the survey. The computer-generated maps are stored on computer diskette for a minimum of 1 year. A log book was maintained during the survey referencing major events, GIMS calibration spectra, and any other related data pertaining the survey. Records of laboratory analysis have been stored in notebooks relating to the specific types of equipment used.

9.0 REFERENCES

EPA, 1991. Generic Quality Assurance Project Plan for the Gamma Isotope Mapping System and the Continuous Sediment Sampling System. Report prepared by Center for Applied Isotope Studies for Battelle Memorial Institute, under contract to the Environmental Protection Agency, Work Assignment 2-203, Contract No. 68-C8-0105.

Appendix A

FORT PIERCE SHIPBOARD DATA – GAMMA RADIATION

APPENDIX A: Fort Pierce Shipboard Data - Gamma Radiation

Site	Latitude	Longitude	Depth (ft)	K-40 (cpm)	Bi-214 (cpm)	Tl-208 (cpm)	Total (cpm)
1	27 26.81	80 13.12	43	17	13	9	1797
2	27 26.90	80 13.11	43	0	4	0	1833
3	27 26.98	80 13.10	43	75	36	20	1873
4	27 27.02	80 13.11	43	103	29	15	1828
5	27 27.08	80 13.09	43	93	32	11	1863
6	27 27.16	80 13.09	43	70	33	22	1802
7	27 27.24	80 13.09	42	66	28	20	1830
8	27 27.32	80 13.13	42	25	42	13	1897
9	27 27.40	80 13.15	43	45	18	6	1896
10	27 27.48	80 13.16	44	82	0	24	1806
11	27 27.55	80 13.17	46	36	17	41	1844
12	27 27.64	80 13.17	46	56	20	11	1816
13	27 27.72	80 13.17	46	61	12	11	1763
14	27 27.80	80 13.16	47	91	12	30	1723
15	27 27.88	80 13.16	48	69	38	5	1814
16	27 27.96	80 13.15	48	29	40	0	1968
17	27 28.04	80 13.15	48	71	31	8	19[illegible]
18	27 28.12	80 13.15	47	71	17	3	1948
19	27 28.19	80 13.15	49	45	41	31	1936
20	27 28.27	80 13.15	51	36	45	31	1831
21	27 28.36	80 13.16	50	81	42	31	1960
22	27 28.43	80 13.15	51	74	25	0	1892
23	27 28.50	80 13.15	51	74	51	26	1934
24	27 28.59	80 13.15	52	91	48	20	1977
25	27 28.66	80 13.15	52	106	45	34	2005
26	27 28.73	80 13.15	52	89	24	12	2043
27	27 28.81	80 13.14	54	74	42	5	2010
28	27 28.89	80 13.14	51	52	37	8	2406
29	27 28.96	80 13.14	48	40	0	30	2334
30	27 29.02	80 13.07	52	58	9	0	1979
31	27 29.00	80 12.98	51	24	16	14	1834
32	27 28.93	80 12.96	50	40	37	21	1883
33	27 28.85	80 12.95	52	66	10	10	1940
34	27 28.76	80 12.94	50	66	24	16	2012
35	27 28.66	80 12.91	51	75	43	17	2026
36	27 28.59	80 12.91	50	52	30	7	2056
37	27 28.54	80 12.91	49	53	12	19	2270
38	27 28.47	80 12.91	52	88	26	24	2175
39	27 28.40	80 12.91	50	80	42	6	2211
40	27 28.33	80 12.92	50	91	21	25	1965
41	27 28.26	80 12.94	50	70	50	0	2241
42	27 28.19	80 12.94	49	42	14	36	215[illegible]
43	27 28.12	80 12.94	50	75	49	48	222[illegible]
44	27 28.05	80 12.94	50	42	37	35	1932

APPENDIX A: Fort Pierce Shipboard Data - Gamma Radiation

Site	Latitude	Longitude	Depth (ft)	K-40 (cpm)	Bi-214 (cpm)	Tl-208 (cpm)	Total (cpm)
45	27 27.97	80 12.95	49	29	64	1	2005
46	27 27.90	80 12.95	48	85	30	22	1839
47	27 27.83	80 12.95	48	20	40	35	2018
48	27 27.76	80 12.96	47	23	43	7	1912
49	27 27.69	80 12.96	47	107	36	17	1931
50	27 27.62	80 12.97	45	32	31	7	1944
51	27 27.55	80 12.96	44	45	19	28	1899
52	27 27.48	80 12.97	46	14	33	23	1937
53	27 27.40	80 12.96	46	53	11	8	1850
54	27 27.34	80 12.96	46	52	51	32	1933
55	27 27.26	80 12.95	45	54	48	31	1874
56	27 27.19	80 12.95	44	88	5	9	1827
57	27 27.12	80 12.96	45	50	26	9	1763
58	27 27.05	80 12.96	45	73	0	7	1735
59	27 26.98	80 12.95	43	53	25	4	1764
60	27 26.91	80 12.95	43	24	34	9	1836
61	27 26.85	80 12.95	43	23	21	10	1746
62	27 26.78	80 12.95	42	82	42	7	1786
63	27 26.71	80 12.95	43	54	59	6	1881
64	27 26.64	80 12.96	42	71	14	15	1870
65	27 26.57	80 12.96	41	38	63	26	1786
66	27 26.49	80 12.96	41	39	34	6	1832
67	27 26.43	80 12.96	40	68	0	14	1749
68	27 26.36	80 12.96	40	29	25	16	1885
69	27 26.29	80 12.96	39	62	29	16	1850
70	27 26.22	80 12.96	40	7	30	20	1837
71	27 26.15	80 12.98	39	48	50	26	1845
72	27 26.08	80 12.96	39	70	6	0	1831
73	27 26.02	80 12.92	39	58	12	10	1850
74	27 25.98	80 12.86	39	29	9	14	1799
75	27 25.97	80 12.80	39	55	26	11	1795
76	27 25.99	80 12.75	40	71	24	6	1783
77	27 26.03	80 12.71	41	51	22	2	1864
78	27 26.08	80 12.70	40	62	43	5	1817
79	27 26.13	80 12.69	43	35	44	22	1820
80	27 26.19	80 12.67	41	65	40	9	1885
81	27 26.24	80 12.69	42	38	20	9	1921
82	27 26.29	80 12.71	42	27	2	31	1760
83	27 26.33	80 12.74	41	36	27	14	1806
84	27 26.37	80 12.77	41	76	44	0	1989
85	27 26.42	80 12.79	43	60	12	0	1830
86	27 26.47	80 12.79	42	79	34	18	1885
87	27 26.53	80 12.79	42	86	27	22	2068
88	27 26.58	80 12.78	43	62	26	40	1972
89	27 26.63	80 12.78	43	50	39	29	1850

APPENDIX A: Fort Pierce Shipboard Data - Gamma Radiation

Site	Latitude	Longitude	Depth (ft)	K-40 (cpm)	Bi-214 (cpm)	Tl-208 (cpm)	Total (cpm)
135	27 27.99	80 12.55	51	62	46	25	1982
136	27 27.91	80 12.56	51	74	25	17	1749
137	27 27.82	80 12.56	51	45	0	31	1803
138	27 27.73	80 12.57	49	84	22	14	1834
139	27 27.64	80 12.57	49	18	24	8	1796
140	27 27.56	80 12.57	49	45	25	24	1906
141	27 27.47	80 12.57	48	36	20	2	1805
142	27 27.38	80 12.57	48	61	12	23	1895
143	27 27.30	80 12.56	47	75	49	14	1774
144	27 27.22	80 12.56	46	58	5	3	1766
145	27 27.13	80 12.55	47	52	32	17	1733
146	27 27.05	80 12.54	46	67	22	24	1738
147	27 26.96	80 12.53	45	32	18	16	1713
148	27 26.88	80 12.55	45	58	20	4	1776
149	27 26.79	80 12.55	45	47	10	16	1777
150	27 26.71	80 12.55	42	15	29	12	1833
151	27 26.63	80 12.56	43	40	35	18	1836
152	27 26.54	80 12.57	41	64	13	13	1839
153	27 26.46	80 12.56	41	39	31	37	1859
154	27 26.37	80 12.57	40	66	39	0	1771
155	27 26.29	80 12.58	41	76	37	21	168[illegible]
156	27 26.22	80 12.54	40	42	30	0	1782
157	27 26.18	80 12.46	41	67	17	15	1794
158	27 26.18	80 12.38	42	22	13	9	1777
159	27 26.21	80 12.33	45	22	49	30	1716
160	27 26.27	80 12.32	44	47	1	6	1897
161	27 26.33	80 12.34	45	7	25	0	1921
162	27 26.38	80 12.36	43	32	33	11	1818
163	27 26.45	80 12.38	43	89	12	29	1907
164	27 26.50	80 12.37	44	46	25	0	1947
165	27 26.56	80 12.35	44	38	18	19	1994
166	27 26.62	80 12.36	45	37	0	18	1837
167	27 26.68	80 12.37	44	15	28	28	1874
168	27 26.73	80 12.35	46	91	18	22	2151
169	27 26.79	80 12.34	46	50	16	8	1866
170	27 26.85	80 12.34	45	80	33	0	1955
171	27 26.91	80 12.36	47	23	26	31	1852
172	27 26.97	80 12.37	47	53	4	0	1693
173	27 27.03	80 12.37	47	33	34	4	1780
174	27 27.08	80 12.35	47	44	16	17	1772
175	27 27.13	80 12.32	47	37	17	4	1734
176	27 27.20	80 12.32	48	4	37	24	1824
177	27 27.25	80 12.34	47	53	56	3	1861
178	27 27.30	80 12.37	48	86	39	20	1923
179	27 27.36	80 12.38	49	56	11	16	1860

APPENDIX A: Fort Pierce Shipboard Data - Gamma Radiation

Site	Latitude	Longitude	Depth (ft)	K-40 (cpm)	Bi-214 (cpm)	Tl-208 (cpm)	Total (cpm)
180	27 27.43	80 12.38	48	27	38	22	1746
181	27 27.48	80 12.36	49	49	18	11	1802
182	27 27.54	80 12.36	50	54	30	18	1823
183	27 27.59	80 12.40	50	40	12	0	1821
184	27 27.65	80 12.38	50	68	31	12	1931
185	27 27.71	80 12.39	51	63	44	22	1752
186	27 27.77	80 12.37	51	76	23	12	1871
187	27 27.83	80 12.36	53	71	20	9	1885
188	27 27.89	80 12.34	53	51	31	1	2021
189	27 27.95	80 12.34	53	67	33	1	1824
190	27 28.00	80 12.36	52	57	14	0	1888
191	27 28.06	80 12.38	53	47	40	21	1888
192	27 28.11	80 12.38	53	75	23	7	1916
193	27 28.17	80 12.39	54	83	32	4	1978
194	27 28.22	80 12.40	53	94	2	25	1961
195	27 28.29	80 12.38	55	0	37	18	1924
196	27 28.34	80 12.37	54	34	44	11	1993
197	27 28.40	80 12.37	53	59	22	20	1945
198	27 28.45	80 12.36	54	69	30	7	1895
199	27 28.51	80 12.35	55	76	64	23	1944
200	27 28.57	80 12.37	55	35	42	14	1911
201	27 28.62	80 12.40	55	81	39	11	1968
202	27 28.65	80 12.46	54	63	15	20	1917
203	27 28.71	80 12.47	50	74	44	17	1992
204	27 28.73	80 12.40	50	62	43	7	2025
205	27 28.73	80 12.32	54	88	36	2	1974
206	27 28.69	80 12.24	55	62	3	24	2030
207	27 28.62	80 12.19	53	66	9	6	1890
208	27 28.53	80 12.21	52	14	37	19	1968
209	27 28.44	80 12.19	52	56	14	14	2145
210	27 28.35	80 12.21	53	76	21	11	2286
211	27 28.27	80 12.18	52	64	42	29	2119
212	27 28.18	80 12.18	53	82	52	26	2097
213	27 28.09	80 12.18	51	111	12	13	2106
214	27 28.01	80 12.18	52	59	0	10	1849
215	27 27.92	80 12.19	51	44	31	3	1749
216	27 27.82	80 12.18	50	41	31	12	1880
217	27 27.74	80 12.17	49	56	43	11	1759
218	27 27.65	80 12.17	50	42	24	0	1777
219	27 27.56	80 12.17	50	49	34	13	1775
220	27 27.47	80 12.17	49	57	32	13	1780
221	27 27.39	80 12.16	49	53	23	0	1686
222	27 27.30	80 12.17	49	62	24	16	1804
223	27 27.21	80 12.17	49	24	41	27	1732
224	27 27.12	80 12.16	49	54	18	17	1862

APPENDIX A: Fort Pierce Shipboard Data - Gamma Radiation

Site	Latitude	Longitude	Depth (ft)	K-40 (cpm)	Bi-214 (cpm)	Tl-208 (cpm)	Total (cpm)
225	27 27.04	80 12.17	46	28	46	5	1769
226	27 26.95	80 12.18	46	53	0	0	1785
227	27 26.87	80 12.18	45	30	25	0	1670
228	27 26.78	80 12.18	45	29	37	20	1744
229	27 26.70	80 12.18	46	56	27	21	1822
230	27 26.61	80 12.16	43	28	33	16	1813
231	27 26.52	80 12.16	44	72	29	42	2142
232	27 26.44	80 12.17	42	69	24	19	1900
233	27 26.35	80 12.18	43	59	0	26	1904
234	27 26.28	80 12.13	42	72	28	17	1794
235	27 26.25	80 12.06	42	35	26	16	1785
236	27 26.26	80 11.98	43	67	2	0	1729
237	27 26.31	80 11.96	43	10	38	4	1778
238	27 26.36	80 11.98	43	60	16	12	1886
239	27 26.44	80 12.00	45	57	56	9	1792
240	27 26.52	80 11.98	45	79	21	19	1745
241	27 26.62	80 11.97	46	87	21	0	1795
242	27 26.70	80 12.00	46	32	17	24	1844
243	27 26.78	80 11.99	46	71	24	13	1959
244	27 26.85	80 11.96	45	25	22	17	187[illegible]
245	27 26.93	80 11.95	46	28	29	7	1802
246	27 27.01	80 11.97	45	45	0	22	1842
247	27 27.08	80 11.99	45	18	19	24	1833
248	27 27.16	80 11.99	47	61	37	7	1830
249	27 27.23	80 11.96	48	65	28	6	1792
250	27 27.30	80 11.97	48	33	40	22	2023
251	27 27.37	80 11.99	51	114	25	22	1976
252	27 27.45	80 12.00	51	77	30	0	1822
253	27 27.53	80 12.01	50	46	6	8	1883
254	27 27.60	80 12.02	50	57	40	19	1809
255	27 27.68	80 12.03	50	45	39	11	1888
256	27 27.75	80 12.01	50	55	25	0	1813
257	27 27.83	80 12.00	50	58	4	12	1805
258	27 27.91	80 12.01	51	73	0	15	1865
259	27 27.98	80 12.01	52	41	19	23	1749
260	27 28.05	80 11.99	53	59	23	9	1750
261	27 28.13	80 11.97	53	40	36	19	1856
262	27 28.20	80 11.99	53	20	63	12	1940
263	27 28.27	80 11.99	53	48	66	18	2126
264	27 28.35	80 11.98	53	39	6	32	2067
265	27 28.42	80 11.97	53	71	23	17	2124
266	27 28.50	80 11.98	54	72	43	21	2085
267	27 28.57	80 12.01	52	20	0	8	2067
268	27 28.64	80 12.05	53	49	32	21	1966
269	27 28.70	80 12.06	56	16	45	1	18[illegible]

APPENDIX A: Fort Pierce Shipboard Data - Gamma Radiation

Site	Latitude	Longitude	Depth (ft)	K-40 (cpm)	Bi-214 (cpm)	Tl-208 (cpm)	Total (cpm)
270	27 28.70	80 11.96	57	63	44	14	1913
271	27 28.64	80 11.87	54	50	16	27	1729
272	27 28.55	80 11.82	53	61	53	22	1825
273	27 28.45	80 11.80	53	54	47	17	1834
274	27 28.35	80 11.81	53	88	26	14	1925
275	27 28.26	80 11.81	52	69	38	9	1894
276	27 28.17	80 11.80	52	78	28	13	1945
277	27 28.09	80 11.80	53	29	26	11	1886
278	27 28.01	80 11.80	54	73	17	24	1807
279	27 27.93	80 11.79	53	73	18	0	1806
280	27 27.85	80 11.79	53	57	36	11	1780
281	27 27.77	80 11.78	52	59	53	12	1763
282	27 27.69	80 11.79	53	122	5	22	1776
283	27 27.60	80 11.78	52	32	48	21	1794
284	27 27.52	80 11.79	51	56	31	17	1821
285	27 27.44	80 11.79	51	49	21	12	1779
286	27 27.36	80 11.79	51	74	25	37	1729
287	27 27.28	80 11.79	51	108	15	4	1847
288	27 27.20	80 11.79	51	38	26	0	1835
289	27 27.12	80 11.80	48	24	38	16	1723
290	27 27.04	80 11.80	50	38	36	0	1795
291	27 26.96	80 11.80	47	44	39	6	1790
292	27 26.88	80 11.80	46	64	6	15	1718
293	27 26.80	80 11.80	45	76	11	27	1821
294	27 26.72	80 11.80	45	58	13	9	1901
295	27 26.65	80 11.80	45	31	25	31	1796
296	27 26.56	80 11.80	44	74	28	13	1826
297	27 26.49	80 11.80	45	76	37	7	1816
298	27 26.41	80 11.79	44	83	27	20	1853
299	27 26.33	80 11.77	45	21	23	4	1794
300	27 26.28	80 11.73	42	59	37	37	1729
301	27 26.28	80 11.63	44	66	40	25	1780
302	27 26.36	80 11.64	43	79	18	14	1781
303	27 26.45	80 11.67	44	66	5	13	1724
304	27 26.52	80 11.66	46	55	10	15	1792
305	27 26.58	80 11.65	46	56	6	8	1800
306	27 26.63	80 11.62	46	76	0	12	1745
307	27 26.70	80 11.61	45	37	29	13	1781
308	27 26.77	80 11.63	46	43	28	0	1816
309	27 26.85	80 11.63	47	53	37	13	1852
310	27 26.92	80 11.63	47	67	45	24	1793
311	27 26.98	80 11.62	48	30	34	16	1825
312	27 27.06	80 11.62	50	63	35	18	1745
313	27 27.13	80 11.62	49	51	47	9	1805
314	27 27.22	80 11.62	51	16	21	14	1741

APPENDIX A: Fort Pierce Shipboard Data - Gamma Radiation

Site	Latitude	Longitude	Depth (ft)	K-40 (cpm)	Bi-214 (cpm)	Tl-208 (cpm)	Total (cpm)
315	27 27.29	80 11.61	51	98	0	3	1781
316	27 27.38	80 11.59	51	67	20	20	1814
317	27 27.47	80 11.60	52	69	36	5	1926
318	27 27.55	80 11.60	53	32	27	14	1757
319	27 27.64	80 11.59	52	102	33	13	1692
320	27 27.73	80 11.59	52	38	15	7	1758
321	27 27.81	80 11.59	52	61	24	4	1770
322	27 27.89	80 11.60	53	84	25	0	1708
323	27 27.98	80 11.61	52	52	35	12	1819
324	27 28.06	80 11.60	51	68	21	21	1873
325	27 28.15	80 11.60	53	89	31	0	1871
326	27 28.23	80 11.61	52	55	3	17	1809
327	27 28.32	80 11.61	52	45	38	7	1999
328	27 28.40	80 11.61	52	35	23	22	1967
329	27 28.49	80 11.60	53	65	47	33	2086
330	27 28.58	80 11.62	54	98	35	21	1953
331	27 28.67	80 11.60	54	62	5	4	1868
332	27 28.74	80 11.57	54	57	5	19	1793
333	27 28.70	80 11.48	53	114	23	27	2040
334	27 28.60	80 11.46	54	56	52	27	1931
335	27 28.48	80 11.46	53	71	39	18	1757
336	27 28.36	80 11.45	51	50	22	15	1791
337	27 28.24	80 11.44	53	57	40	14	2028
338	27 28.13	80 11.42	54	59	46	13	1856
339	27 28.01	80 11.41	54	59	22	14	1795
340	27 27.92	80 11.41	53	52	36	12	1782
341	27 27.83	80 11.42	52	26	43	15	1928
342	27 27.74	80 11.42	53	73	3	8	1748
343	27 27.66	80 11.43	54	46	14	6	1884
344	27 27.57	80 11.45	54	61	27	7	1835
345	27 27.48	80 11.44	53	55	8	7	1777
346	27 27.40	80 11.45	53	58	42	21	1771
347	27 27.30	80 11.45	51	35	32	7	1849
348	27 27.21	80 11.44	50	55	36	9	1824
349	27 27.11	80 11.44	50	66	6	4	1736
350	27 27.01	80 11.44	48	65	30	0	1772
351	27 26.91	80 11.43	48	54	33	13	1769
352	27 26.81	80 11.42	47	52	31	3	1801
353	27 26.71	80 11.42	46	53	24	0	1817
354	27 26.62	80 11.42	45	56	44	14	1757
355	27 26.51	80 11.42	48	81	8	15	1787
356	27 26.42	80 11.42	46	36	44	6	1685
357	27 26.32	80 11.41	47	64	27	21	1692
358	27 26.24	80 11.35	46	63	37	14	1792
359	27 26.20	80 11.25	48	53	32	12	171[illegible]

APPENDIX A: Fort Pierce Shipboard Data - Gamma Radiation

Site	Latitude	Longitude	Depth (ft)	K-40 (cpm)	Bi-214 (cpm)	Tl-208 (cpm)	Total (cpm)
360	27 26.20	80 11.17	47	110	0	17	1714
361	27 26.25	80 11.11	46	62	33	2	1854
362	27 26.30	80 11.12	46	45	24	17	1781
363	27 26.35	80 11.18	46	48	12	18	1766
364	27 26.40	80 11.23	46	78	27	14	1854
365	27 26.46	80 11.26	46	54	17	16	1724
366	27 26.53	80 11.24	47	55	10	10	1833
367	27 26.60	80 11.23	47	66	33	4	1824
368	27 26.67	80 11.21	48	50	35	4	1786
369	27 26.74	80 11.21	47	86	0	11	1770
370	27 26.81	80 11.22	47	40	9	16	1827
371	27 26.90	80 11.22	48	86	30	9	1804
372	27 26.98	80 11.23	49	42	15	12	1881
373	27 27.05	80 11.22	49	55	40	23	1942
374	27 27.14	80 11.23	51	40	44	17	1856
375	27 27.22	80 11.21	53	109	15	0	1855
376	27 27.30	80 11.20	52	61	40	14	1783
377	27 27.38	80 11.20	53	36	11	10	1827
378	27 27.47	80 11.21	52	31	59	0	1877
379	27 27.54	80 11.22	52	95	44	2	1840
380	27 27.63	80 11.21	51	58	30	21	1819
381	27 27.71	80 11.21	52	36	25	22	1758
382	27 27.79	80 11.21	53	48	18	13	1688
383	27 27.87	80 11.22	54	59	11	2	1807
384	27 27.95	80 11.21	52	97	15	0	1910
385	27 28.04	80 11.22	54	91	26	14	1996
386	27 28.12	80 11.23	53	62	36	24	1906
387	27 28.20	80 11.22	56	44	15	8	1805
388	27 28.28	80 11.24	52	78	13	0	1849
389	27 28.37	80 11.23	51	29	40	20	2055
390	27 28.45	80 11.23	55	78	44	0	2303
391	27 28.53	80 11.22	53	57	24	18	1832
392	27 28.61	80 11.21	50	23	39	12	2114
393	27 28.69	80 11.20	49	69	48	31	2429
394	27 28.76	80 11.19	50	77	14	35	2382
395	27 28.78	80 11.10	54	84	53	17	2395
396	27 28.70	80 11.04	51	87	20	24	2049
397	27 28.59	80 11.03	53	49	62	0	2394
398	27 28.48	80 11.04	55	41	45	11	2178
399	27 28.37	80 11.03	51	56	18	38	2144
400	27 28.27	80 11.02	53	63	8	0	1909
401	27 28.20	80 11.02	51	66	29	8	1847
402	27 28.13	80 11.02	53	42	34	0	1810
403	27 28.06	80 11.02	52	104	29	0	2045
404	27 27.99	80 11.02	51	31	39	10	1801

APPENDIX A: Fort Pierce Shipboard Data - Gamma Radiation

Site	Latitude	Longitude	Depth (ft)	K-40 (cpm)	Bi-214 (cpm)	Tl-208 (cpm)	Total (cpm)
405	27 27.92	80 11.02	52	71	15	17	1946
406	27 27.84	80 11.01	51	52	13	0	1853
407	27 27.77	80 11.01	51	50	21	24	1832
408	27 27.70	80 11.02	52	80	16	9	1887
409	27 27.62	80 11.02	55	57	19	17	1852
410	27 27.55	80 11.02	53	77	0	12	1881
411	27 27.47	80 11.01	53	63	16	21	2017
412	27 27.40	80 11.02	54	79	0	0	2040
413	27 27.33	80 11.02	53	41	33	21	2045
414	27 27.26	80 11.01	53	62	27	3	2065
415	27 27.19	80 11.01	53	58	55	9	2180
416	27 27.12	80 11.00	52	64	14	6	1879
417	27 27.05	80 11.01	51	58	8	3	1861
418	27 26.98	80 11.01	50	65	5	22	1901
419	27 26.91	80 11.01	50	29	0	33	1898
420	27 26.84	80 11.00	49	88	35	34	1935
421	27 26.76	80 11.01	50	54	32	18	1851
422	27 26.69	80 11.01	51	71	1	9	1914
423	27 26.62	80 11.01	50	63	0	19	1936
424	27 26.55	80 11.01	47	65	30	24	1816
425	27 26.48	80 11.01	47	67	8	14	1913
426	27 26.41	80 11.02	46	61	0	19	1827
427	27 26.34	80 11.01	45	77	19	36	1858
428	27 26.28	80 10.97	44	54	21	35	1803
429	27 26.26	80 10.91	44	66	15	4	1808
430	27 26.27	80 10.84	48	49	64	0	1805
431	27 26.33	80 10.82	50	46	6	7	1854
432	27 26.40	80 10.81	48	102	18	12	1815
433	27 26.46	80 10.81	48	68	17	9	1868
434	27 26.52	80 10.82	49	71	5	16	1767
435	27 26.58	80 10.83	48	66	28	16	1755
436	27 26.65	80 10.82	51	21	34	16	1739
437	27 26.72	80 10.83	50	83	35	10	1717
438	27 26.78	80 10.83	49	84	35	14	1733
439	27 26.84	80 10.83	50	60	12	33	1872
440	27 26.91	80 10.84	52	59	18	14	1939
441	27 26.97	80 10.85	50	35	0	9	1793
442	27 27.04	80 10.84	51	62	14	18	1810
443	27 27.10	80 10.85	52	48	39	24	1932
444	27 27.16	80 10.86	53	74	13	0	1922
445	27 27.22	80 10.83	55	57	25	15	1830
446	27 27.29	80 10.82	53	105	33	14	1971
447	27 27.35	80 10.83	53	75	22	7	2042
448	27 27.41	80 10.82	55	84	28	26	2007
449	27 27.48	80 10.80	55	28	10	10	206[illegible]

APPENDIX A: Fort Pierce Shipboard Data - Gamma Radiation

Site	Latitude	Longitude	Depth (ft)	K-40 (cpm)	Bi-214 (cpm)	Tl-208 (cpm)	Total (cpm)
450	27 27.54	80 10.80	54	53	17	21	1919
451	27 27.61	80 10.81	55	83	30	0	2027
452	27 27.69	80 10.83	55	81	35	12	2182
453	27 27.77	80 10.84	56	43	4	11	1805
454	27 27.84	80 10.86	54	81	10	17	1899
455	27 27.92	80 10.86	53	28	35	3	1829
456	27 28.01	80 10.85	54	89	42	15	1769
457	27 28.09	80 10.84	50	42	34	9	1886
458	27 28.17	80 10.82	52	83	23	21	2313
459	27 28.24	80 10.82	53	51	31	28	2188
460	27 28.32	80 10.82	53	64	14	26	1712
461	27 28.39	80 10.81	54	73	52	22	2219
462	27 28.47	80 10.83	56	93	31	18	2224
463	27 28.54	80 10.85	53	97	53	39	2196
464	27 28.62	80 10.88	49	102	59	1	2478

Appendix B

FORT PIERCE ODMDS – CS^3 SAMPLE STATIONS

APPENDIX B: Fort Pierce ODMDS - CS3 Sample Stations

Site	Latitude	Longitude	Depth (ft)
1	27 26.57	80 13.12	22
2	27 26.76	80 13.13	24
3	27 26.89	80 13.11	23
4	27 27.06	80 13.12	22
5	27 27.20	80 13.11	23
6	27 27.36	80 13.10	22
7	27 27.49	80 13.11	23
8	27 27.62	80 13.10	24
9	27 28.48	80 12.76	28
10	27 28.36	80 12.73	28
11	27 28.20	80 12.73	27
12	27 28.00	80 12.72	27
13	27 27.80	80 12.72	27
14	27 27.73	80 12.72	26
15	27 27.59	80 12.74	26
16	27 27.43	80 12.75	25
17	27 27.31	80 12.75	24
18	27 27.15	80 12.77	24
19	27 26.99	80 12.77	23
20	27 26.84	80 12.77	23
21	27 26.70	80 12.78	23
22	27 26.55	80 12.77	22
23	27 26.57	80 12.38	25
24	27 26.80	80 12.37	25
25	27 26.89	80 12.35	25
26	27 27.02	80 12.34	26
27	27 27.17	80 12.32	26
28	27 27.36	80 12.33	26
29	27 27.47	80 12.34	28
30	27 27.61	80 12.35	28
31	27 27.76	80 12.37	27
32	27 27.93	80 12.38	29
33	27 28.08	80 12.37	28
34	27 28.22	80 12.38	29
35	27 28.37	80 12.36	29
36	27 28.53	80 12.34	30
37	27 28.73	80 12.09	30
38	27 28.54	80 11.96	28
39	27 28.37	80 11.98	29
40	27 28.21	80 11.98	28
41	27 28.08	80 11.98	28
42	27 27.92	80 11.99	29
43	27 27.78	80 12.00	27
44	27 27.63	80 11.98	27

APPENDIX B: Fort Pierce ODMDS - CS3 Sample Stations

Site	Latitude	Longitude	Depth (ft)
45	27 27.48	80 11.98	26
46	27 27.33	80 11.96	26
47	27 27.18	80 11.99	26
48	27 27.03	80 11.98	25
49	27 26.88	80 11.99	26
50	27 26.73	80 11.98	25
51	27 26.58	80 12.00	24
52	27 26.54	80 12.01	24
53	27 26.56	80 11.61	25
54	27 26.70	80 11.63	25
55	27 26.86	80 11.59	27
56	27 27.01	80 11.61	27
57	27 27.15	80 11.59	28
58	27 27.30	80 11.59	28
59	27 27.45	80 11.61	28
60	27 27.61	80 11.63	28
61	27 27.75	80 11.61	29
62	27 27.90	80 11.63	29
63	27 28.06	80 11.61	30
64	27 28.22	80 11.63	28
65	27 28.36	80 11.61	29
66	27 28.51	80 11.64	29
67	27 28.56	80 11.63	29
68	27 28.75	80 11.38	30
69	27 28.53	80 11.22	30
70	27 28.37	80 11.21	28
71	27 28.23	80 11.23	29
72	27 28.08	80 11.22	30
73	27 27.93	80 11.22	29
74	27 27.77	80 11.21	28
75	27 27.63	80 11.20	28
76	27 27.48	80 11.21	29
77	27 27.33	80 11.21	28
78	27 27.18	80 11.22	26
79	27 27.02	80 11.24	28
80	27 26.88	80 11.23	26
81	27 26.73	80 11.24	27
82	27 26.59	80 11.23	27
83	27 26.53	80 11.23	26
84	27 26.56	80 10.82	26
85	27 26.72	80 10.82	27
86	27 27.20	80 10.83	28
87	27 27.31	80 10.86	29

Appendix C

QUALITY ASSURANCE AND CONTROL

C.0 QUALITY ASSURANCE AND CONTROL

Several steps were taken to ensure that the systems used to perform the survey were operating properly at all times. The methods for the quality assurance and control are documented in the QAPjP (EPA, 1991) for this project.

C.1 GIMS

To check the operating system of the GIMS, a CAIS monazite-sand standard was used. A spectrum was printed on paper before and after the survey. The operator of the system reviewed the spectrum to ensure that the operational peaks were in the proper settings. The operator also checked the systems gain, reference channel, and resolution. Figure C-1 shows the two calibration spectra recorded before and after the GIMS portion of the survey.

C.2 XRF (CS^3 and box core)

A replicate sample analysis was performed for the box-core pellet. Table C-1 shows the results of the replicate analyses for the pellet processed from box core 1 sediments. The precision results were generated by repeating XRF analysis on the same pellet five times. The accuracy determinations were generated by repeating XRF analysis on an NIST Standard 2704.

The replicate series for box core 1 did show three elements to be inconsistent with the expected precision range. P, Zr, and Pb did exceed the expected ranges for precision as stated by the QA/QC project plan. It has been determined that P and Pb sometimes experience signal peak interference with other elements during XRF analyses. Steps are currently underway to eliminate this problem. Zr was possibly nearing the minimum detection limit (MDL) for these elements. Determination of the MDLs for the XRF are currently being investigated and will be appended to the QAPjP.

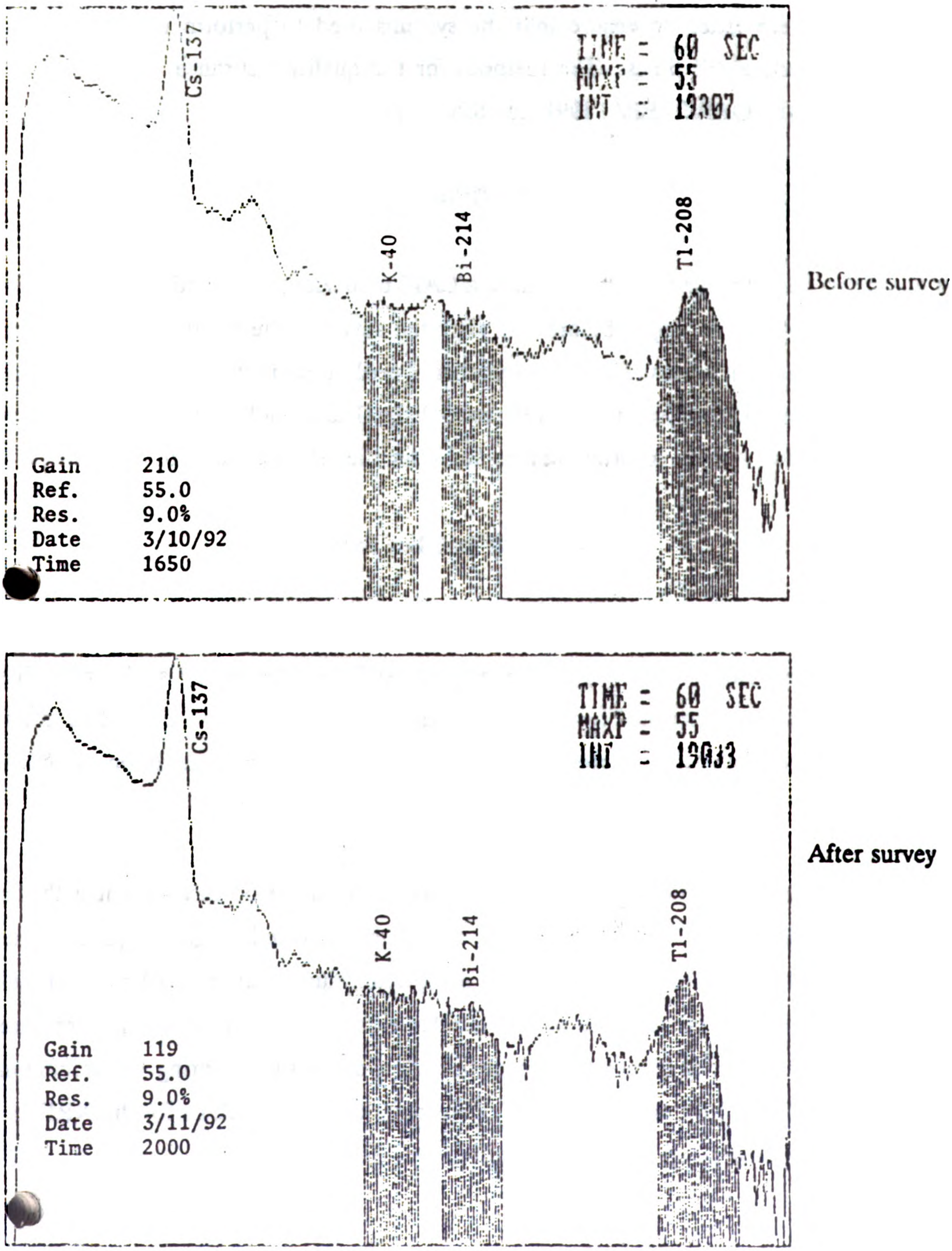


Figure C-1. Calibration spectra for GIMS.

Table C-1. XRF Data Quality Measurements for Box Core 1

System	Analyte	Precision[a]	Accuracy[b]	Precision[c]	Accuracy[c]
XRF	Al	±5.6%	±0.5%	±25%	±25%
wt%	Si	±1.2%	±0.3%	±25%	±25%
	S	±7.1%	±1.0%	±25%	±25%
	Fe	±0.4%	±0.4%	±25%	±25%
	Ca	±0.4%	±0.8%	±25%	±25%
	Mg	±8.6%	±2.7%	±25%	±25%
	P	±32.8%	±21.1%	±25%	±25%
	Sr	±0.0%	±2.2%	±25%	±25%
ppm	Ti	±4.0%	±0.9%	±25%	±25%
	Cr	±19.2%	±4.6%	±25%	±25%
	Mn	±16.4%	±7.8%	±25%	±25%
	Ni	±6.6%	±18.2%	±25%	±25%
	Cu	±19.9%	±1.5%	±25%	±25%
	Zn	±6.6%	±0.5%	±25%	±25%
	Zr	±58.1%	±0.9%	±25%	±25%
	Cd	±31.9%	±11.9%	±40%	±40%
	Sb	±31.3%	±21.7%	±40%	±40%
	Sn	±23.0%	±18.6%	±40%	±40%
	Ba	±14.6%	±2.8%	±25%	±25%
	Pb	±50.2%	±11.2%	±25%	±25%

[a]Relative standard deviation based on replicate analysis of box core 1.
[b]Difference from true value based on replicate analysis of NIST 2704.
[c]Acceptance/rejection values.

C3 Ge(Li) Detector

A replicate analysis of box core 2 was performed. U was found to be at a concentration level of 205 pCi/kg, Th was 49 pCi/kg, and K was 308 pCi/kg for the first analysis. For the second analysis, U was 214 pCi/kg, Th was 39 pCi/kg, and K was 278 pCi/kg. An EPA pitchblende standard was analyzed along with the six box-core samples to monitor the operation of the Ge(Li) detector. The standard was recorded at 3174 pCi/kg U, which lies within the expected range of ±25% error. A background sample was also analyzed with the box-core samples, and recorded no detectable levels of gamma radiation.