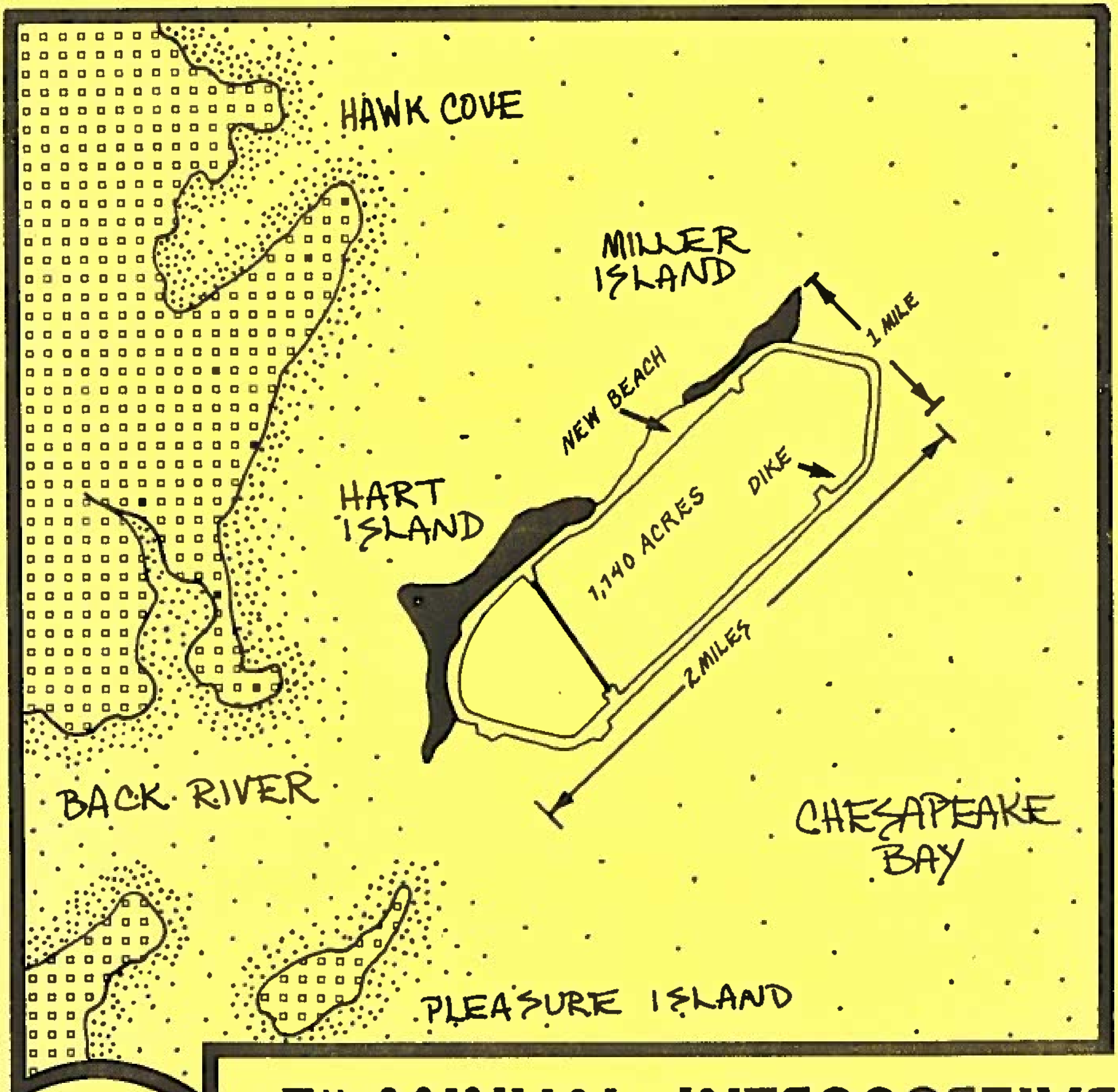
ASSESSMENT OF THE ENVIRONMENTAL IMPACTS OF THE HART AND MILLER ISLANDS CONTAINMENT FACILITY



5th ANNUAL INTERPRETIVE REPORT AUG.'85≈AUG.'86

MARYLAND DEPARTMENT OF NATURAL RESOURCES
TIDEWATER ADMINISTRATION

November 1987

FOREWORD

Maryland is rich in natural resources. Its wild game, woods, beaches,rivers, and Chesapeake Bay with its abundant aquatic resources provide a bountiful outdoor environment for our citizens. The task of the Department of Natural Resources is to manage these resources in such a way that their enhancement, conservation, use and development ensures the greatest good for the greatest number of Marylanders, now and in the future. The employees of DNR are personally and professionally committed to this task and with public understanding and support, we will achieve our goal.

Torrey C. Brown
Secretary
Department of Natural Resources

ACKNOWLEDGMENTS

We are grateful to the scientists who contributed to and critically reviewed this report. We also thank Lenora Dennis and Lorane Bruce for their indispensible help in typing this report. Ty Obitz, Bob Watson and Maureen Jablinske provided editorial assistance.

The Monitoring and Data Management Section of the Tidewater Administration has prepared this report for submission to the Water Resources Administration under MPA Contract. The environmental monitoring of the Hart and Miller Islands is done by the Maryland Department of Natural Resources and the Chesapeake Biological Laboratory of the University of Maryland on behalf of the Maryland Port Administration. The monitoring program is part of the State of Maryland's commitment to the Chesapeake Bay.

EXECUTIVE SUMMARY

The Hart and Miller Islands Containment Facility was designed to receive material from channel dredging projects in the Baltimore Harbor and its approaches. The disposal site is located northeast of the Baltimore Harbor in the Chesapeake Bay. This report contains the results of the Department of Natural Resources fifth year monitoring effort to assess the impacts to the biological and sedimentary environment exterior to the dike. Samples of sediments, fish and benthic populations were taken at a number of sites in the vicinity of the Hart and Miller Islands during fall 1985 and spring 1986. Data collected from this and the previous four years of monitoring indicate there have been no significant changes in the environment other than those resulting from construction, approach channel dredging, and barge traffic near the rehandling piers.

Use of the area by fish and crabs appears considerable and indicates the structure functions as an artificial reef. Changes in benthic populations have been related to seasonal and yearly variations in salinity, dredging and boat traffic at the rehandling pier. Species diversity was found to be low in the study area, however, the presence of large numbers of a few species is not uncommon in this region where low and variable salinity levels prevail. With the exception of color changes in the fluid muds deposited during construction of the dike and the reclassification of sediment types at some of the sampling stations, the physical and chemical composition of sediments has remained consistent with preconstruction samples. The color changes are attributed to biogenic activity. Difficulty in reoccupying exact sampling locations may explain the inconsistent shifts in sediment types at specific stations.

The beach erosion study was continued as part of the fifth year monitoring program. The overall configuration of the recreational beach remains similar to previous study years, but erosion from wind-generated wave attack and deposition from the transport of sediments was more destructive during the 1985-1986 study period than in previous years.

Overall, there has been no evidence of detrimental impacts related to seepage or spills of contaminants associated with operation of the facility.

Key Words: dredged material, monitoring, Chesapeake Bay, benthic fauna, sediments, trace metals, fish, toxic substances, bioaccumulation, beach erosion.

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PROJECT II: SEDIMENTARY ENVIRONMENT

PROJECT III: BIOTA

PART 1: BENTHIC STUDIES

DEFINITION OF TERMS

Bathymetric - Referring to contours of depth below the water's surface.

Benthos - The bottom of a sea or lake. The organisms living on sea or lake bottoms.

Bioaccumulation - The accumulation of foreign substances, particularly toxic contaminants, within the tissues of organisms. Results from chronic exposure to contaminated food or habitats.

Biogenic - Resulting from the activity of living organisms. For example, bivalve shells are biogenic minerals.

Biometrics - The statistical study of biological data.

Biota - The animal and plant life of a region.

Bioturbation - Mixing of sediments by the burrowing and feeding activities of sediment-dwelling organisms. This disturbs the normal, layered patterns of sediment accumulation.

Brackish - Salty, with saline content less than that of sea water.

Desiccation - The act of drying thoroughly; exhausting or depriving of moisture.

Diversity index - A statistical measure that incorporates information on the number of species present in a habitat with the abundance of each species. A low diversity index suggests that the habitat has been stressed or disturbed.

Dominant (species) - Designating an organism or a group of organisms which, by their size and numbers or both, determine the character of a community.

Dredge - Any of various machines equipped with scooping or suction devices used in deepening harbors and waterways and underwater mining.

Effluent - Something that flows out or forth; An outflow or discharge of waste, as from a sewer.

Epifauna - Benthic animals living on the surface of bottom material.

Flocculent - Having a fluffy or wooly appearance.

Gas chromatography - A method of chemical analysis in which a sample is vaporized and diffused along with a carrier gas through a liquid or solid adsorbant for differential adsorption. A detector then records separate peaks as various compounds are released (eluted) from the column.

Hydrography - The scientific description and analysis of the physical conditions, boundaries, flow, and related characteristics of oceans, rivers, lakes, and other surface waters.

Infauna - Benthic animals living in bottom material.

Littoral - Of or pertaining to the seashore, especially the region between tide lines.

Mean low water - The average water level at low tide.

Radiograph - An image produced on a radiosensitive surface, as a photographic film, by radiation other than visible light, especially by x-rays passed through an object or by photographing a fluoroscopic image.

Revetment - A facing, as of masonry, used to support an embankment.

Salinity - The concentration of salt in a solution. Full strength seawater has a salinity of about 35 parts per thousand (ppt or o/oo). Sediment- That which settles to the bottom, as in a flask or lake.

Seine - A large fishing net made to hang vertically in the water by weights at the lower edge and floats on the top.

Spawn - To produce and deposit eggs, with reference to aquatic animals.

Spectrophotometer - An instrument used in chemical analysis to measure the intensity of color in a solution.

Spillway - A channel for an overflow of water.

Substrate - A surface on which a plant or animal grows or is attached.

Surficial - The top, or surface layer of sediment.

Trace metal - A metal that occurs in minute quantities in a substance.

Trawl - A large, tapered fishing net of flattened conical shape, towed along the sea bottom. To catch fish by means of a trawl.

Assessment of the Environmental Impacts of the Hart and Miller Islands Containment Facility

Fifth Annual Interpretive Report
August 1985-August 1986
November 1987

Submitted to
Maryland Water Resources Administration
Prepared for
Maryland Port Administration
by
Department of Natural Resources
Tidewater Administration
Coastal Resources Division
Monitoring and Data Management

INTRODUCTION

The Hart and Miller Islands Containment Facility monitoring program was established to collect and analyze data to determine the effects of the containment facility on the surrounding environment. The program was launched in 1981 so that environmental data for pre-construction and pre-operational conditions could be compared with the data collected during operation of the facility. The Fifth Annual Interpretive Report presents the results of the environmental monitoring of the Hart and Miller Island Containment Facility from August 1985 through August 1986.

DESCRIPTION OF THE CONTAINMENT FACILITY

The site is environmentally and economically important to Maryland and the Chesapeake Bay region. The State of Maryland contracted for the construction of a diked area at Hart and Miller Islands during 1981-1983, and the facility was completed in 1983. It was designed to receive 51 million cubic yards of material, most of which will be bottom sediments produced by deepening the Baltimore Harbor and its approach channels to 50 feet. Once the facility reaches its containment capacity, it will be converted to a permanent wildlife and recreational area.

The dike is 18 feet above mean low water and encloses an area of 1,140 acres. It was constructed from sand deposits within and underlying the enclosure site. The Bay-side face is riprapped with stone over filter cloth. The typical side slopes are 3:1 (three horizontal to one vertical) on the exposed outside face, 5:1 on the inside and 20:1 on the Back River side. The completed dike is approximately 29,000 feet long and contains 5,800 cubic yards of stone. The facility is divided into two containment cells by an additional interior dike of approximately 4,300 feet in length.

DREDGED MATERIAL DISPOSED

Material dredged in 1985 in the amount of 3.7 million cubic yards (mcy) was deposited into the North Cell. Of the 7.7 mcy of dredged material disposed in 1986, 3.7 mcy was deposited into the North Cell and 3.8 mcy was deposited into the South Cell. The breakdown of dredged material received by project is listed on Table 1. It is noted that the disposed volumes shown on the table for 1985 and 1986 represent the entire 1985 and 1986 dredging seasons (April 1985 through September 1985 and June 1986 through January 1987 respectively).

The quantity of material disposed was not sufficient to require a release of supernatant water during the August 1985 through August 1986 reporting period. Discharge of the supernatant was initiated on October 25, 1986 and will be discussed in further detail in the 6th Annual Report.

TABLE 1
DISPOSAL OPERATIONS

YEAR	PROJECT NAME	CUT QUANTITY DISPOSED (Cubic Yards)
1983	Hart-Miller Personnel Pier	26,000
1984	42-ft Channel Maintenance	3,908,000
1984	Dundalk Marine Terminal	550,000
1984	Hart-Miller Barge Unloading Pier	180,000
	TOTAL 1984	4,638,000
1985	42-ft Channel Maintenance	3,145,000
1985	Bethlehem Steel	596,000
	TOTAL 1985	3,741,000

TABLE 1 (continued)
1986 DISPOSAL OPERATIONS
(JUNE 1986 THROUGH JANUARY 1987)

PROJECT NAME	CUT QUANTITY DISPOSED (Cubic Yards)
42' Channel Maintenance	7,100,000
Canton-Seagirt	410,000
South Locust Point	185,000
Back River Bridge	18,000
Bethlehem Steel Ore Pier	6,000
Rukert Terminal	17,000
Hess Oil	7,000
TOTAL	7,743,000*

* Quantities shown are for entire 1986 dredging season (June 17, 1986 through January 17, 1987).

the beach erosion study.

Monitoring and documentation of the sedimentary environment is necessary to detect any changes which may occur as a result of the operation of the containment facility. Currently, highly organic, fine-grained sediments from the approach channels to Baltimore Harbor are being placed inside the dike structure. Improper handling or leakage of these dredged materials from the dike structure may produce changes in sand : mud ratios and the physical appearance of the surrounding sediments as well as increase the levels of trace metals and organic contaminants. In five years of monitoring, no major changes have occurred within the sedimentary environment as a result of the operational phase of the facility.

Sediments are collected not only at various sites surrounding the containment facility, but also at several reference sites outside the immediate area of the facility. The sediments are put through a rigorous series of tests including organic contaminant, trace metal, textural and radiographic analyses. These studies determine the amount of biogenic activity, benthic recolonization, bioturbation and trace metals. Textural and trace metal data from the 1985-86 monitoring year indicate no major changes occurred again this year.

The beach erosion study initiated in spring, 1984 yielded additional data which can be interpreted to define geomorphic (natural) processes and anthropogenic (human) activities that shape the beach. Erosional processes are still operating and appear to be correlated with the slope, textural characteristics of the beach material, littoral drift, rainfall and wind direction. The main agent of erosion on the beach has been wave attack on the foreshore by wind generated waves. The dike face is being altered primarily by pluvial and aeolian processes (rain and wind). During the fifth year of monitoring, erosion of the beach increased dramatically, resulting in a steeper, more gravelly beach.

PROJECT III: BIOTA

PART 1. BENTHIC STUDIES

Benthic invertebrates surrounding Hart and Miller Islands in the Upper Chesapeake Bay have been included in the ongoing monitoring program since August 1981. The primary objectives of the benthic studies are to survey the species, abundance and distribution of benthic organisms in this area and to determine effects of construction and operation of the diked disposal facility on this fauna.

Benthic studies are part of the comprehensive environmental monitoring program for the Hart and Miller Islands containment facility for two reasons. First, as benthic species reach maturity, they generally become more sedentary and cannot avoid physical or chemical changes in their environment. When and if adverse conditions arise, they are directly subjected to such variation. The second reason for monitoring is the highly variable physical environment in this area of the Chesapeake Bay. Sudden decreases in salinity, large shallow areas subject to wind-induced wave action, high summer water temperatures, and ice formation in winter are some of the physical variables. As a result, benthic populations are never stable, and thereby undergo changes with species and density both seasonally and yearly.

Certain groups or species of benthic animals are better adapted to specific bottom sediment types, and therefore occur in varying numbers, depending on the bottom types. For this reason, several different bottom types are investigated. Reference sites as well as sites in the immediate area of the facility were monitored. Several types of statistical analyses were performed. These analyses almost always grouped stations by infaunal response to bottom type. Since the beginning of the project in 1981, the dominant species have remained relatively stable in the different bottom types. Epifaunal populations followed the same yearly pattern as described in previous reports. During the winter, populations were eliminated by ice movement or desiccation at low tide. However, in the spring, the populations are reestablished by species capable of movement.

This year's results clearly indicate that only localized and temporary effects on the benthos are a result of the containment facility. These effects are primarily limited to the area near the rehandling pier, and are a result of tug props washing away the bottom.

Infaunal and epifaunal benthic populations should be monitored no less critically in the upcoming year, when effluent discharge from the containment island will probably take place. Four years of data from pre-construction through construction and early operation of the facility are a valuable baseline and will be essential for assessment of possible future benthic population changes.

PART 2. FISH AND CRAB POPULATION STUDIES

Populations of fish and crabs in the vicinity of Hart and Miller Islands have been studied since 1981. The objective of this study is to assess the impacts of the containment facility on these populations. The extensive data collected since the beginning of the project provide a detailed description of the quantity and compositions of the populations and also provide a basis for future comparisons.

The quantity and composition of the fish population is determined by the number of individuals and the different species caught. Three gear types: trawls, seine and eel pots, were used during the 1985-86 sampling period. Finfish, blue crabs and eels were the major species sampled.

The data indicate that the containment facility has no detrimental effects on the fish population, and may even have beneficial impacts. The results show that use of the area by finfish and crabs is considerable. Induced currents, caused by the artificial structure along the south and east faces, may reduce its use by some desirable species. The structure can still function as an artificial reef.

PROJECT IV: ANALYTIC SERVICES

The Water Resources Administration, Department of Natural Resources, in cooperation with the U.S. Environmental Protection Agency Central Regional Laboratory in Annapolis, analyzed samples of sediments, fish and brackish-water clams for toxic organic contaminants. Only data on trace organics in sediments (November cruise) were received in time for this report. The analyses indicated that none of the stations showed any of the constituents tested above detection limits.

Project I-Scientific Coordination and Data Management

Department of Natural Resources
Tidewater Administration
Coastal Resources Division
Monitoring and Data Management

Stephen J. Jordan

Development and implementation of a monitoring program which is sufficiently sensitive to environmental effects of dredged material containment at Hart and Miller Islands continues to be a complex and difficult undertaking. The environmental monitoring activities have evolved over the five years of the project. Ongoing studies have included physical and chemical characterization of sediments and population studies of benthos and finfish. Baseline data on water column nutrients and productivity, submerged aquatic vegetation, trace metals and organic contaminants were included in the First and Second Interpretive Reports for 1981 - 1983 (Cronin et al.). Bathymetric studies were completed in the first three monitoring years to identify pre- and post-construction changes in currents and erosion. A beach erosion study was initiated in the spring of 1984 and is included in the third, fourth and fifth annual reports.

Scientific planning, review and coordination of the monitoring activity is provided by Monitoring and Data Management personnel. Sampling procedures, data analysis, and future directions of the program were discussed with principal investigators. Descriptions of any changes in sampling methods are included in the individual investigator project reports that follow. Compilation, editing, technical review, and printing of the Interpretive and Data Report are the responsibilities of the Monitoring and Data management Section. During the first five years of the environmental assessment program, data collected by the Department of Natural Resources and research institutions was stored in the Tidewater Administration's "Resource Monitoring Data Storage System." The IBM-OS File/SAS Data Base is used for computer storage and analysis of data. Each principal investigator submits data forms or a magnetic tape with data appropriately formatted. Permanent storage of the data in a readily accessible form provides a continuous, documented record of baselines and trends in biota, sediments and contaminant levels. Data from the 1985-1986 monitoring year is included in the Fifth Year Data Report which is compiled and printed separately from the Interpretive Report.

Project II - Sedimentary Environment

Department of Natural Resources
Maryland Geological Survey
Coastal and Estuarine Geology

Darlene V. Wells, Robert Cuthbertson and James Hill

ABSTRACT

The Coastal and Estuarine Geology Program, Maryland Geological Survey (CEG-MGS) has been involved in monitoring the physical and chemical behavior of the sediments around the Hart and Miller Island Containment Facility as part of Maryland's environmental assessment of the facility. This report presents the results of the fifth year monitoring effort which consisted of two studies: (1) monitoring changes in the sedimentary environment, and (2) measuring erosional and depositional changes on the recreational beach.

Textural and trace metal data from sediments collected around the exterior perimeter of the dike facility show that no major changes occurred within the sedimentary environment as a result of the operational phase of the Facility. The blanket of fluid mud that was deposited during dike construction continued to remain very distinct. Although the top portion of the fluid mud layer had been reworked by benthic activity (bioturbated), there was no increase in the level of activity compared to last year's observations of benthic activity.

The distribution and range of enrichment factors for trace metals in the sediments remained consistent with previous years. Generally, the average enrichment factors for metals continued to be lower for the fluid muds. However, a slight increase in the enrichment factor values was associated with the bioturbated zone of the fluid mud and attributed to benthic activity.

Based on data collected for the Beach Study, erosion continued to have deleterious effects on the recreational beach. Although much of the erosion occurred as a result of wave attack on the foreshore, gully and sheetwash erosion increased due to steeper slopes along the lower dike face, particularly at the north end of the beach. It was calculated that approximately 4700 cubic yards (3600 m^3) of material had been eroded from the beach since the beginning of the beach study. Furthermore, the erosional processes have selectively removed the sand-sized material resulting in a more gravelly beach.

PART 1: SEDIMENTARY ENVIRONMENT

INTRODUCTION

The areal distribution and characteristics of bottom sediments reflect the complex interaction of physical, chemical, and biological processes, actingsingly or in combination. In addition to these natural processes, certain anthropogenic events such as dredging and overboard disposal may produce sudden changes in the nature of the bottom sediments. During construction of the diked structure at Hart and Miller Islands both the dredging of the nearshore bottom for suitable building material and the overboard disposal of such materials were necessary. These activities produced changes in the bottom environment.
Monitoring and documentation of these sedimentary changes have been necessary in order to detect further environmental changes during the operational phase of the Facility, which began in 1983. During this phase, highly organic, fine-grained sediments from the approach channels to Baltimore Harbor have been placed inside the dike structure. Improper handling or leakage from the dike structure may produce changes in the sand:mud ratios and the physical appearances in the surrounding sediments as well as increase the trace metal and organic content.

PREVIOUS WORK

Changes in the sedimentary environment around the Hart and Miller Island Containment Facility were documented during the first four years of the State's monitoring project and are detailed in several reports (Kerhin et al. 1982a; Wells et al. 1984, 1985, and 1986). Knowledge of the physical characteristics and areal distribution of the sediment types prior to the construction of the facility was based on data collected by the Maryland Geological Survey in 1978 (MGS, in prep.). The sediments graded from sands in the nearshore to sand-silt-clays and silty-clays just northeast of the islands. On the Hawk Cove and southern side of the complex, the sediments graded from nearshore sands to silty-clays, the latter having been described as dark-grey muds with high water content and shells. Live bivalves, *Rangia cuneata* and *Macoma balthica*, were common (Kerhin et al. 1982b).

Radiographic examination of cores taken in the area around Hart and Miller Islands before construction began revealed low levels of bioturbation (reworking of sediments by organisms) in the Back River-Hawk Cove area and higher bioturbation levels elsewhere along the island complex. Moreover, at several sampling locations south of the complex, surface death assemblage layers of the mactrid bivalve mollusc, *R. cuneata*, were found.

During the active construction of the dike structure, which began in the fall of 1981, subtle changes in the sand-silt-clay percentages were detected in the sediments collected at established stations around the Hart and Miller Island complex. The sediments became siltier, particularly at those stations adjacent to the active construction areas. In the summer of 1982, gross changes in the physical appearance of the sediments were observed. The five-grained sediments collected prior to the summer of 1982 were described consistently as dark grey muds. However, sediments collected in July 1982, south and adjacent to the dike wall structure were very fluid light grey to pink muds,resembling pre-Holocene sediments that were dredged for dike construction. It was determined that a "blanket" of this fluid mud had accumulated south and east of the dike structure as a result of construction (Wells et al. 1983, 1984). Radiographic examination of the fluid mud accumulations revealed little or no bioturbation.

Trace metal analyses of sediment samples were conducted, and based on trace metal enrichment factors, the sediments collected before and after dike construction were similar except in the area where the light-colored fluid muds had accumulated. There, the enrichment factor values were low (see RESULTS section for discussion of enrichment factors).

The dike structure was completed in spring 1983. Continued monitoring after the completion of the dike structure revealed few additional changes in the characteristics of the sediments. The layer of fluid mud introduced during the construction of the dike remained evident. The only changes observed in the fluid were slight color changes, which were attributed to biogenic activity. Radiographic analyses of sediment cores taken around the dike structure were consistent with previous years' studies. Bioturbation levels of the cores taken within the area of fluid accumulation increased with time. However, the enrichment factor values remained low for the fluid mud accumulation. In other areas outside the fluid mud accumulations, the zinc enrichment factor remained consistent with pre-construction values.

OBJECTIVES

The purpose of the fifth year study was to continue monitoring the vertical and areal distribution of sediments and their geochemical components. The objectives were:

1. To identify the sedimentological and geochemical conditions of the near-surface sedimentary column in the project area.
2. To provide information necessary to assess gross environmental changes that may occur during the project life.

METHODOLOGY

FIELD METHODS

Field sampling of surficial sediments was conducted twice during the year, November 1985 and April 1986. Twenty-five stations were visited during each sampling cruise, (See Figure 1 for their locations).

In the field, the geographical positions of the stations were determined using the Loran-C Navigational System. The Loran-C coordinates and the latitude and longitude for each station are given in the Fifth Year Data Report.

Undisturbed samples of the top 8-10 cm of the sediments were collected with a dip-galvanized Van Veen sampler. Two grab samples were collected at each station one for textural and trace metals analysis and a second for organic contaminant analysis. At three stations adjacent to the northeast sluice gate (#11, 21, and 24), triplicate grab samples were obtained. Trace metal subsamples were collected using plasticware rinsed with distilled water. These were taken several centimeters into the grab, below the flocculent layer, away from the sides of the sampler, to avoid possible contamination from the sampler.

Samples for organic analyses were collected using stainless steel or aluminum sampling devices which were rinsed in pesticide-grade methylene chloride.

The sediment and trace metal samples were placed in 18 oz. (0.5 liter) "Whirl-Pac" bags. The sample designated for textural analysis was stored out of direct sunlight at ambient temperature; the sample designated for trace metal analyses was refrigerated and maintained at 4°C until processed. Samples for organic contaminant analyses were placed in pre-cleaned glass jars, immediately refrigerated and delivered to the Water Resources Technical Services Laboratory in Annapolis, for analysis.

During the sampling period in April, one core was collected at each of the seven Box Core stations (BC1-BC7) and at Station 21B (Figure 1). A benthos-type gravity corer, Model # 2171, with clean cellulose butyrate (CAB) liners (diameter 6.3 cm), was used to collect the cores. Each core was cut and capped at the original level of the sediment-water interface and refrigerated until X-rayed and processed in the lab.

Concurrent with the collection of the cores, two transects, one from Stations BC1 to BC2 and the second from BC3 to BC4, were surveyed using the Datasonics DFS-210 system to obtain a subbottom stratigraphic profile of the Bay bottom. The boat path for each transect was determined using the Loran-C navigational system. At specific time intervals during the surveys, the boat position was noted by recording the Loran-C time delays (TD's), and referenced on the Datasonics output record. The locations of the cores were referenced in the same manner. The Loran TD's and the latitudes and longitudes of the boat paths for the two transects are listed in the accompanying Fifth Year Data Report.

LABORATORY PROCEDURES

Textural Analysis

In the laboratory, subsamples from both the surficial and gravity cores were analyzed for water content, sand, silt, and clay percentages. Water content was determined as the percentage of water weight in the total wet weight of the sample. The weight of water was determined by drying the sediment at 65°C,

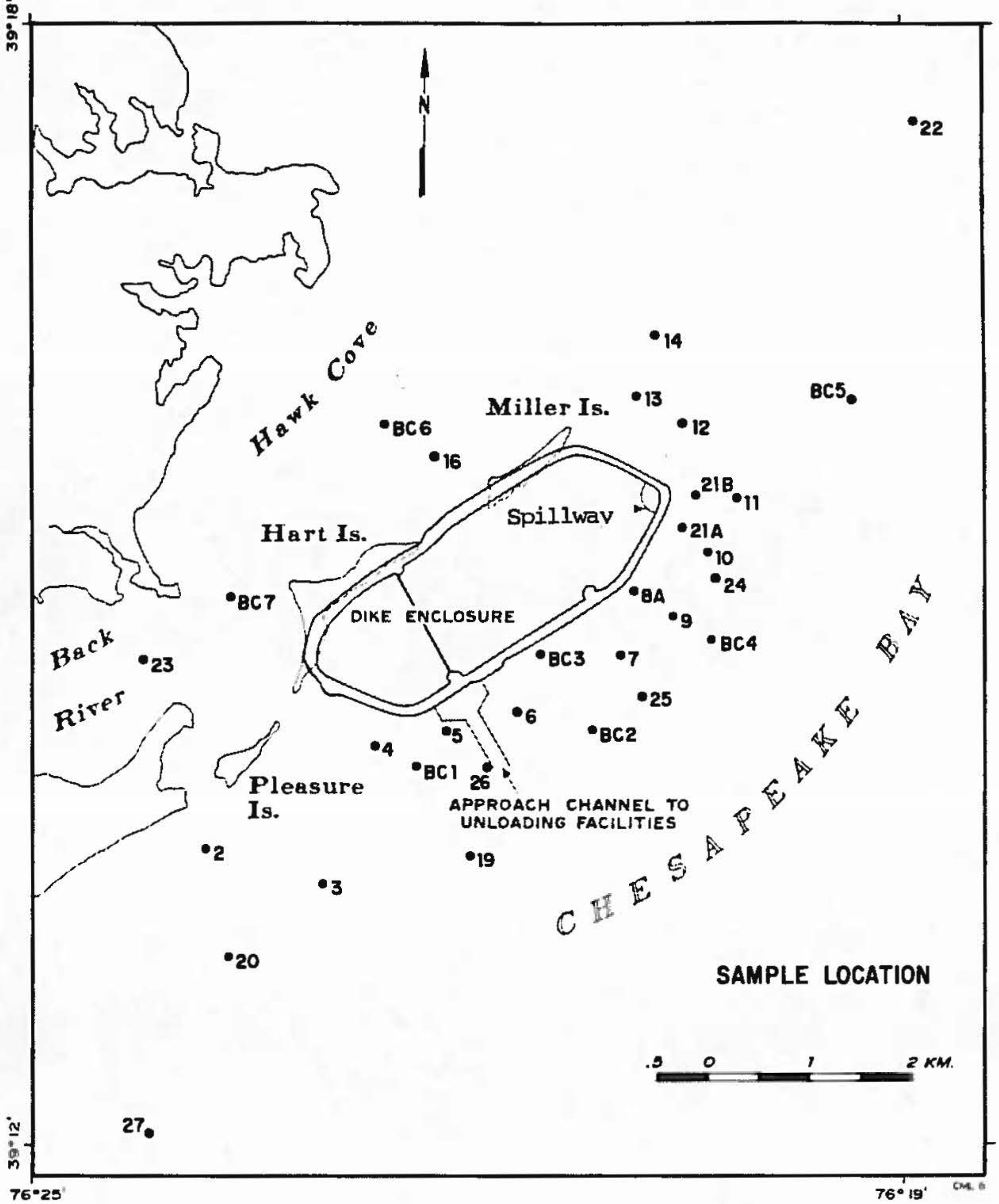

Figure 1

Map of the Hart and Miller Islands Diked Facility and vicinity, showing locations of the surficial sediment and core stations sampled during the fifth year monitoring.

recording the dry weight, and taking the difference between total wet weight and dry weight.

The percentages of sand, silt, and clay were determined using the sedimentological procedures described in Kerhin et al. (1983). The sediments were classified according to Shepard (1954), based on the percentages of sand, silt and clay (Figure 2) present. The total combined amount of carbonates and organics in the sediment was calculated as percent weight loss after digestion with hydrochloric acid and hydrogen peroxide.

Radiographic Technique

Prior to processing, the upper 60 cm of each core was X-rayed by the Department of Radiography at Johns Hopkins Hospital in Baltimore, using a CTR x-ray unit. A positive X-ray image of the core was obtained by xeroradiographic processing. The radiographs are presented in Appendix A.

Each core was then extruded, photographed and described. Sediment samples for textural and trace metal analyses were taken at selected intervals from each core based on physical criteria obtained from the radiographic and visual observations.

Trace Metal Analyses

Sediment solids were analyzed for trace metals using a lithium metaborate fusion technique followed by flame atomic absorption spectrophotometry. However, to improve the sensitivity of chromium (Cr) in the sediment solids of the core samples collected in April 1986, Cr was analyzed using the same lithium metaborate fusion technique, but followed by graphite furnace AA spectrophotometry (see discussion of Table 1 at the end of this section). The lithium

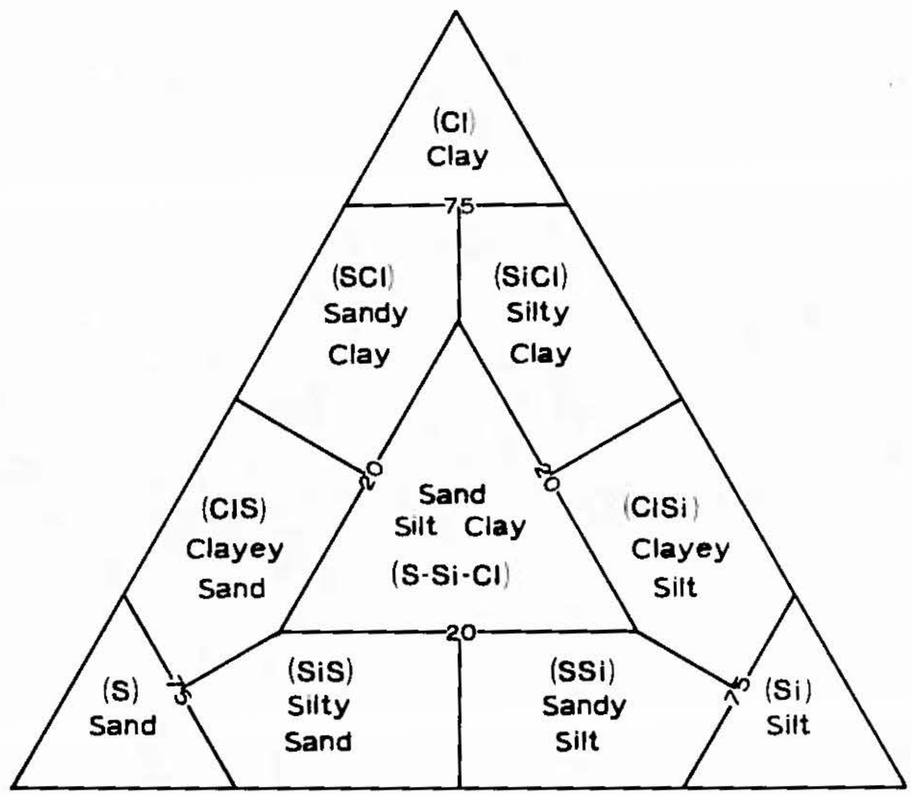

Figure 2

Ternary diagram showning the sediment classification as defined by Shepard's (1954) nomenclature.

metaborate fusion technique is similar to that used by Sinex et al. (1980, 1981) and Cantillo (1982), on sediments throughout the entire Chesapeake Bay region. The technique is based on the work of Suhr and Ingamells (1966), who developed the fusion technique for whole rock analysis. Details of the sample handling and preparation procedures used by the MGS laboratory are as follows:

1) Samples were homogenized in the "Whirl-Pac" bags in which they were stored (refrigerated at 4°C);

2) Approximately 10 g of wet sample were drawn into a modified "Leur-Loc" syringe fitted with a 1.25 mm polyethylene screen (used to remove shell material and large pieces of detritus);

3) Sieved samples were disaggregated in high-purity water and dried in teflon evaporating dishes at 110°C overnight;

4) Dried samples were then hand ground in an agate mortar and pestle and stored in "Whirl-Pac" bags;

5) Samples were weighed (0.2000 ± 0.0002 g) into a depression formed in $LiBO_2$ (1.00 ± 0.01 g) at the bottom of drill-point graphite crucibles (7.8 cc vol.);

6) These crucibles were placed in a highly regulated muffle furnace at 1050 +5°C for 30 min.;

7) The molten beads produced were poured directly into teflon beakers, containing 100 ml of a solution composed of 4% HNO_3, 1000 ppm La (from $La(NO_3)_3$) and 2000 ppm Cs (from $CsNO_3$), and stirred for 10 min. (if dissolution did not occur after 30 minutes, the solution and bead were thrown out and the sample re-fused), and;

8) The dissolved samples were transferred to CPE bottles and stored for analysis.

All surfaces which came in contact with the samples were acid washed (3 days 1:1 HNO_3; 3 days 1:1 HCl), rinsed six times in high purity water (greater than 5 Mohms resistivity) and stored in high purity water until use.

The dissolved samples were analyzed using the method of bracketing standards. The instrumental parameters used to determine the solution concentrations of Cr, Ni, Zn, and Cu were the recommended, standard F.A.A.S. conditions given in the IL 751 manual (Emmel et al. 1977). Fe and Mn were analyzed using an acetylene-nitrous oxide flame in order to eliminate interferences due to Al and Si (Butler, 1975). Blanks were run every 12 samples, and National Bureau of Standards reference material #1646 (Estuarine Sediments; NBS-SRM #1646) was run every 24 samples (5 times).

The results of the analyses of NBS-SRM #1646 are given in Table 1, and are compared to the NBS certified values. There was close agreement between the NBS certified concentrations and the analytical results of the MGS lab; most of the elements fell within the range of the determined standard deviation. However, several elements are suspect; Cr (Nov. 1985) because it was ~10% high, Cu (Nov. 1985) because of its large standard deviation (~50%), and Ni (all sample sets) because of its large standard deviation (~30%). The discrepancies for Cu and Ni were the results of working close to the instrumental detection limit for these elements. However, the discrepancy for Cr was thought to be due to a problem with the flame atomic absorption spectrophotometry. The last sample set (core samples) was analyzed for Cr using the graphite furnace method to increase the sensitivity with a corresponding increase in precision.

TABLE 1. Results of the MGS analyses of NBS-SRM #1646 compared to the certified values.

Element Concentrations	NBS Certified surficials	Nov. 1985 surficials	MGS Results April 1986 sample	Core Analyzed
Cr	76 ± 3	86 ± 12	76 ± 23	76 ± 5
Cu	18 ± 3	18 ± 9	20 ± 5	18 ± .03
Fe	3.35 ± 0.10%	3.35 ± 0.03%	3.32 ± 0.05%	3.39 ± 0.07%
Mn	375 ± 20	341 ± 6	360 ± 13	355 ± 10
Zn	138 ± 6	120 ± 4	116 ± 7	117 ± 4
Ni	32 ± 2	34 ± 12	32 ± 10	27 ± 10

All concentrations are in $\mu g/g$ dry weight except Fe, which is reported in parts per hundred.

RESULTS AND DISCUSSION

SEDIMENT DISTRIBUTION

November 1985

During the fall sampling cruise, sediment samples were collected at 25 stations. Triplicate samples were collected at three of the stations adjacent to the northeast sluice gate (Figure 1). Very little textural change (since April 1985) was seen in the sediment. At several stations the classification of sediment type changed. These stations were essentially the same stations that exhibited change the previous monitoring year: Stations 3, 5, 8A, 12, 21B and 22. Because many of the stations are adjacent to the dike structure and within either the fluid mud area or the sediment transitional zones, a wide range of sediment types have been seen at these locations throughout this monitoring effort.

Figure 3a is a ternary diagram plot of the type of sediments collected in November 1985. As with the previous period (June 1985) the basic trend of the sediments passes from sand through sand-silt-clay to the silty-clay/clayey-silt boundary. The siltier sediments were collected at stations within the fluid mud area. These samples are indicated in Figure 3a. Generally, the coarser sediment types were found at stations adjacent to the south and northeast perimeter of the dike (Figure 4), whereas finer-grained sediments were found at stations located in Hawk Cove and on the east side of the diked structure.

The field descriptions of the sediments indicated very little change in physical appearance since June 1985. Material that was introduced in the area during dike construction was still evident at Stations 4, 5, 6, 8A, 26 and BC3. This material was described as "steel grey, white or pink, smooth fluid mud".

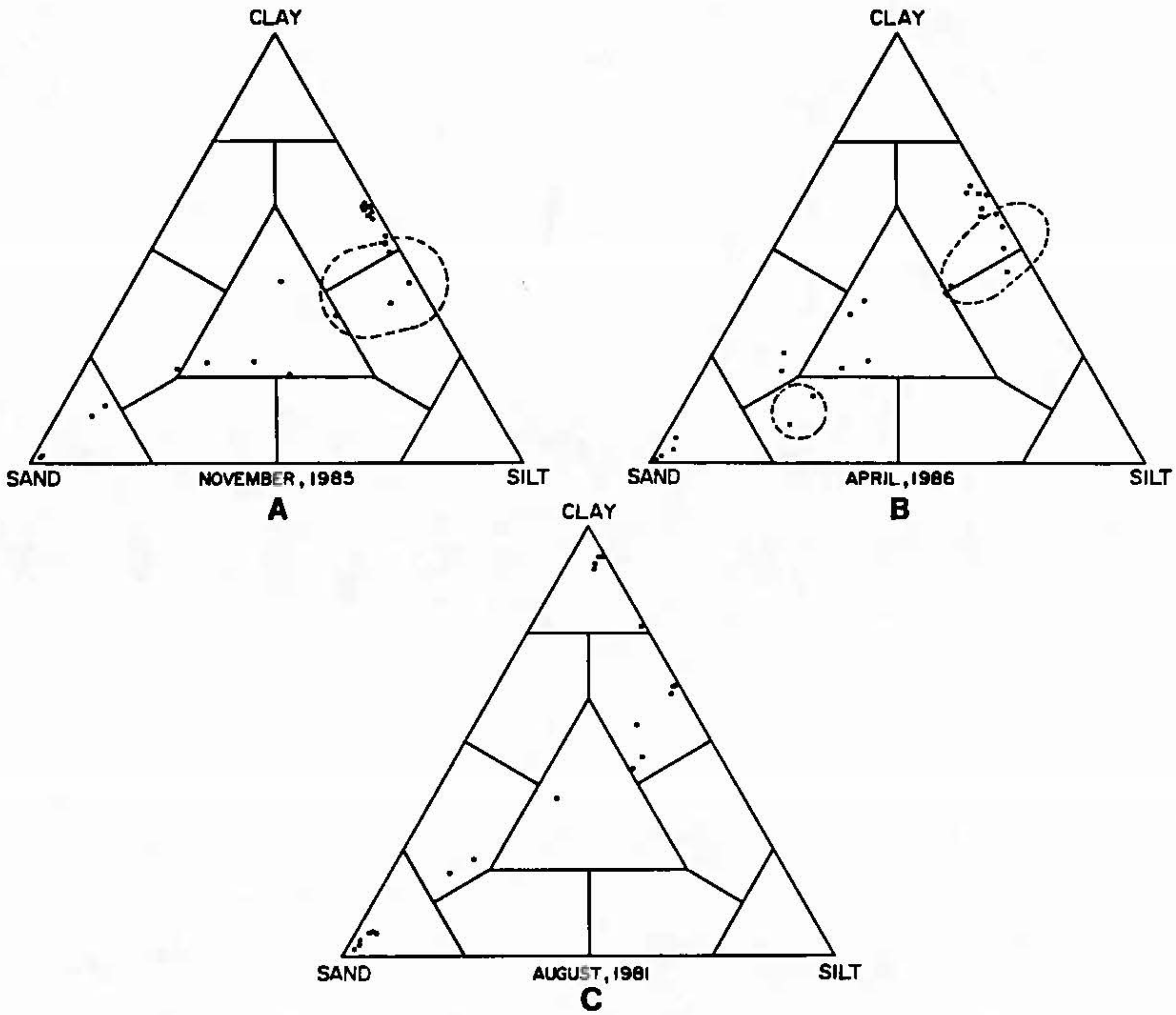

Figure 3

Ternary diagram plot of the sediment types of samples collected: a) November 1985; b) April 1986; and c) August 1981, prior to the onset of dike construction.

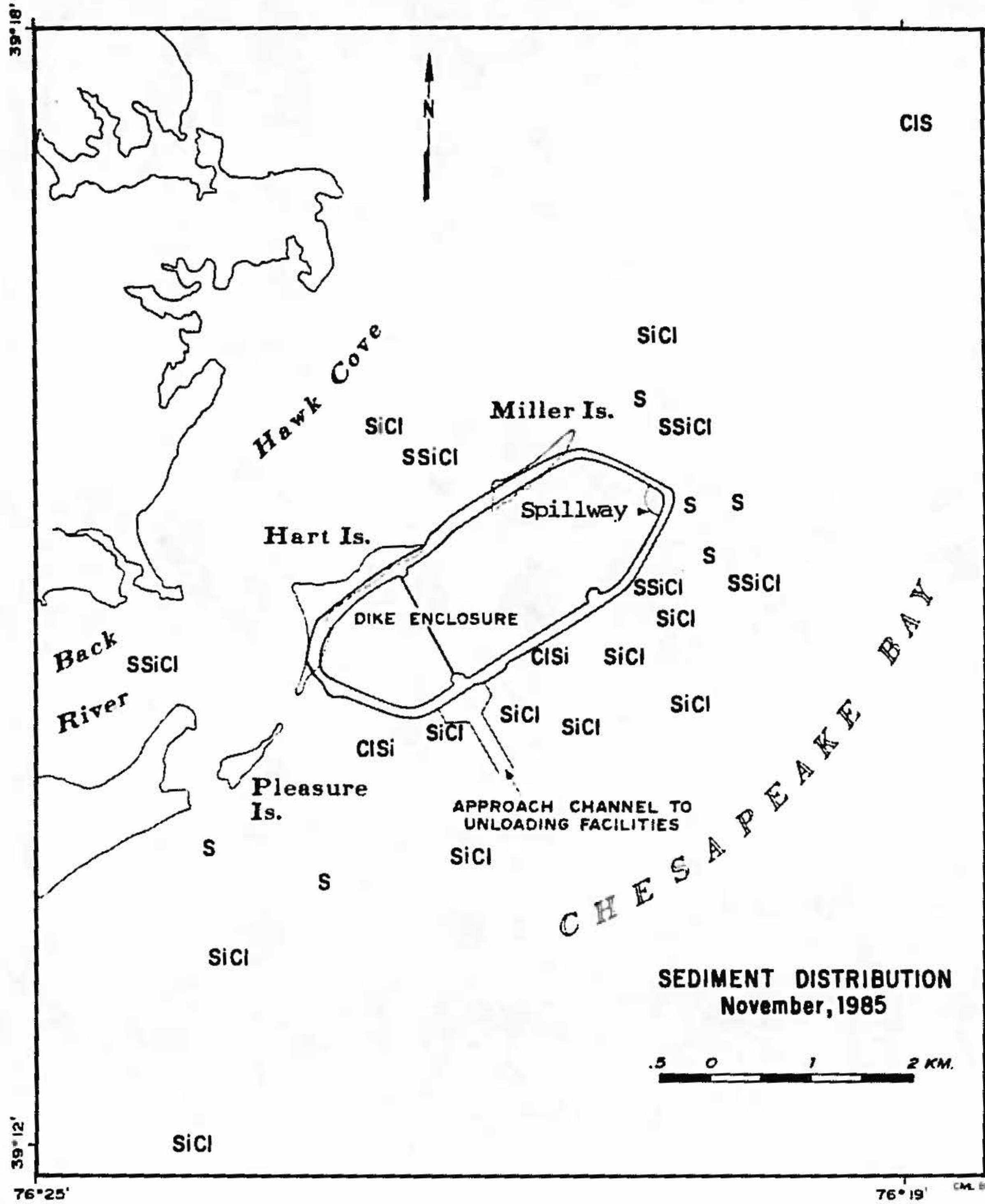

Figure 4

Maps showing the distribution of the sediment types based on surficial sediment samples collected in November 1985.

At many of the stations, surface assemblages of articulated shells were found. These sediments had a high percentage weight loss upon digestion (cleaning), indicating high organic and carbon content.

April 1986

Surficial sediment samples were collected at 25 stations in April 1985. Triplicate samples were collected at three stations located near the northeast sluice gate and also at stations BC-3 and BC-6. Generally the sediment classifications remained unchanged except at Stations 3, 4, 8A, 16, 20 and 21B. The changes at these stations appeared to be somewhat random and were attributed to the stations being close to the dike perimeter or in transitional sediment zones. However, at Station 20, the sediment changed from silty clay to sand-silt-clay. There is no obvious explanation for this change.

The spring samples revealed a pattern similar to that observed in November (Figure 3b). As before, the fluid mud sediments are indicated on the diagram. Generally, the sediments around the diked facility were siltier than those collected in the area just before the dike was constructed (Figure 3c). Sediments near the northeastern perimeter of the dike were coarser than those collected elsewhere in spring 1986 (Figure 5).

Based on visual appearances of the sediments, the light colored fluid muds introduced during dike construction were found at the same stations in this survey as in November 1985. Moreover, at many stations, surface assemblages of shells were encountered. Both *R. cuneata* and *M. balthica* were represented. The sediments at those stations also yielded a high percentage weight loss (>20%) upon digestion (cleaning), indicating high organic and carbon content.

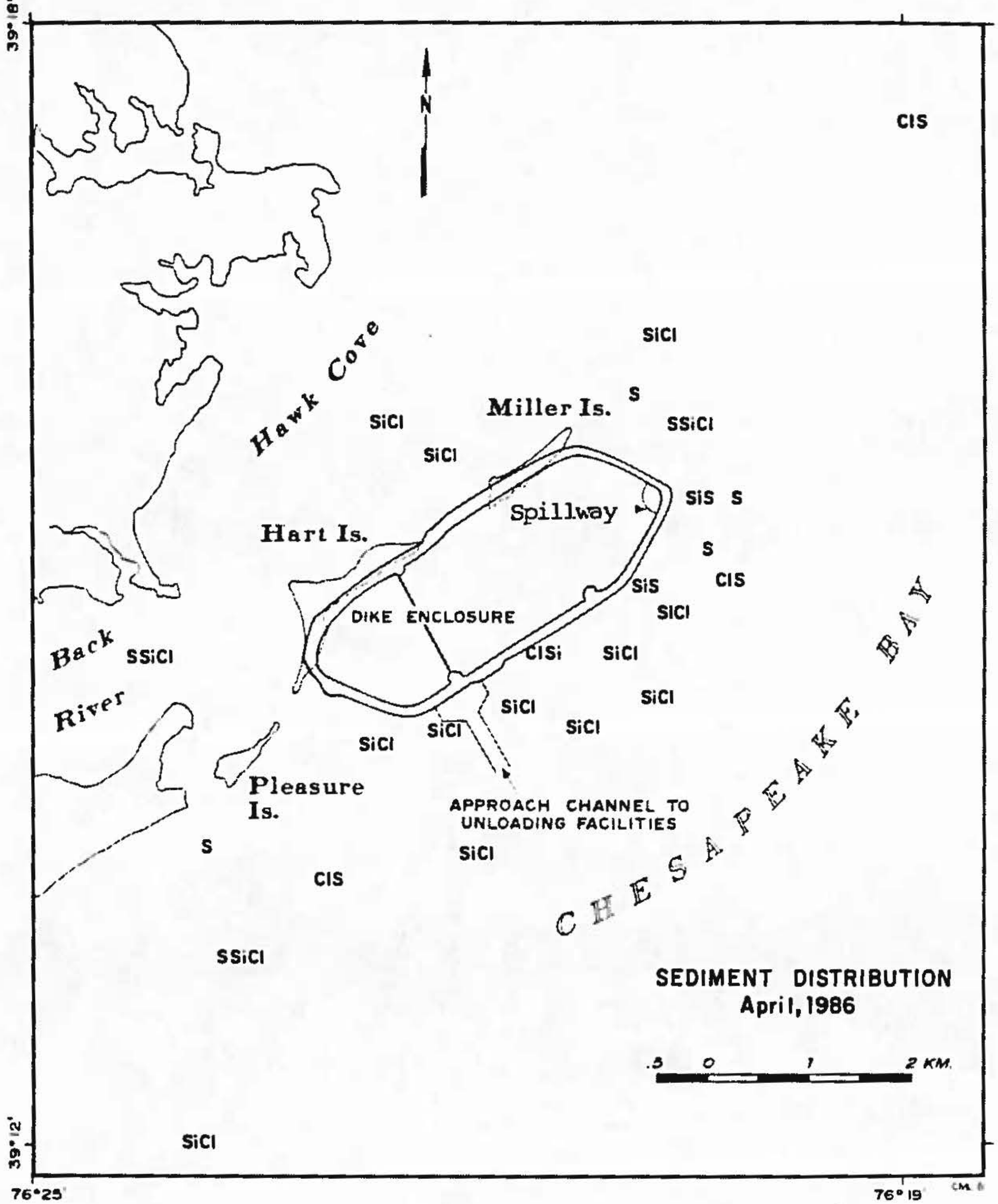

Figure 5

Map showning the distribution of sediment types based on surficial samples collected in April 1986.

RADIOGRAPHIC STUDIES

In the spring of 1986, cores were collected at the seven "BC" stations and at Station 21B. Based on radiographic analysis, the cores were very similar to those collected during spring 1985, indicating that no major changes occurred in the sedimentary column during the past year. Cores collected at Stations BC-2, BC-4, BC-5 and BC-6 consisted of dark grey silty clays and contained surface layers of shells (Figures A2, A4, A5, and A6). The core collected at BC-7 also yielded dark grey, silty clays and clayey silts but did not contain any shell layers (Figure A7). Highly reticulated networks of burrows and tubes were present in all of these cores throughout the sediments, indicating high bioturbation levels.

At two stations, BC-1 and BC-3, the respective cores penetrated the fluid mud layer. Both cores consisted of a top layer (23 to 27 cm thick), of finely laminated light brown, tan and grey, very smooth mud overlying dark grey, very cohesive mud (Figures A1 and A3). In both cases, the top 10 cm of the lighter muds were disrupted or mixed by biogenic activity (bioturbated), obscuring the laminae. The core collected at Station BC-3 contained a surface layer of shells. Textural analyses of sediments taken at selected intervals from these two cores revealed that the overlying lighter mud was siltier than the underlying darker colored sediments.

An eighth core was collected at Station 21B adjacent to the northeast spillway. This core was used to identify the sedimentological and geochemical conditions of the near-surface sedimentary column in that area before effluent began to be discharged from the spillway. Unfortunately, the hard substrate precluded deep penetration: only 11 cm of core were collected, consisting of sediment that was greater than 90% sand and contained many *R. cuneata* and *Crassostrea virginica* (oyster) shells (Figure A8).

NEAR SURFACE STRATIGRAPHY

Information from the two cores collected at locations BC-1 and BC-3 indicates that the fluid mud layer remains very distinct almost four years after deposition. The layer is also distinct in the subbottom stratigraphic record. In Figure 6, reduced interpretations of the subbottom record for two transects, between stations BC-1 and BC-2 and stations BC-3 and BC-4, are shown in relation to the diked structure. The fluid mud layer shows up on the record as a very thin light grey surface layer, 30 to 50 cm thick, along the western end of each transect before it pinches out south of the dike perimeter. Another feature seen in Figure 6 is the approach channel to the unloading basin of the dike facility. In the stratigraphic record, the channel appears as a depression. A thin layer of material is seen within the depression and may represent sediment deposited in the channel since it was dredged in 1983. A core taken within this channel consisted of a layer, 37 cm thick, of grey-green to very dark grey, almost black watery mud overlying very stiff, smooth, steel-blue mud (Table 10, see data report). The latter was similar to the "heavy clay substrate" that Pfitzenmeyer (1986) encountered during benthic sampling in previous years.

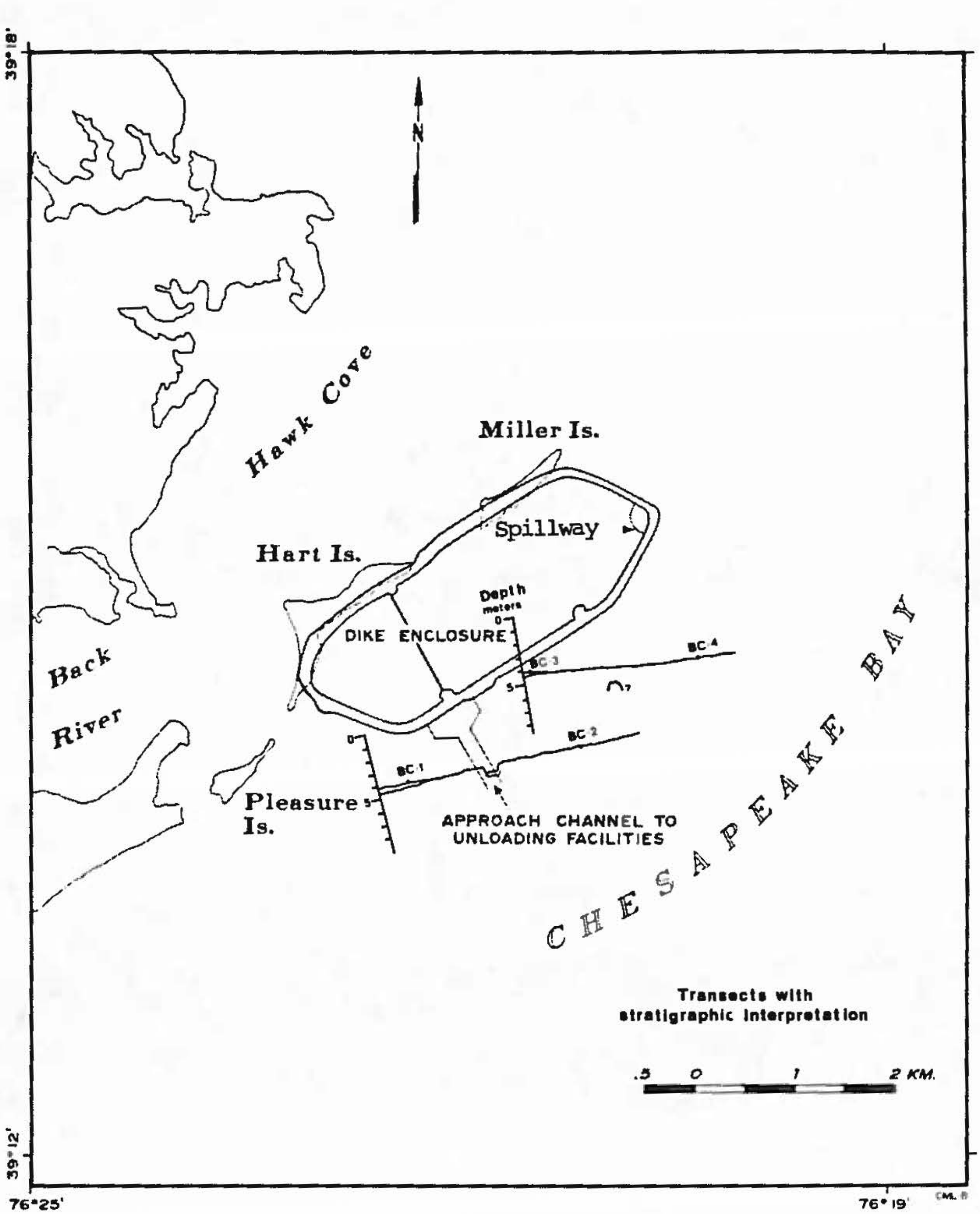

Figure 6

Maps showing the location of transects with overlay interpretations of the stratigraphic record, surveyed April 1986.

TRACE METALS

Samples for trace metal analyses were collected as part of the continuing monitoring effort around Hart and Miller Island. Enrichment factors were used to interpret changes from one sampling period to the next.

Enrichment factors are defined as:

$$EF(x)_{Ref} = (X/Y)_{sample} / (X/Y)_{ref}$$

$(X/Y)_{sample}$ is the ratio concentration of an element of interest (X) in the sample divided by the concentration of an element (Y) which is immobile and is not influenced by anthropogenic inputs (such as Al or Fe).

$(X/Y)_{ref}$ is the ratio of the concentration of the elements X and Y in a reference material, such as an average crustal rock type (Turekian and Wedepohl, 1961).

Enrichment factors used to interpret trace metal concentrations around the Hart and Miller Islands Facility during the monitoring effort were based on Fe and referenced to an average shale composition. These were chosen because the sediments of the Bay closely resemble shale, and Fe had been analyzed in previous monitoring studies of surficial sediments around Hart and Miller Islands dating back to 1976. There are several advantages to using enrichment factors in lieu of actual elemental concentrations:

1. The sample levels are normalized to a reference material, therefore, enrichment factors are direct comparisons to a known material; in our case, to what might be expected of "pristine" levels in average shale;
2. The ratio of elemental concentrations provides a check on the reliability of a set of analytical results and allows comparison of data sets obtained by different analytical techniques (Wells, et al. 1986);
3. Differences in elemental concentrations due to grain size variations are minimized (see below);
4. Variations in enrichment factors from the reference material indicate the presence of natural processes or anthropogenic activity. In smaller study areas, such as the Hart and Miller Islands vicinity, local average enrichment factors are used instead of the reference level (i.e. the standard shale).

These characteristics make enrichment factors useful for examining spatial and temporal trends in trace element contents in sediments. The enrichment factor for Zn is used in the following discussion as an indicator for variations in the sedimentary environment. This is because:

1. Zn has been the least influenced by variations in analytical techniques;
2. Variation in enrichment factors due to changes in reference material (i.e. from sandstone to shale) is small, less than 20%;
3. It is one of the few metals in the Bay which has been shown to be influenced by anthropogenic inputs;
4. There is a significant down-Bay gradient in Zn enrichment factors which can be used to detect imported material;
5. Zn is strongly correlated with most of the trace metals of interest.

Figure 7 shows the variation in the enrichment factors for Zn at those stations immediately surrounding the containment facility from the start of the current monitoring effort to the present. The dashed line in each graph, at an enrichment factor of 3.0, indicates the approximate average enrichment factor for the Hart and Miller Island area, and the shaded area indicates the deviation from the average.

The data presented in Figure 7 show three prominent features. The first feature is seen in the pre-construction samples, taken in April 1981. All but one of the stations had enrichment factors close to the long-term average of the area; Station 8 was the site of an over-board disposal (Kerhin, 1982a). This indicates that no major changes have occurred in this area. The next feature can be seen in the stations from the area of fluid mud (marked by the asterisks next to the station numbers). These stations had enrichment factors below or near the average. The fluid mud, as older or pristine material, would be expected to have an enrichment factor of one. Consequently, as this material was mixed with recent sediments, it would lower the enrichment factor of the mixed sediments. The non-fluid mud stations generally had enrichment factors greater than or quite close to the average.

The final major feature seen in Figure 7 is that the behavior of the enrichment factors generally has been uniform through time. In all but three of the stations, horizontal lines, representing an average with time, can be drawn within the error bars of the data (± 20%; not shown in the Figure). Station 8 showed increasing enrichment factors approaching 3.0, and Station BC-6 showed enrichment factors decreasing to 3.0. Station 2 did not show a uniform trend; enrichment factors were stable between 1981-1983 and 1983-1985. This may have been due to dredging operations in the area or to differences in analytical methodology (which would have been greater in sandy sediments).

The enrichment factors can be contrasted to the trace metal concentrations, Figure 8. The format of Figure 8 is the same as Figure 7; the average value used is the approximate average concentration of Zn around the dike structure (200 $\mu g/g$). Only two of the stations were close to the average concentration of Zn in the area. Samples from the zone of fluid mud had Zn levels below the average, similar to the enrichment factor in the fluid mud. However, contrary to the pattern of Zn enrichment factors, Zn concentrations at most of the stations outside this zone, were also below average. The value of normalizing to an average shale composition can be seen by directly comparing the Zn concentrations of Station BC-6 with Stations 10, 12, and 13. Station BC-6 had Zn levels greater than 2-10 times higher than Stations 10, 12, and 13. However, the enrichment factors for these stations were within ~30% of one another.

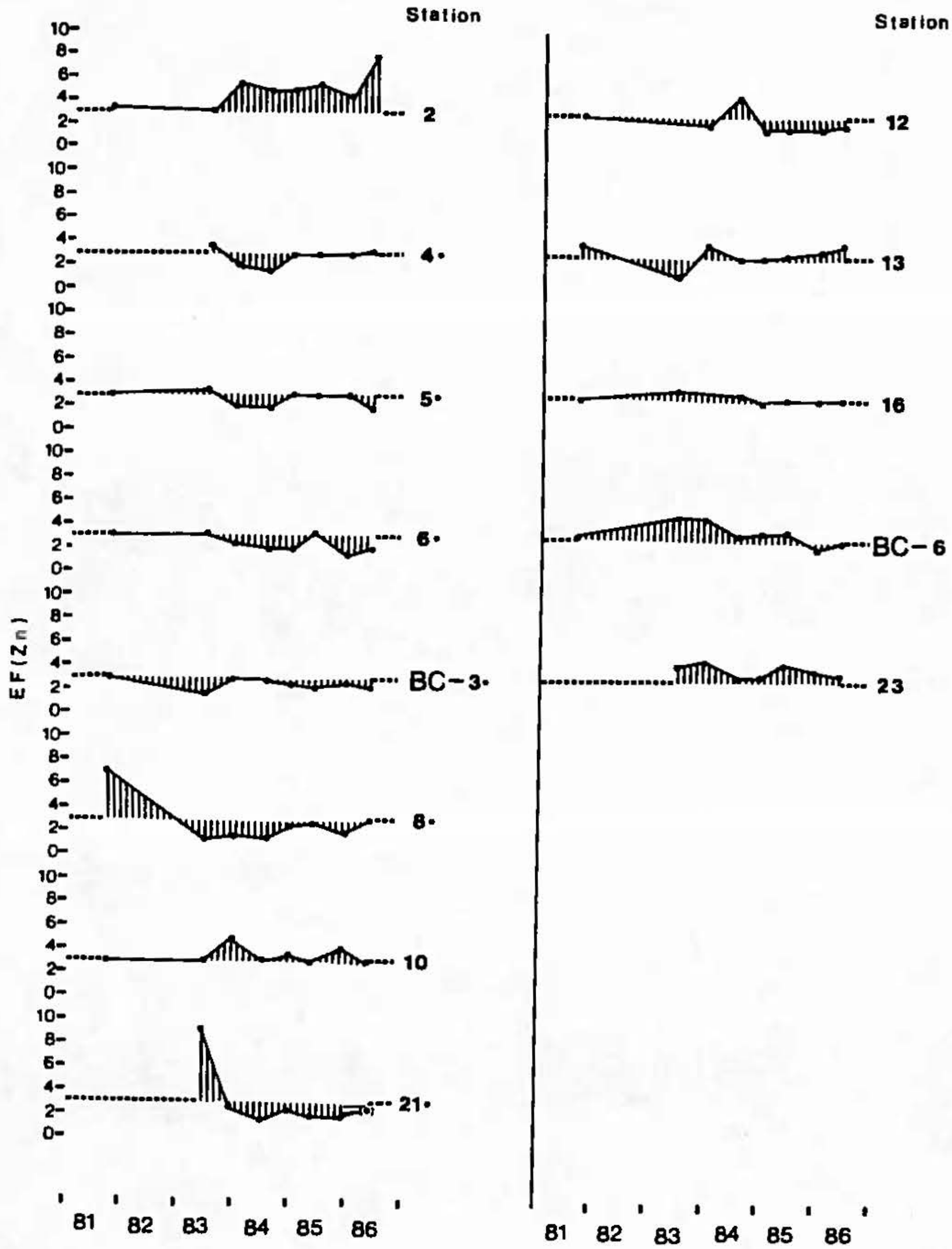

Figure 7

Graphs showing variations in the average enrichment factors of Zn since 1981 at stations nearest the perimenter of the Hart and Miller Island Containment Facility.

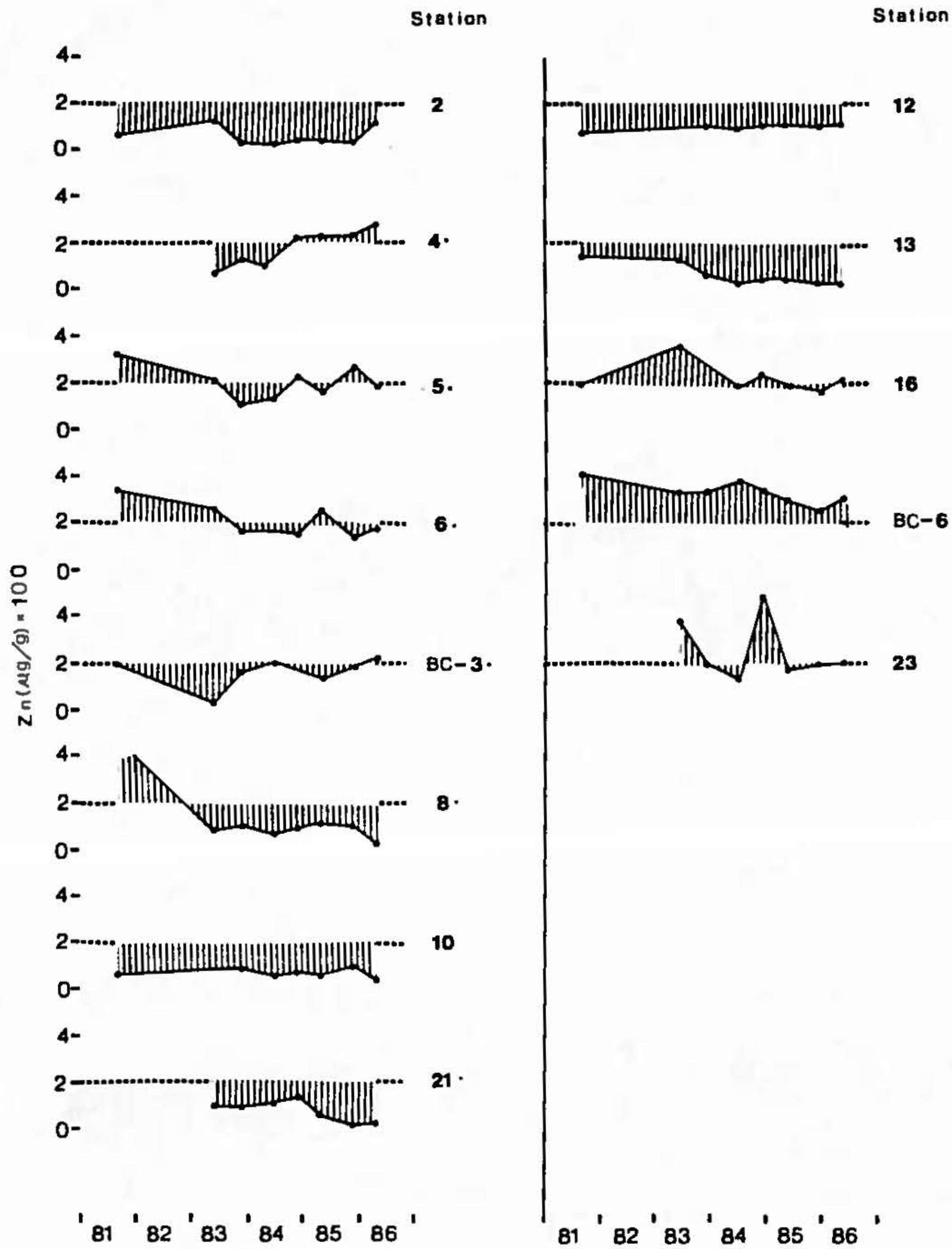

Figure 8

Graphs showing variations at the concentrations of Zn (ug/g dry weight) since 1981 at stations nearest the perimeter of the Hart and Miller Island Containment Facility.

The major source of variation in trace metal concentrations was due to differences in grain size. This can be seen in the correlation matrix of elemental concentrations with corresponding grain sizes (Table 2). All of the elements were strongly related to one another. They were directly related to percent clay, and inversely related to percent sand (sand is virtually pure SiO_2 and dilutes the trace metal content of the sediment).

Table 2. Correlation Matrix for HMI Trace Metal and Sediment Textural Data based on surficial sediments collected April 1986. Values are Pearson correlation coefficients (r). Critical Values of r : 99% = 0.479, 95% = 0.347.

	Cr	Mn	Fe	Ni	Zn	Cu
Cr	1.000	-	-	-	-	-
Mn	0.418	1.000	-	-	-	-
Fe	0.754	0.619	1.000	-	-	-
Ni	0.666	0.506	0.8033	1.000	-	-
Zn	0.593	0.537	0.867	0.774	1.000	-
Cu	0.620	0.471	0.809	0.743	0.786	1.000
% Sand	0.593	-0.412	0.884	-0.619	-0.712	-0.636
% Silt	0.407	0.267	0.622	0.306	0.454	0.425
% Clay	0.623	0.440	0.919	0.725	0.768	0.676

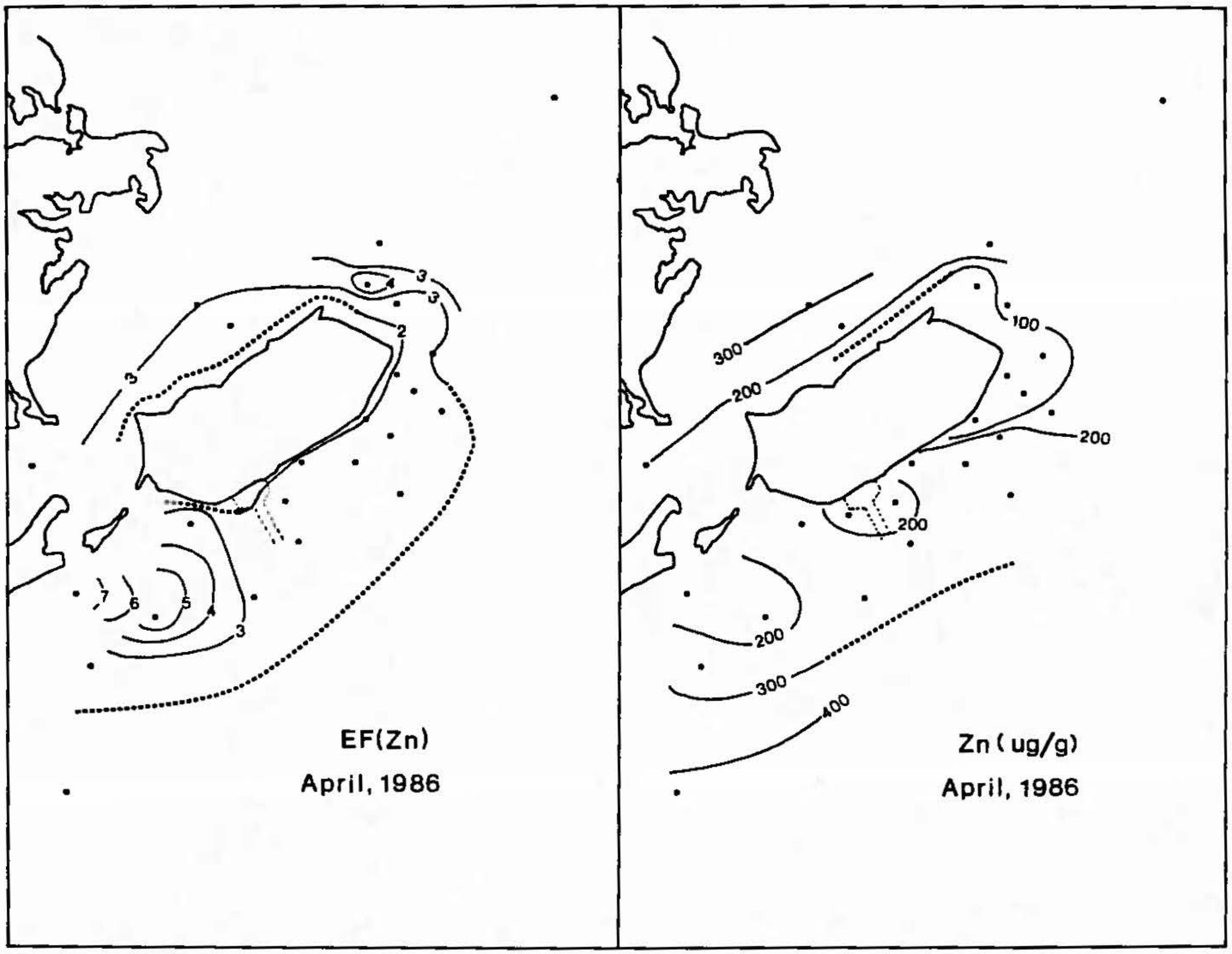

Figure 9

Contour maps, based on surficial sediments collected April 1986, depicting the spatial distribution of a) enrichment factor values for Zn and b) concentrations (ug/g dry weight) of Zn.

This relationship of trace metal content to grain size could lead to an erroneous interpretation of the trace metal data. Zinc concentration contours show areas of low Zn levels near the access channel, the spillway and in the sandy area around Station 2 (Figure 9). This could be interpreted to mean that the operation of the dike and the dredging activities in the area have lowered trace metal levels. In contrast, the contour map of enrichment factors (Figure 9) shows that the whole area is uniform, except for the area around Station 2. Those high enrichment factors are probably due to highly absorbent iron and manganese oxy-hydrides associated with the sands in this area.

Trace metal analyses of sediments from the cores (Figures 10-12) provide information about the behavior of trace metals in the sedimentary column through time. Lower enrichment factors were associated with the "fluid mud" layer (Figures 10 and 12). This association also was observed in the spatial distribution of enrichment factor values for Zn for surficial sediments. Below the fluid mud boundary (indicated by a horizontal line in Figures 10 and 12), enrichment factor values increased, then decreased "down core." The decrease was expected because, presumably, sediments were increasingly older with depth. Older sediments were less affected by anthropogenic influence, the probable source of enrichment for many of the trace metals. This pattern was quite apparent in cores BC-4, BC-5, and BC-6 (Figures 13, 14, and 15 respectively), which represented sedimentary environments unaffected by dike construction.

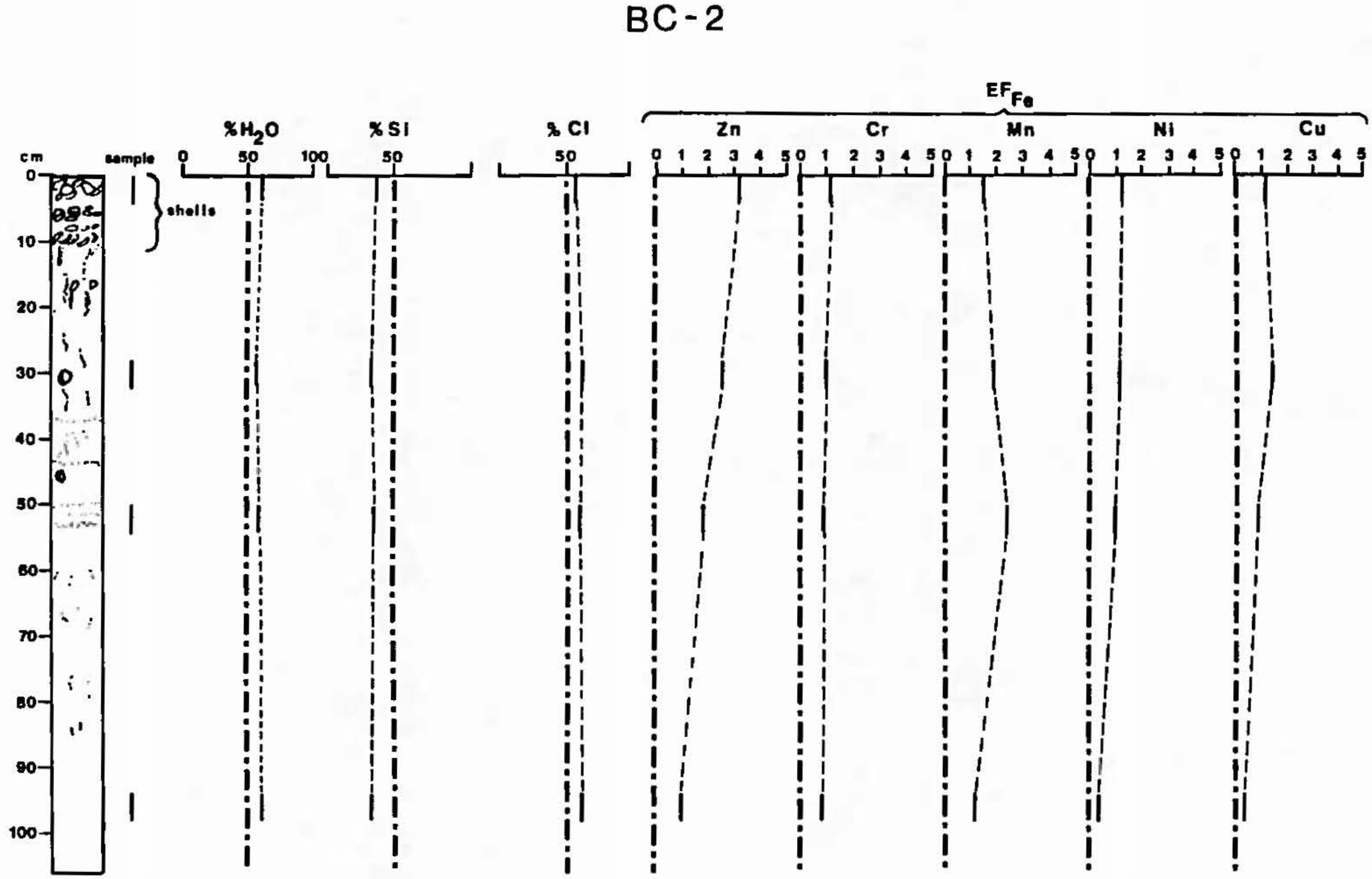

Figure 11

Graph showing "down-core" variations in enrichment factor values for five trace metals in core B-2.

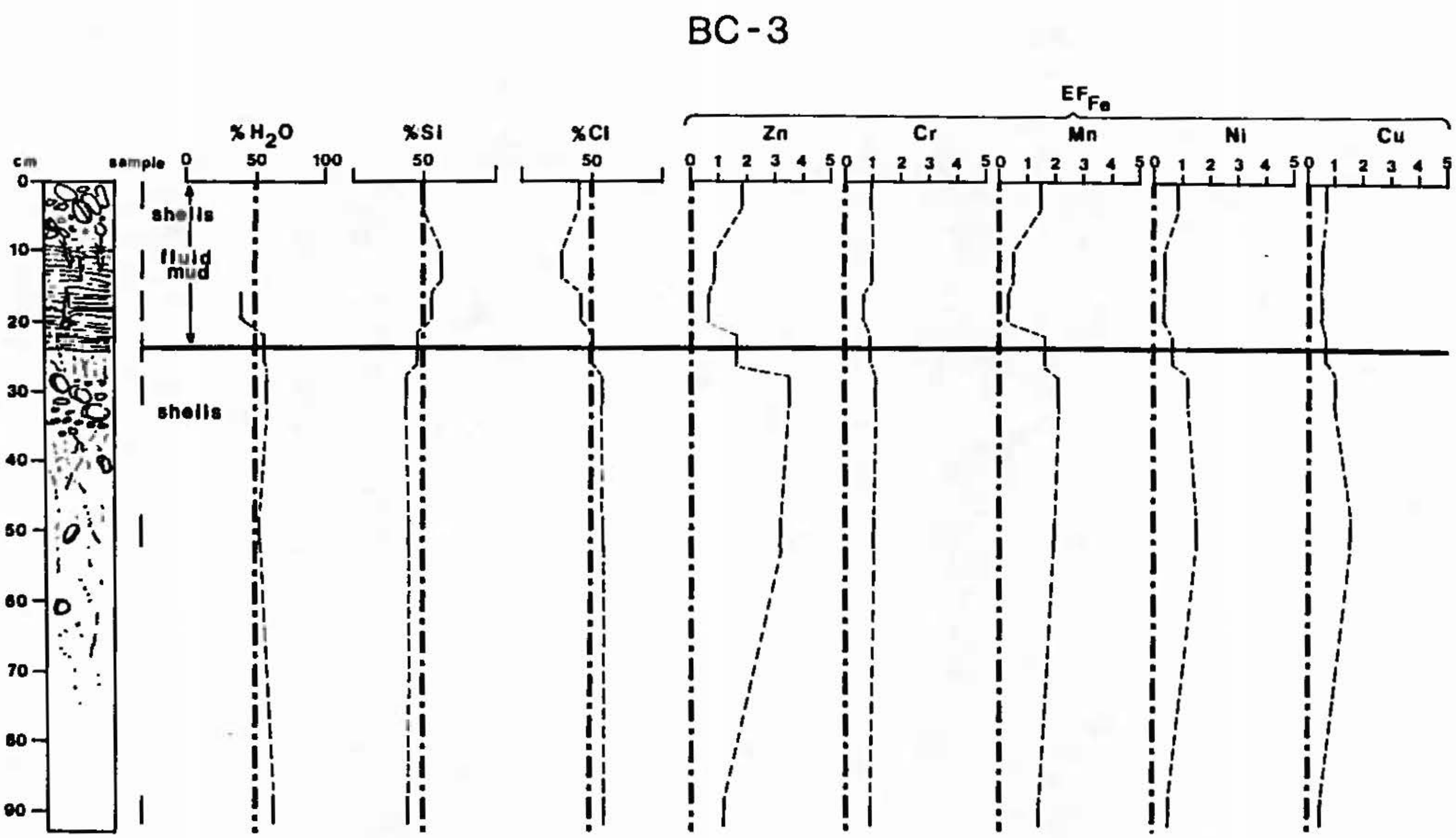

Figure 12

Graph showing "down-core" variations in enrichment factor values for five trace metals in the core BC-3.

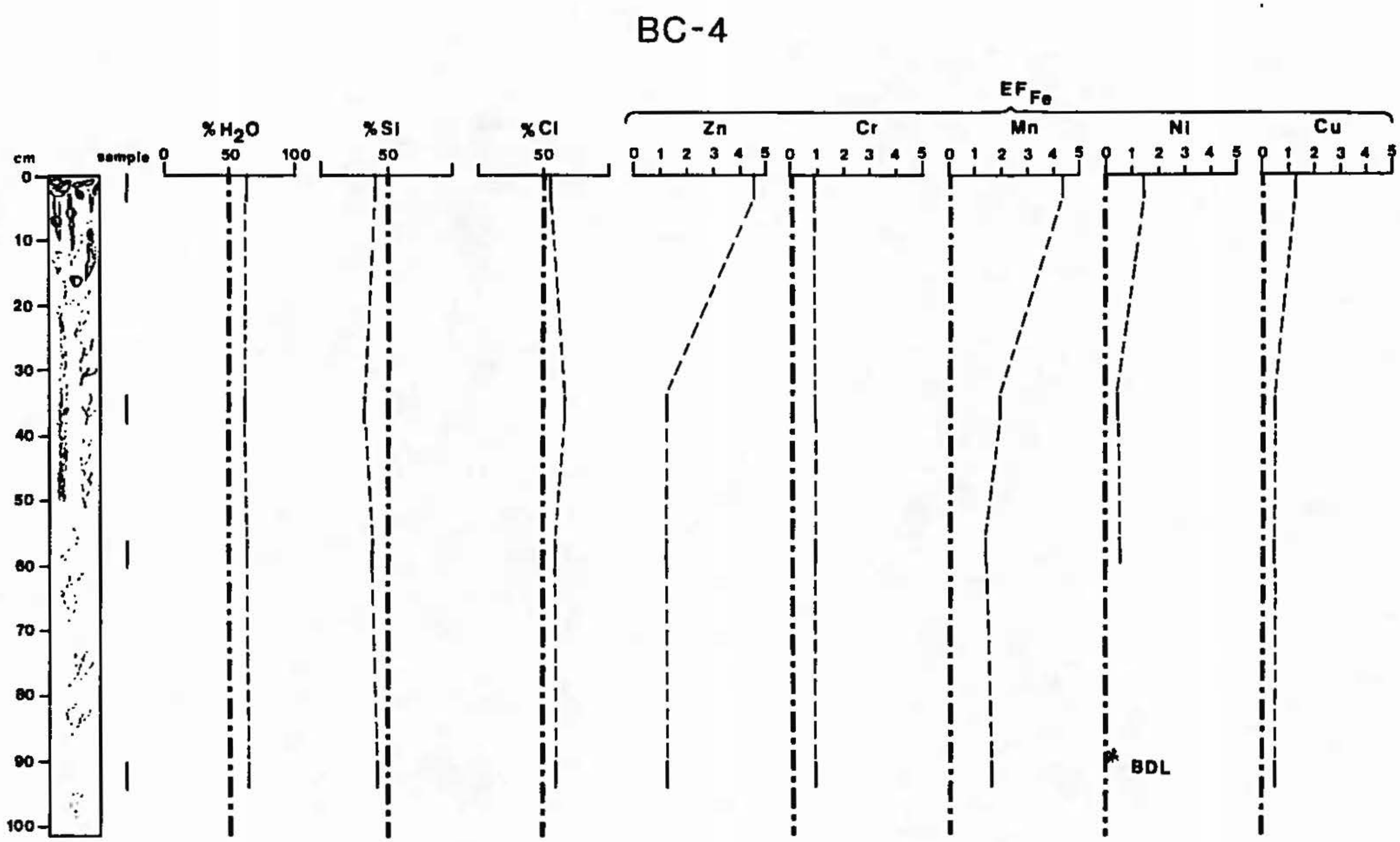

Figure 13

Graph showing "down-core" variations in enrichment factor values for five trace metals in the core BC-4.

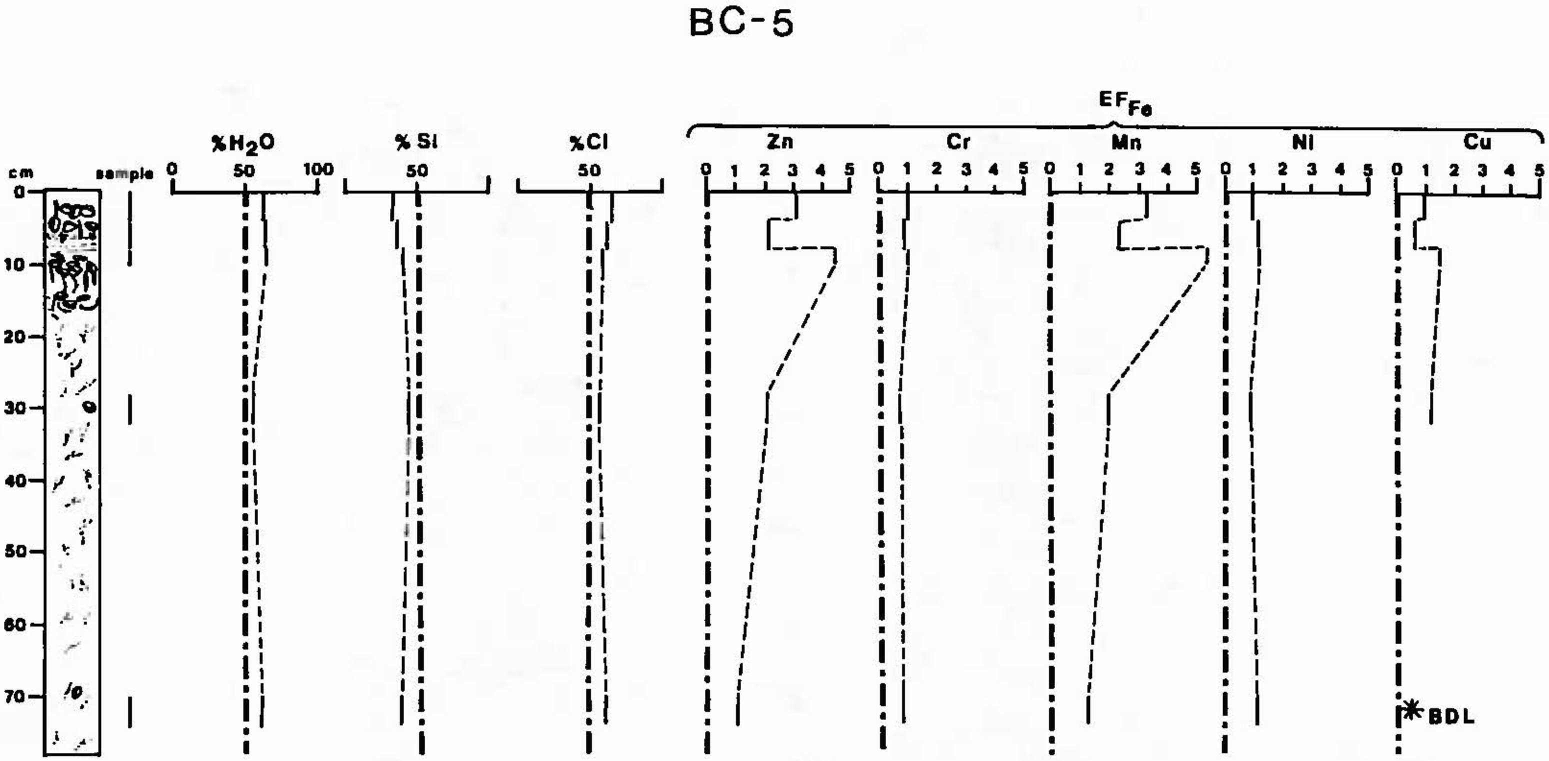

Figure 14

Graph showing "down-core" variations in enrichment factor values for five trace metals in the core BC-5.

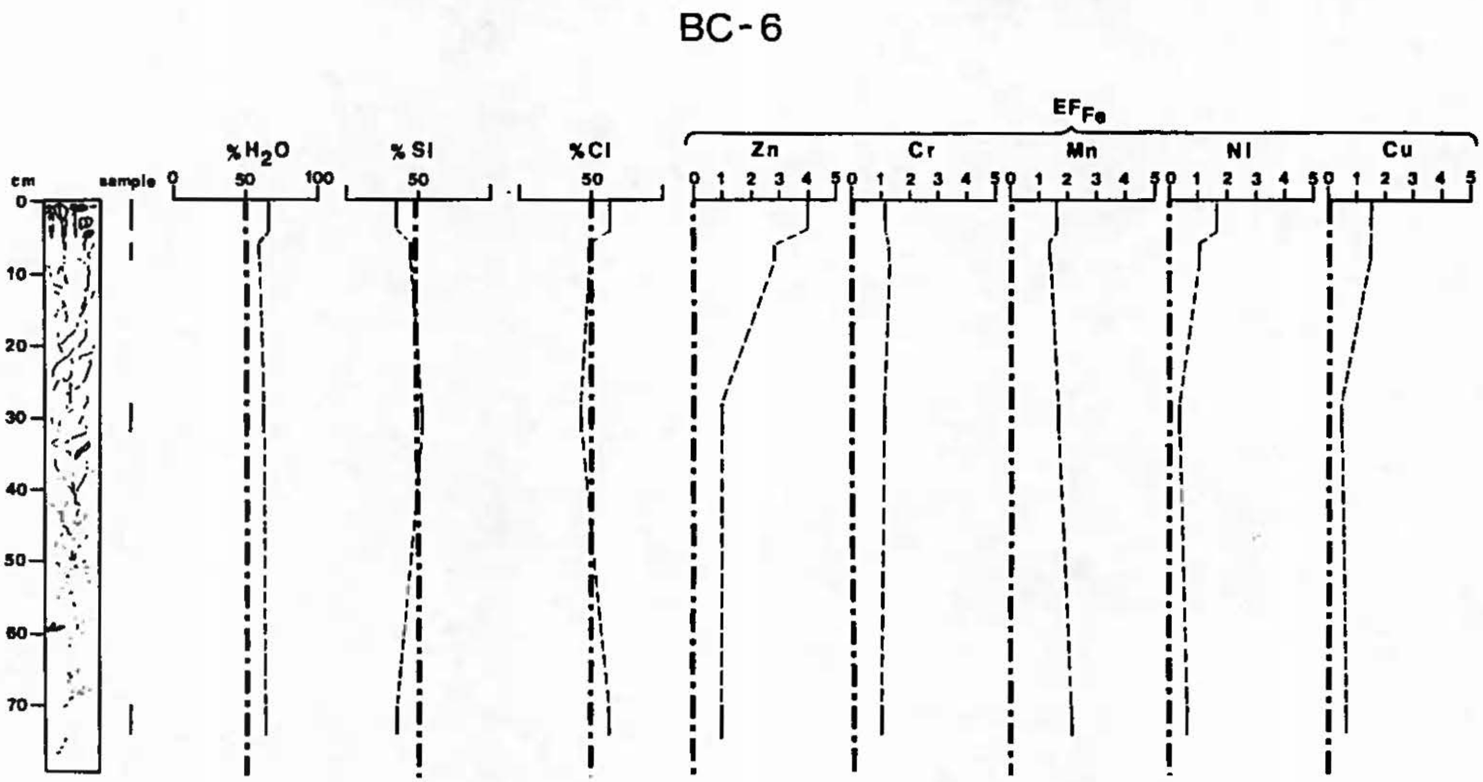

Figure 15

Graph showing "down-core" variations in enrichment factor values for five trace metals in the core BC-6.

However, a "down core" decrease in enrichment factors was not present in cores BC-7 and 21B (Figures 16 and 17). The erratic pattern in core BC-7 may have resulted from that station's proximity to Back River. Periodic flushing of Back River during storm events may cause deposition of highly enriched material in the area of BC-7. Trace metal concentrations for sandy sediments in core 21B were very low and near the detection limit. Therefore, the accuracy of the enrichment factors at 21B was suspect.

Higher enrichment factors were associated with shell layers. This was particularly the case for Zn and Mn. Because great care was taken to remove the shells from the sediment sample prior to trace metal analysis, it is not likely that the shells contributed to the high enrichment factors. It is more probable that decayed animal tissues contributed to the enrichment. Many benthic organisms, including mollusks, are efficient accumulators of trace metals, and thus quicken the process by which trace metals from the water column are transferred to the sediment. In this case, the fluid mud is "enriched" with certain trace metals by way of benthic activity.

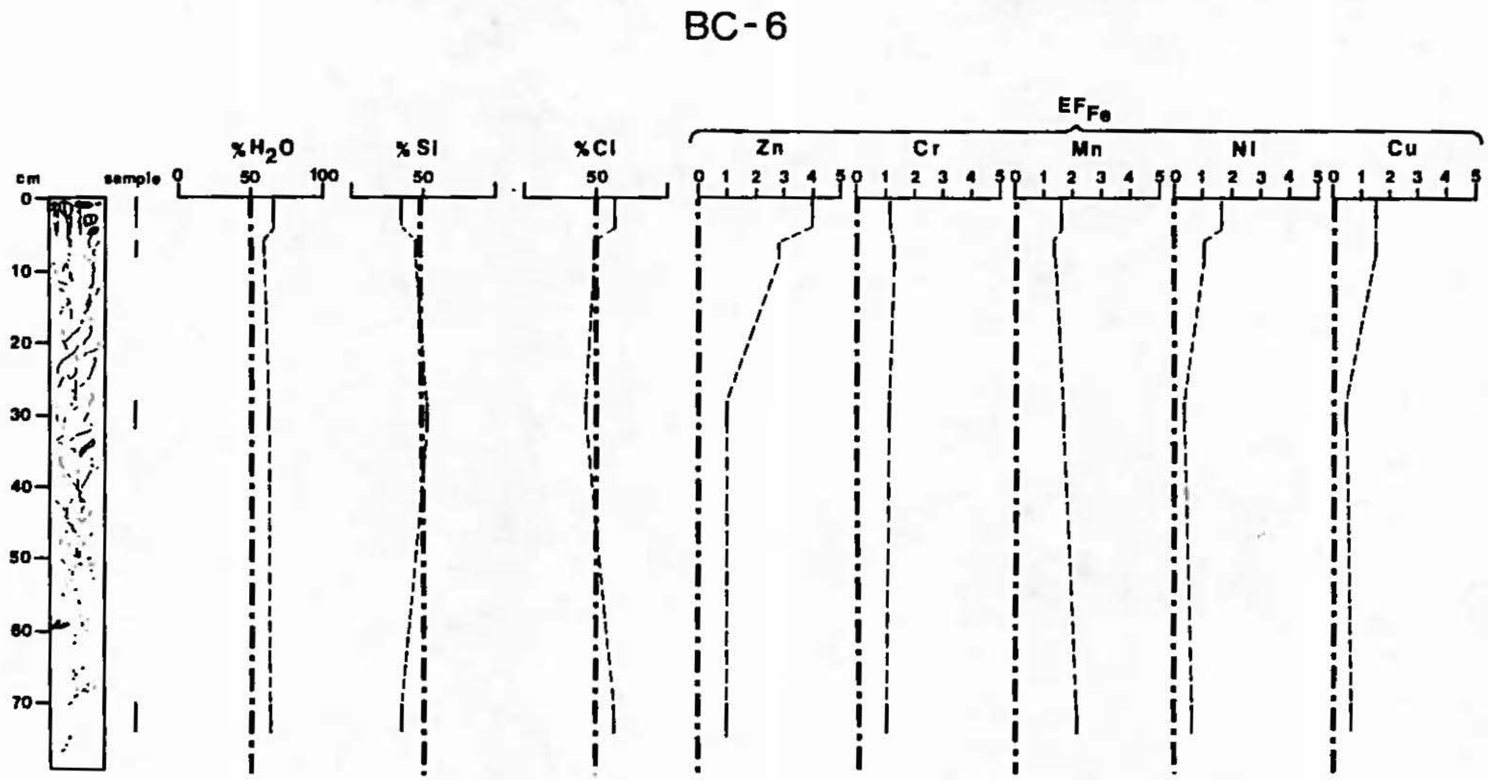

Figure 15

Graph showing "down-core" variations in enrichment factor values for five trace metals in the core BC-6.

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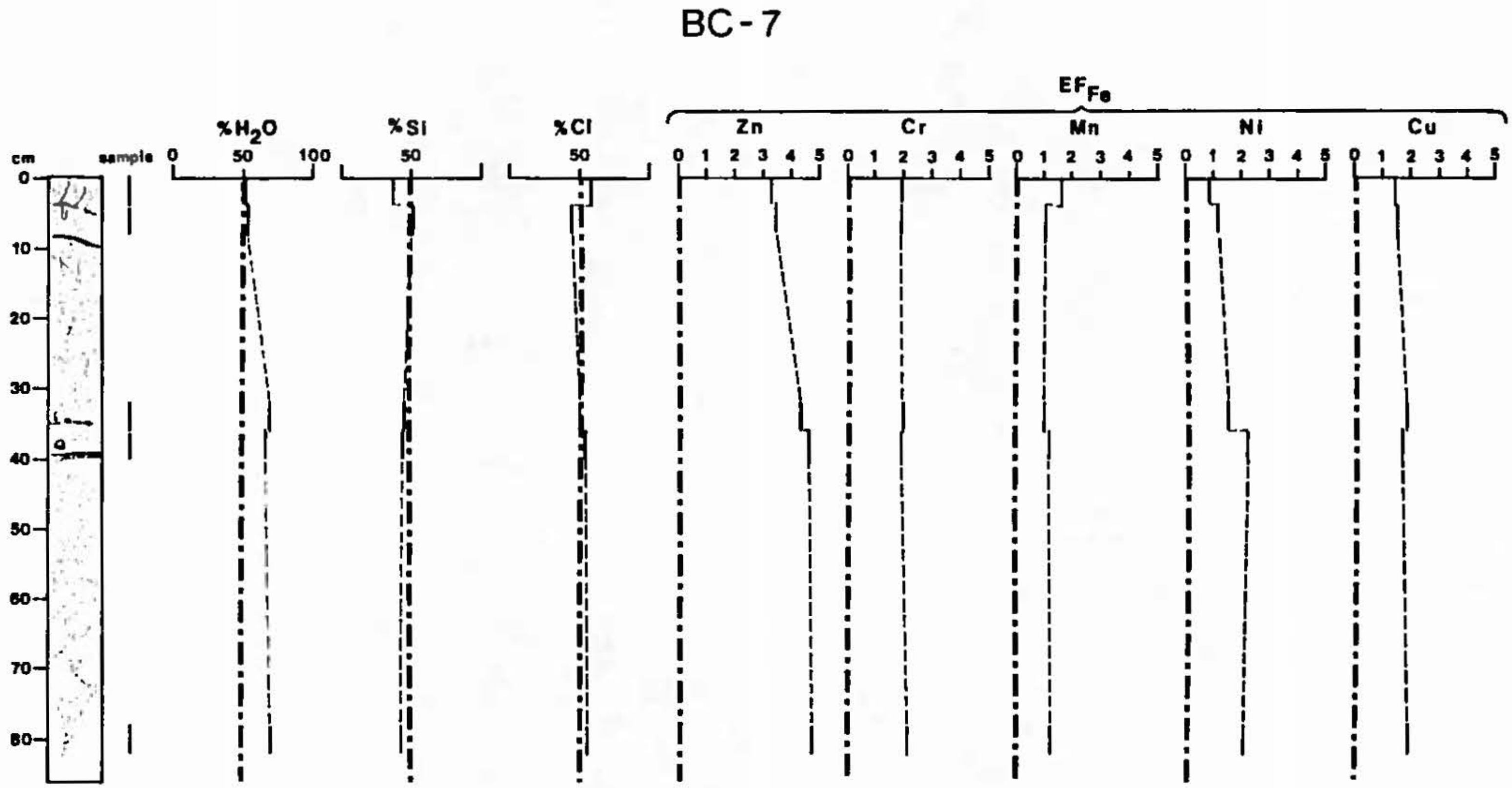


Figure 16

Graph showing "down-core" variations in enrichment factor values for five trace metals in the core BC-7.

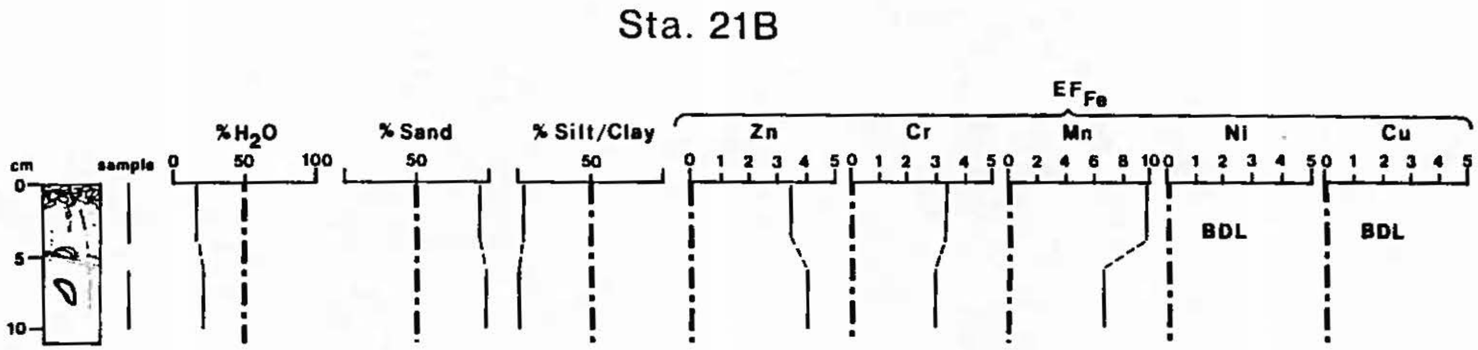


Figure 17

Graph showing "down-core" variations in enrichment factor values for five trace metals in core 21B.

CONCLUSIONS

During the fifth year study, very few changes were observed in the sedimentary environment around the Hart and Miller Island Containment Facility. Generally, the sediments around the facility remained siltier than pre-construction sediments (Figure 3). The blanket of fluid mud deposited during dike construction was still very distinct after 4.5 years. Visual and radiographic studies of the fluid mud show that there was no increase in bioturbation levels compared to the previous year. Only the top 10 cm of the fluid mud was reworked by benthic activity.

The distribution and range of enrichment factors for trace metals in the sediments around the dike facility were consistent with the findings of previous years. The average enrichment factors for the fluid muds continued to remain lower than pre-construction levels. However, slight increases in the enrichment factors were observed in the bioturbated zone of the fluid mud layer indicating that benthic activity contributed to the "enrichment" of sediments with certain metals.

RECOMMENDATIONS

It is recommended that the sedimentary environment around the Hart and Miller Islands Containment Facility continue to be monitored. Although little change in the environment has been observed since dike construction, the five years of data provide an invaluable baseline for comparisons with future observations. Moreover, the next two years of monitoring may be crucial since usage of the containment facility will increase during the ambitious Baltimore Harbor and Approach Channel dredging project. Futhermore, during this same period, the volume of effluent discharged from the dike will increase considerably.

Among critical areas that should be monitored closely in the future is the area around the northeast spillway. Additional coring station(s) northeast of the spillway would provide added information on the effects, if any, of the effluent discharge on the sediment column. The coring station(s) should coincide with benthic population sampling to allow for the comparison of trace metal data from sediments and benthic organisms.

The present sampling frequency is sufficient. However, if changes are seen in the next year, sediments should be sampled more often than twice a year.

PART II: BEACH EROSION STUDY

INTRODUCTION

An immediate benefit of the Hart and Miller Island Containment Facility was the recreational beach created during the early stages of dike construction. Because the beach afforded immediate access to the public, management and maintenance of the beach were placed under the auspices of the Department of Natural Resource's Forest, Park and Wildlife Service. As part of the management program, the Maryland Geological Survey was enlisted to monitor the beach in order to document certain changes in the beach which began shortly after its creation. These changes were erosional in nature, particularly in the form of sheet-wash from the dike face and the formation of a wave-cut escarpment along the foreshore of the beach.

The beach study was initiated in late spring 1984. The results of the first and second year studies are detailed in Wells et al. (1985, 1986). It was determined from changes in the beach profile over a two-year period, that two distinct morphological processes were acting on the beach and dike face, respectively. The beach face changes were a result of wave and storm-related processes, whereas changes in the dike face were controlled by pluvial and aeolian processes (rain and wind).

OBJECTIVES

This continuing study has focused on the erosional patterns of the recreational beach constructed between Hart and Miller Islands. The problems observed in the first two surveys (Wells et al. 1985, 1986) are reviewed and expanded upon in this report, which covers the period from September 1985 to September 1986. The study has three objectives:

1. To analyze the beach configuration;
2. To evaluate the erosional-depositional process acting on the beach,
3. To determine the time scales of erosional responses are adjustment cycles to known geomorphic and anthropogenic processes in the area.

METHODOLOGY

FIELD METHODS

Ten profile lines were surveyed along the recreational beach area between Hart and Miller Islands. The locations of these profiles were established during the first year's study (Wells et al. 1985), and are shown in Figure 18. A benchmark located 20 feet southeast from the centerline of the dike roadway at Station 30+00 was the starting point for profiling. All of the profile origins were located along the centerline of the dike roadway, with elevations transferred from the 30+00 benchmark. Each profile was measured down the dike face past the level of low tide.

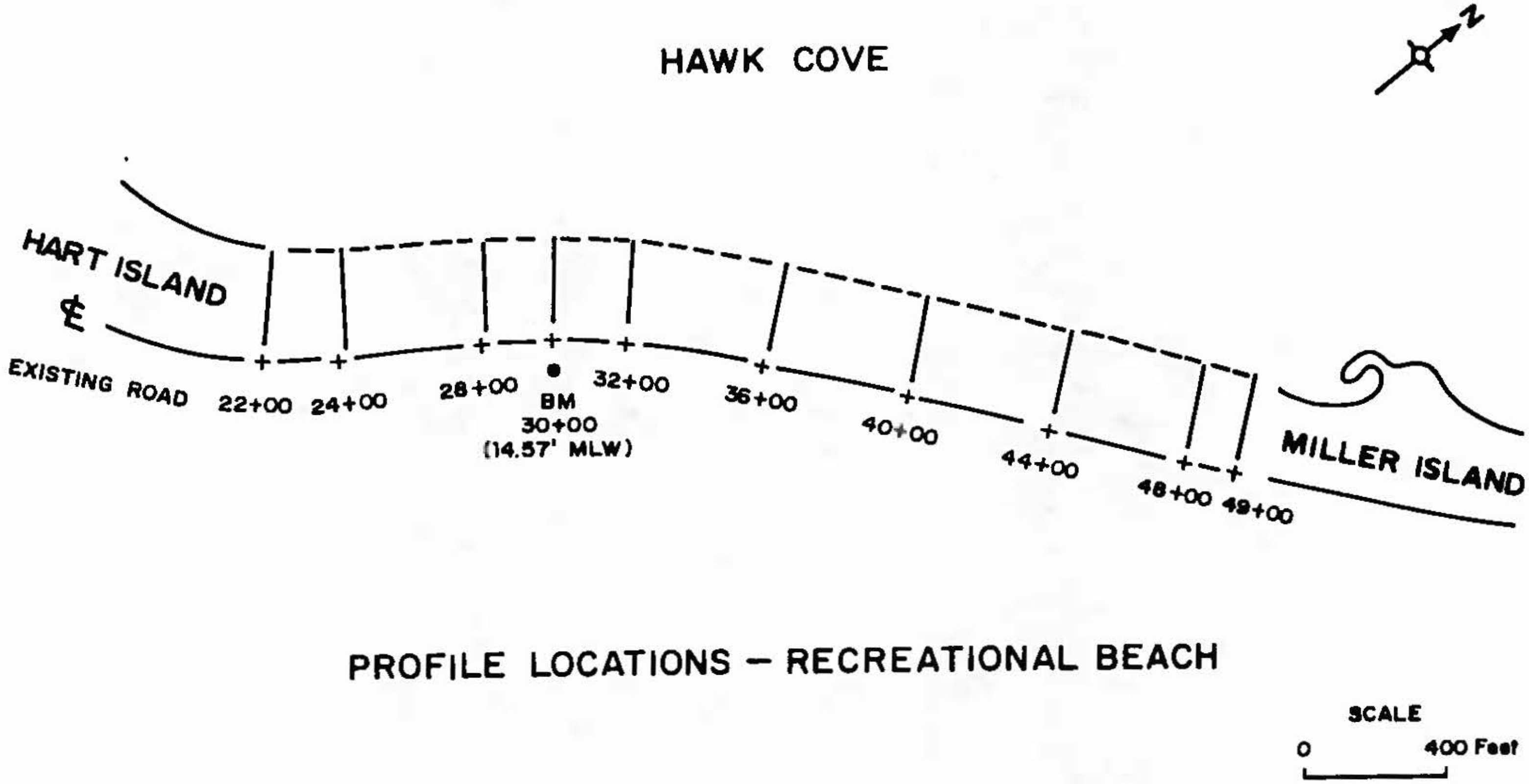


Figure 18

Recreational beach on the Hart and Miller Island Containment Facility showing the locations of the profile lines.

Profile measurements were made using standard surveying techniques. The beach profiles were surveyed four times during this third year of the beach study (Table 3). The distance and elevation data from the surveys are presented in the accompanying Fifth Year Data Report.

Table 3. Dates on which beach profiles were surveyed.

Profile Station	1st Survey	2nd Survey	3rd Survey	4th Survey
22+00	12-10-85	4-7-86	6-24-86	9-15-86
24+00	12-10-85	4-7-86	6-24-86	9-15-86
28+00	12-10-85	4-7-86	6-24-86	9-15-86
30+00	12-10-85	4-7-86	6-24-86	9-15-86
32+00	12-10-85	4-8-86	6-24-86	9-15-86
36+00	12-11-85	4-8-86	6-25-86	9-15-86
40+00	12-11-85	4-8-86	6-25-86	9-18-86
44+00	12-11-85	4-8-86	6-25-86	9-18-86
48+00	12-11-85	4-8-86	6-25-86	9-18-86
49+00	12-11-85	4-8-86	6-25-86	9-18-86

During the April and June 1986 surveys, sediment samples were collected at changes in slope and/or every fifty feet along each profile line. Sediment samples were collected during the two surveys in order to determine the distribution of sediment types on the recreational beach before and after regrading, which was done in late April 1986.

Aerial photographs were taken after each profiling survey to view any overall changes in the configuration of the recreational beach. Any special features or observations were also documented photographically.

LABORATORY METHODS

Beach sediment samples were processed using the same method as described earlier in this project (see SEDIMENTARY ENVIRONMENT : TEXTURAL ANALYSIS). Percent gravel, sand and silt/clay are listed in the Fifth Year Data Report. For the Beach Study, the silt and clay-sized components of the sediments were combined and reported as a single percentage. Silt/clay is sometimes referred to as "fine-grained" material in the text.

RESULTS AND DISCUSSION

The recreational beach between Hart and Miller Islands was created during the early stages of construction of the diked disposal facility. Over 500,000 cubic yards (382,000 cubic meters) of material were pumped between the islands in an overall configuration similar to the dike structure. A roadway runs along the crest of the recreational beach which is at +18.00 feet, (5.44 meters) mean low water (mlw). Originally, the recreational beach was to have sloped down to the water edge with a grade of 1:20 (gradient of 2.8°).

To facilitate the discussion of the findings in this report, the recreational beach has been divided into three zones, which are illustrated in Figure 19. The outer dike face (or "dike face") is defined as that part of the beach from the roadway to high water mark (which is usually identified as an escarpment in this study). The zone between the high water mark and mean low water (0 feet mlw) is termed the foreshore. Nearshore refers to the zone beyond mean low water.

CHANGES IN BEACH PROFILE CONFIGURATION

To document the changes that occurred along the recreational beach, contour maps and cross-sectional profiles were constructed from the survey data. Both the cross-sectional profiles and the contour maps are presented in Appendix B. Contour maps for June and September 1985 (from the previous year's study), are included for comparison with this year's contour maps. The changes indicated in both the cross-sectional profiles and contour maps showed the same trends as observed in previous years.

The contour maps revealed subtle changes on the beach. From June 1985 to April 1986, the overall beach configuration remained the same (Figures B-1 through B-4). However, an increase in slope was evident below the 6′ contour, as indicated by the increasingly tighter contour lines on each subsequent map. The increased slope was due to the erosion of sediments from the lower dike face and foreshore by wave action. The regrading of the beach in late April reestablished a smooth, attractive beach with a slightly greater slope. This is indicated by the smooth, evenly spaced contours seen on the June 1986 map (Figure B-5). By September 1986 (Figure B-6) the 0′ contour had shifted away from the beach indicating reworking, and deposition of sediments in the nearshore area.

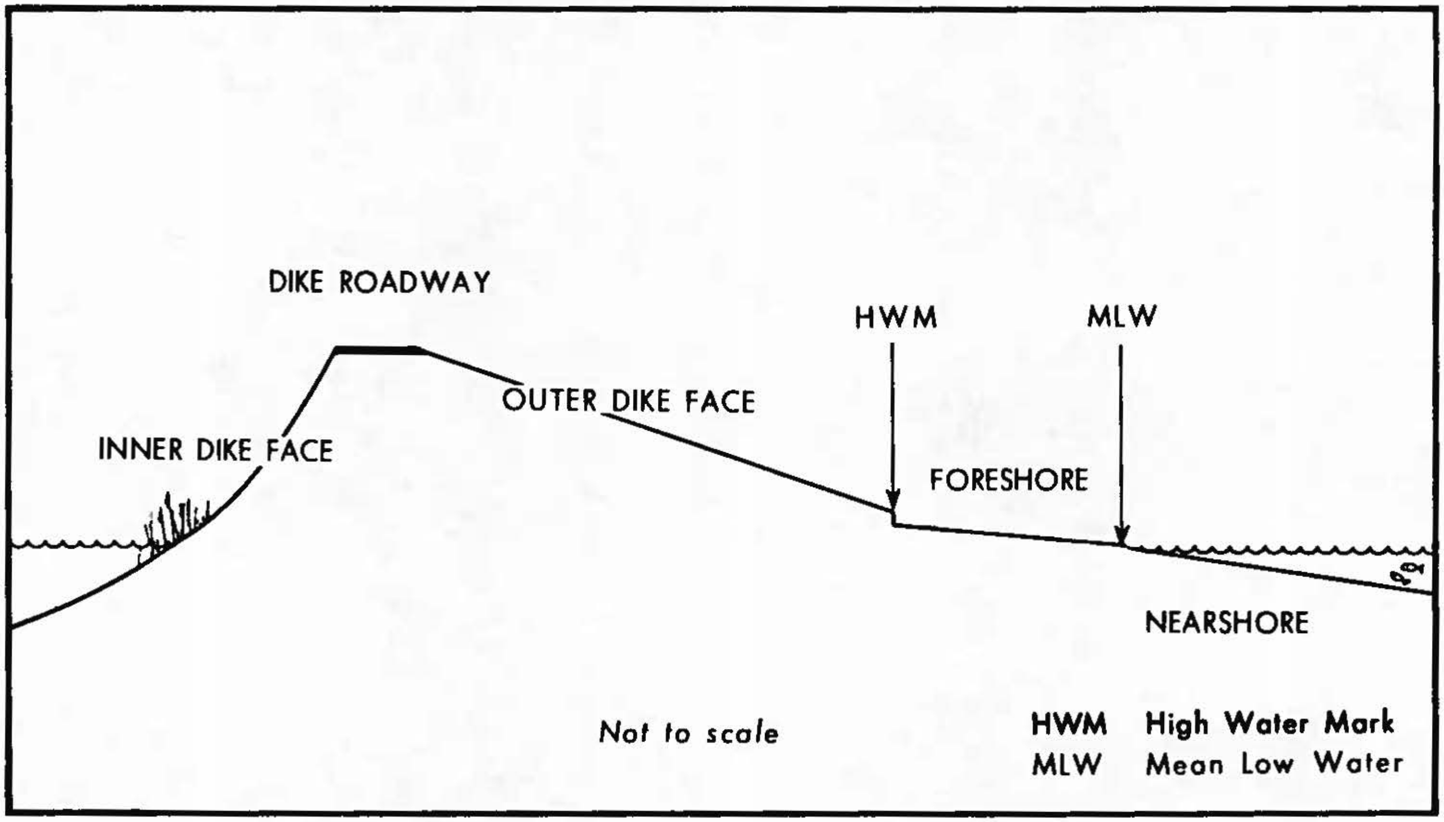


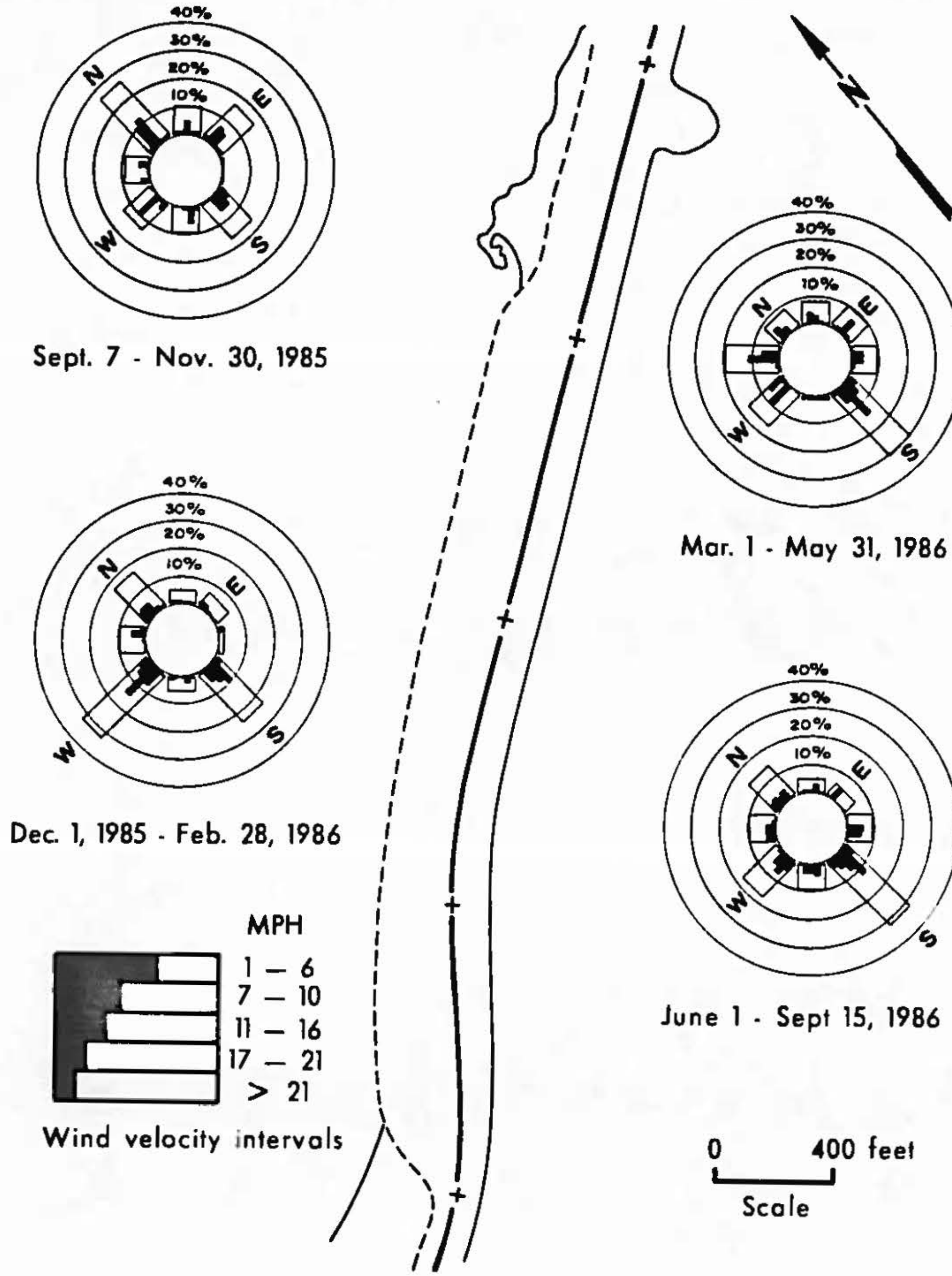
Figure 19

Schematic cross-section of the dike illustrating the terminology used in this report to describe the beach profile.

The cross-sectional profiles (Figures B-7 through B-16) show the changes in the recreational beach in greater detail than the contour maps. The profiles reveal that very little erosion took place on the upper dike face during the study period. Erosion, however, had taken place on the lower dike face and in the foreshore areas. Wave-cut escarpments continue to be noticeable features on many of the cross-sectional profiles. Although the escarpments are not as severe as they were the previous study year, they continue to be most pronounced at the northern end of the beach (profile locations 44+00, 48+00, and 49+00). Escarpment formation is also evident at profile location 22+00, the most southern profile line (Figure B-7). Escarpments were not observed at this location in previous years.

The escarpments were formed as a result of wind-generated waves assaulting the beach. More severe wave conditions occur when winds blow from the north or northeastern direction, the direction with the greatest generating area or fetch. The wind roses in Figure 20 summarize seasonal wind patterns for the time between September 1985 and September 1986. More severe wave conditions occurred in the fall and spring, with winds from the north and northeast. However, the frequency of northerly winds was lower than usual for this time of year. This may have accounted for the less pronounced escarpment formation this year compared to the previous year.

Another erosional feature observed on the beach this year was the formation of gullies. The gullies are not readily evident on the cross-sectional profiles or contour maps. However, gullies were observed on the lower dike face during each survey. During the December 1985 survey, shallow gullies were present at locations 28+00, 30+00, 32+00, and 44+00; sharp, deeply incised gullies were observed at locations 48+00 and 49+00. Much of this gully erosion probably took



WIND CLIMATE: HART-MILLER ISLAND VICINITY

Figure 20

Wind rose diagrams for the Hart and Miller Island vicinity based on wind data collected by MES for the period between September 1985 and September 1986.

place during two large pluvial events: Hurricane "Gloria" (September 26 to 27, 1985) and Hurricane "Juan" (November 3, 1985). In early April 1986, gullies were observed at the same locations but were partially filled in with fine-grained material which was deposited by aeolian processes (wind-blown). The beach was regraded at the end of April, at which time all erosional features were erased. By June 1986, small gullies had started to form at the north end of the beach (location 49+00). By September 1986, second order gullies were observed on the beach, similar to those found the year before.

Gully formation is indicative of pluvial (rainfall related) processes. Three variables are fundamental to the formation and location of gully erosion: gradient or slope, amount of rainfall and sediment composition. Average slope measurements were calculated (Table 4) and compared to the cross-sectional profiles. The profiles with average gradient of 4.2 degrees or less were relatively free of any gully erosion (locations 22+00, 24+00, 36+00, and 40+00). For areas with gradients greater than 4.2 degrees, gully erosion was observed.

The headward extent of the gully formation depended on the gradient changes along the profile configuration. Observations of the headward extent of the gully erosion found on the beach indicated that the erosion was confined to areas between the 3' and 8' contour. This was generally the area with the greatest degree of slope or gradient on each profile configuration. However, at profile locations 48+00 and 49+00, the headward extent of the gullies reached further up the dike face. The gradient at these locations were found to be the steepest, as high as 6 and 7 degrees.

Table 4. Average slope of recreational beach from centerline of roadway to mean low water.

Date	6/85	9/85	12/85	4/86	6/86	9/86
Station			Slope (°)			
22+00	3.5	3.5	3.4	3.5	3.5	3.6
24+00	3.5	3.6	3.6	3.7	3.7	3.6
28+00	4.2	4.1	4.2	4.4	4.2	4.3
30+00	4.6	4.5	4.3	4.7	4.6	4.7
32+00	4.1	4.1	4.6	4.6	4.7	4.6
36+00	3.8	3.8	4.1	4.1	4.2	4.2
40+00	3.9	3.9	3.8	4.0	4.1	4.1
44+00	4.2	4.2	4.4	4.6	4.4	4.4
48+00	5.3	4.8	5.3	5.4	5.7	5.5
49+00	4.7	4.2	4.8	4.8	5.0	4.9

BEACH SEDIMENT DISTRIBUTION

During this study period, beach samples for textural analysis were collected in April 1986, before beach regrading, and June 1986, after beach regrading. Samples were collected before regrading in order to evaluate the role of natural processes in sediment distribution during the year (since the 1985 regrading). The distribution of sediment types on the beach was compared before and after regrading. This was used to determine the distribution of sediment types after artificial regrading.

Much of the finer material (silt/clay) was found on the upper dike face, above the 5′ contour (Figure 21). The finer material has been removed from the lower dike face and foreshore by wave activity. Compared to the previous year, the percentages of silt/clay were higher and covered a larger area on the dike face. This pattern reflected an increase in the frequency of southern winds recorded in the current monitoring (5th year) as compared to the same period the

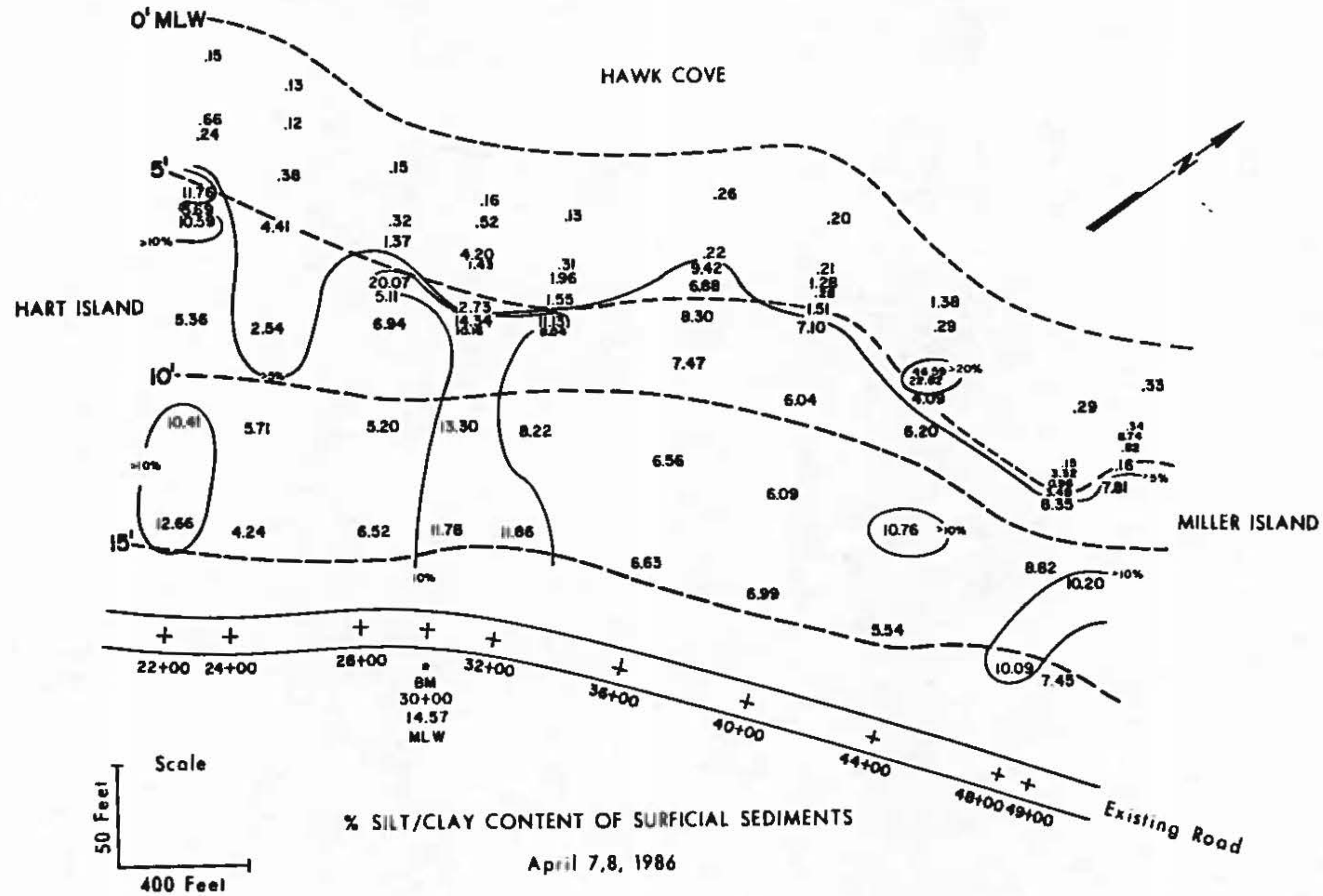


Figure 21

Maps showing distribution of silt/clay on the beach in April 1986 (before regarding).

previous year (see Figure 20 for wind roses). In the fourth year, wind removed much of the fine material from the upper dike face and deposited it on the inside of the dike. This year the reverse took place: southerly winds removed the fine material from the back side of the dike face and redeposited it on the beach.

The distribution of gravel, however, appeared to be the result of a combination of erosional and anthropogenic processes. In the Fourth Year Interpretive Report (Wells et al. 1986) it was explained that the high percentages of gravel found on the northern end of the recreational beach in June 1985 were probably a result of winnowing of the finer material (sand and silt/clay) by gully erosion and sheetwash. However, regrading the beach may have contributed to the process by concentrating additional material containing gravel toward the north end of the beach.

A similar distribution of gravel was noted in April 1986 with high percentages of gravel found on the northern end of the beach (Figure 22). However, considerable amounts of gravel were also found in a broad middle area of the dike face (locations 28+00, 30+00 and 32+00), whereas in the previous year gravel was not found in this area. Because there is no process other than regrading that would transport and deposit the gravel in that area, the higher percentages of gravel may be the result of the removal of the sand component, since the beach was not regraded between June 1985 and April 1986. In the same area the percentage of silt/clay also increased. The sand component was probably removed by gully erosion and sheetwash during the winter months and the silt/clay component deposited during the summer by wind.

After regrading, the distribution of silt/clay and gravel revealed slightly different patterns. Figure 23 depicts the distribution of silt/clay on the beach in June 1986, one month after regrading. As with the April distribution, the

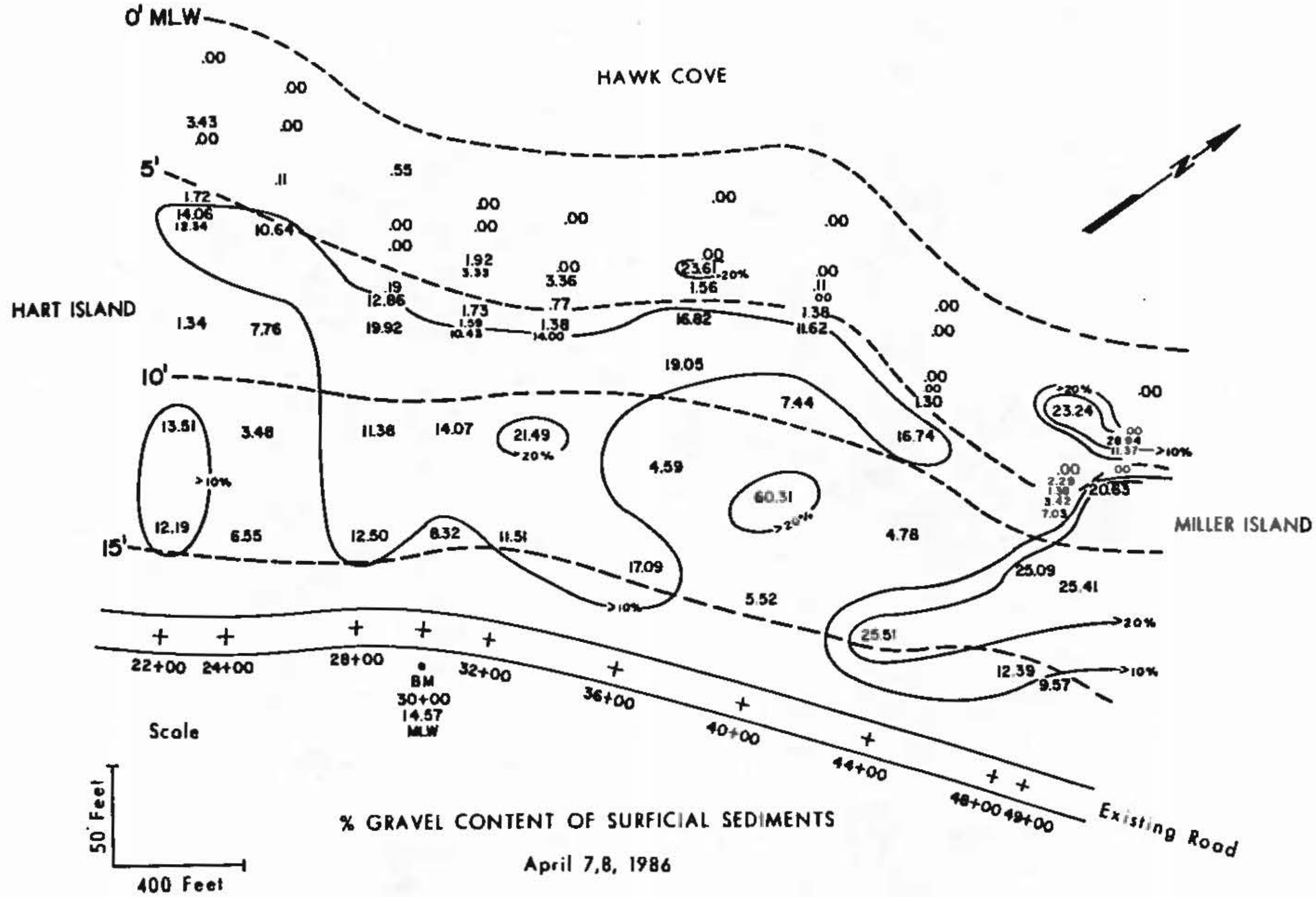


Figure 22

Map showing distribution of gravel on the beach in April 1986 (before regarding).

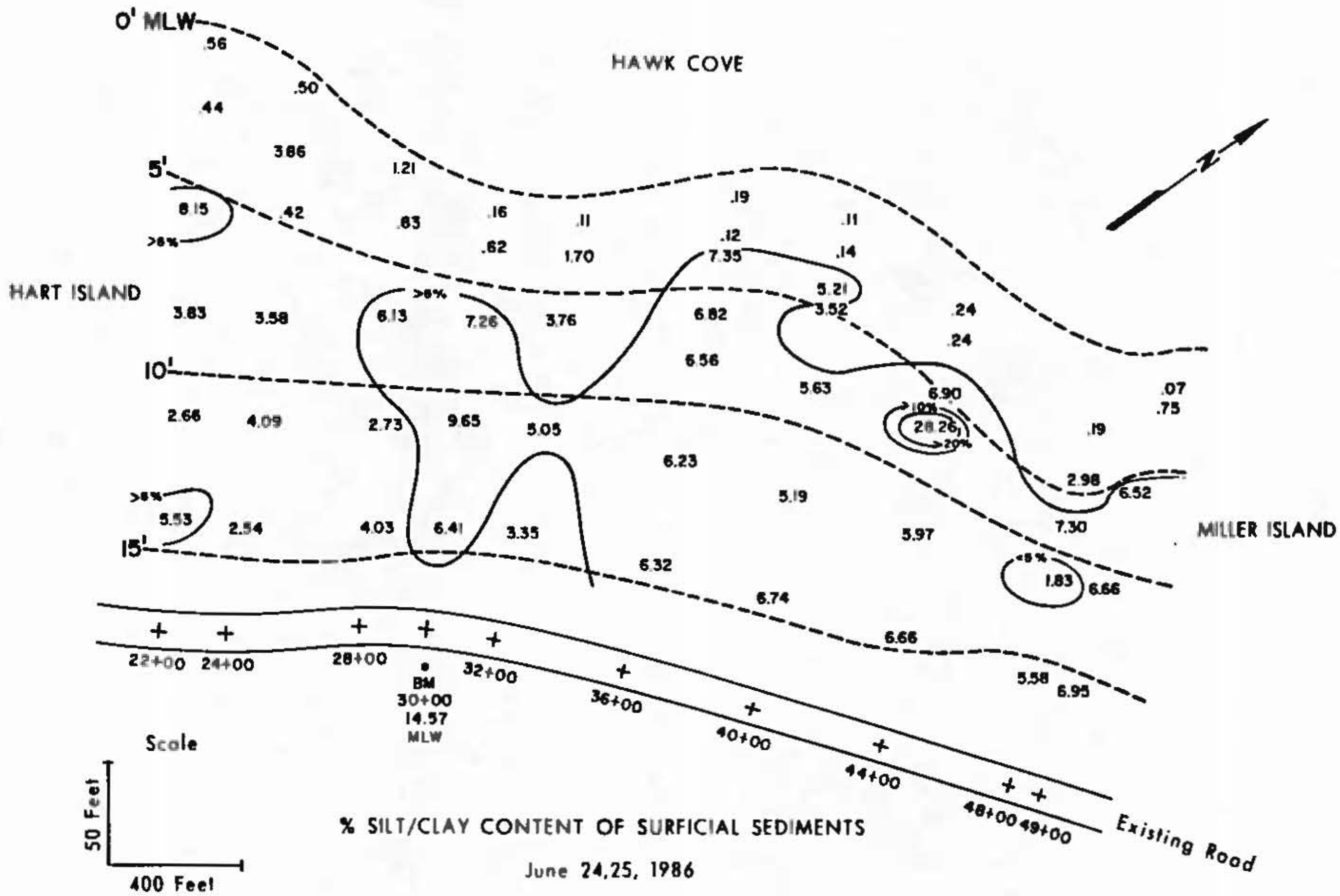


Figure 23

Map showing distribution of silt/clay on the beach in June 1986 (after regarding).

higher percentages of silt/clay were still confined to the upper dike face, but less silt/clay was found at the southern end of the dike along profiles 22+00, 24+00 and 28+00. Although this change in distribution may have been a result of wind, regrading also may have accounted for the redistribution of the fine material. When the beach was regraded, material was taken from one area, presumably the upper dike face and southern end of beach, and placed in areas of erosion, particularly the north end. This pattern of regrading is further suggested by the change in the distribution of gravel after regrading (Figure 24). Before regrading, large percentages of gravel (>10%) were found along the entire length of the upper dike face. However, in June 1986, most of the gravel removed from the southern end of the beach and concentrated in the north end.

NET EROSION AND DEPOSITION

Since the beginning of the recreational beach study (May 1984) approximately 4700 cubic yards (3600 m^3) have been removed from the beach above the 0 foot contour. This amount is considerably more than the 300 cubic yards reported removed in the previous year (Wells et al. 1987). Last year the amount of material eroded from the beach was offset by the considerable deposition of material at the south end, resulting in the widening of the beach. During this study year, the southern end of the beach did not grow as much as the previous year. At the same time, erosion continued to take place on the foreshore and lower dike face along much of the beach. At the northern end, erosional processes appear to have accelerated as a result of steeper gradients. In Figures B-17 through B-26, a comparison of the cross-sectional profiles for June 1984 and September 1986 for each profile station illustrates the net changes the

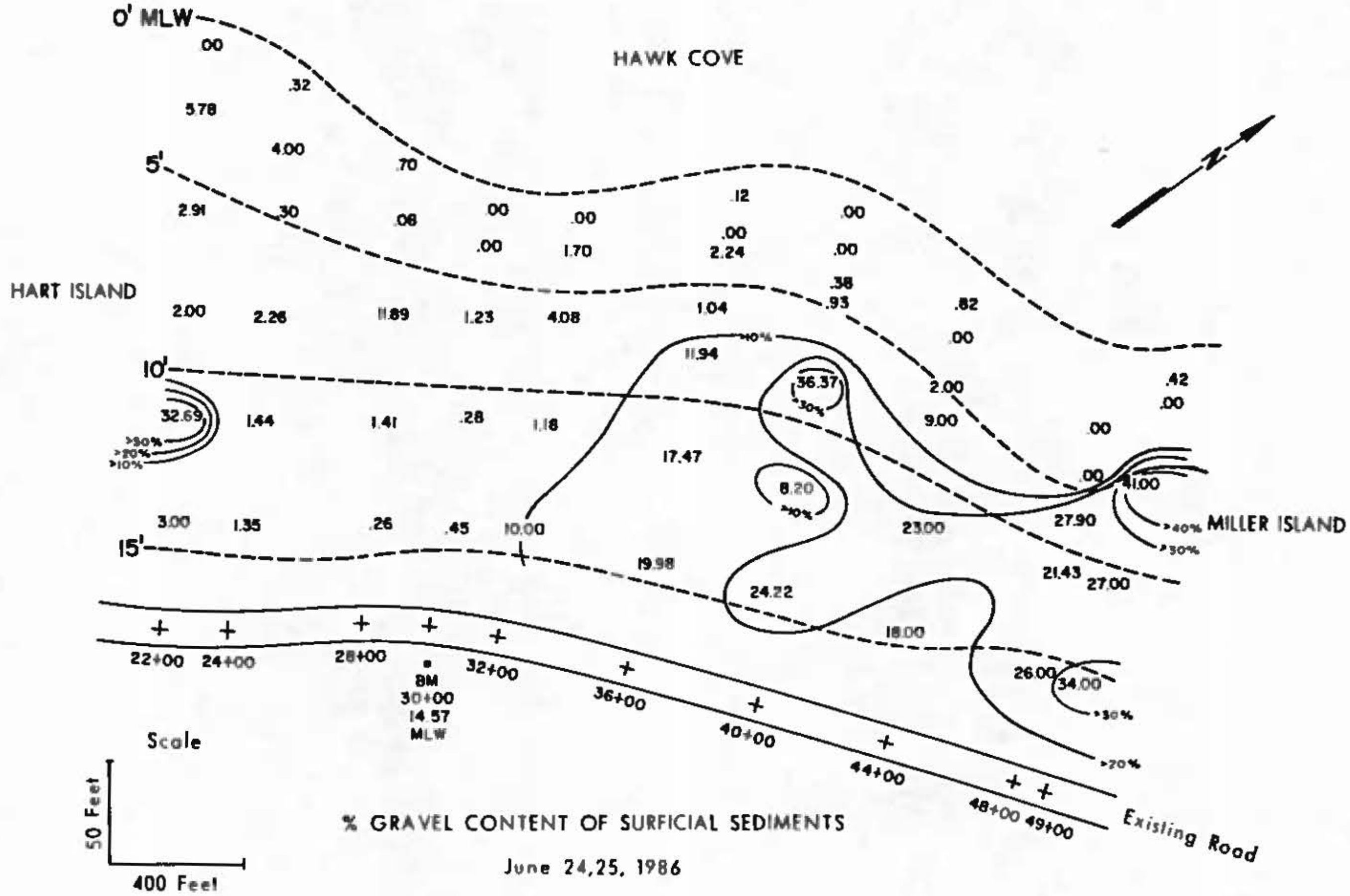


Figure 24

Map showing distribution of gravel on the beach in June 1986 (after regarding).

beach had undergone since the study began. Volumetric changes due to erosion and/or deposition were also calculated from these profiles.

CONCLUSIONS

Based on the observed changes in the beach configuration, several distinct geomorphic processes continued to operate on the recreational beach. The main agent of erosion continued to be wave attack on the foreshore producing escarpments along the beach. However, gully erosion (and sheetwash) of the lower dike face has become more prominent as a result of increasingly steeper gradients, particularly at the north end of the beach. The accelerated rate of erosion has resulted in a tenfold increase in the amount of material removed from the foreshore and dike face this year. It has been calculated that approximately 4700 cubic yards (3600 m^3) of material has been eroded from the beach (above 0' mlw) since the beginning of the beach study (June 1984). Furthermore, the erosional processes have selectively removed the sand-sized material, resulting in a more gravelly beach not conducive to recreational use.

RECOMMENDATIONS

To alleviate these erosional problems it is recommended that the recreational beach be replenished with suitable material so that the slopes of both the lower dike face and foreshore areas are decreased. The gentler slopes would be less subject to gully erosion and/or sheetwash and more resistant to the formation of wave-cut escarpments. It is also recommended that medium to coarse sand be used as replenishment material to enhance the beach for recreational use.

Appendix A

X-Radiographs of Gravity Cores

Figures A-1 through A-8

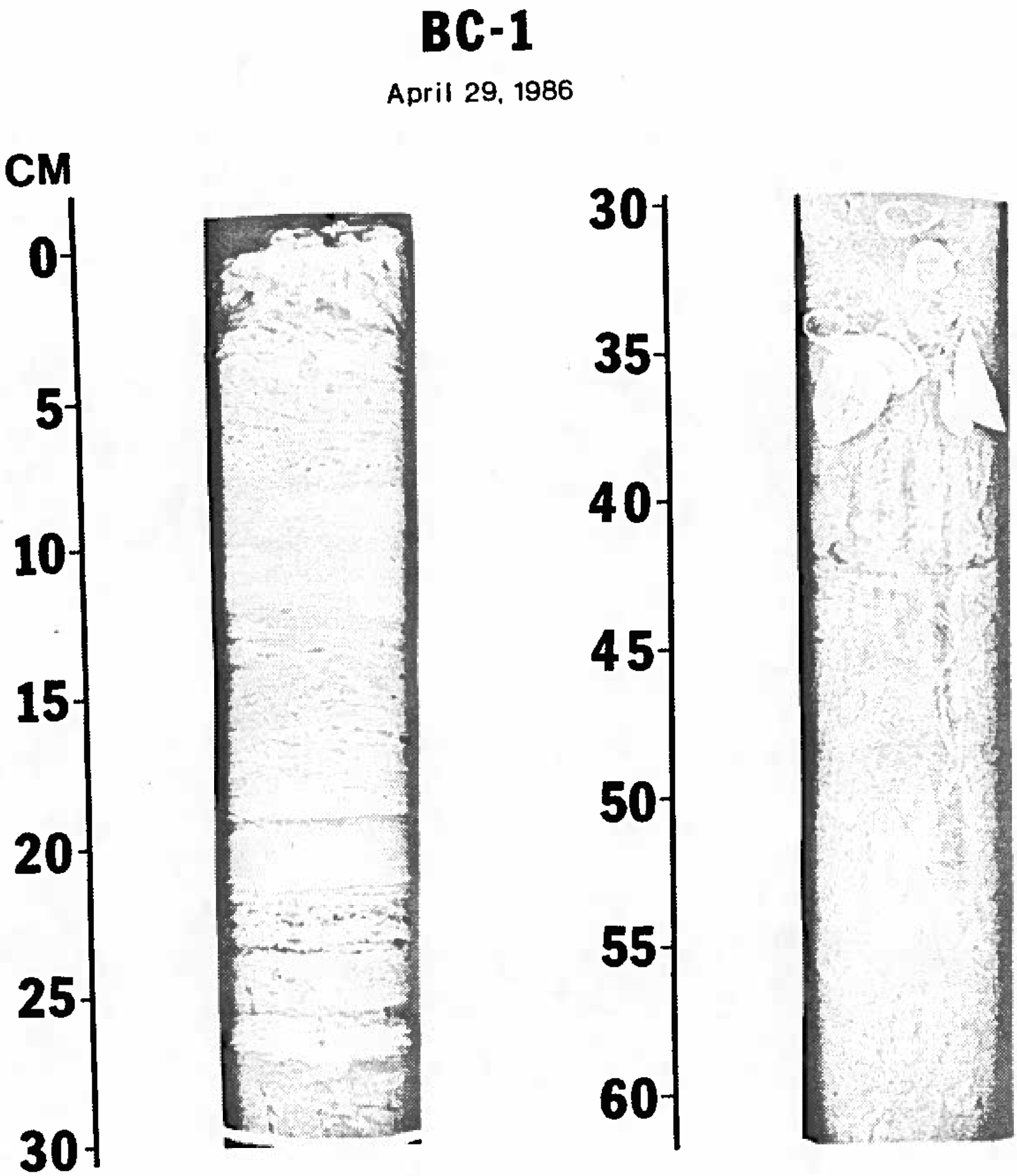


Figure A-1

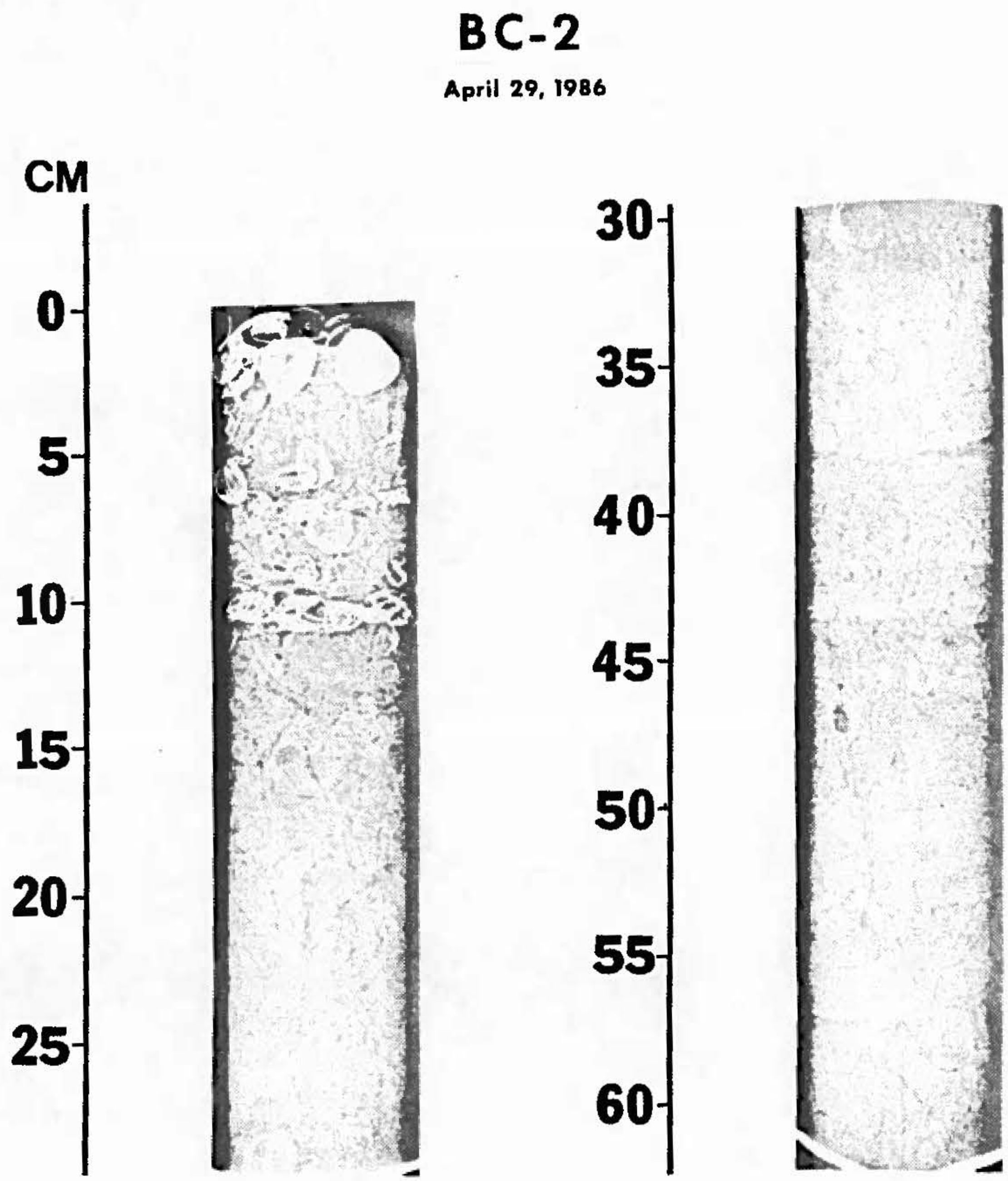


Figure A-2

BC-3

April 29, 1986

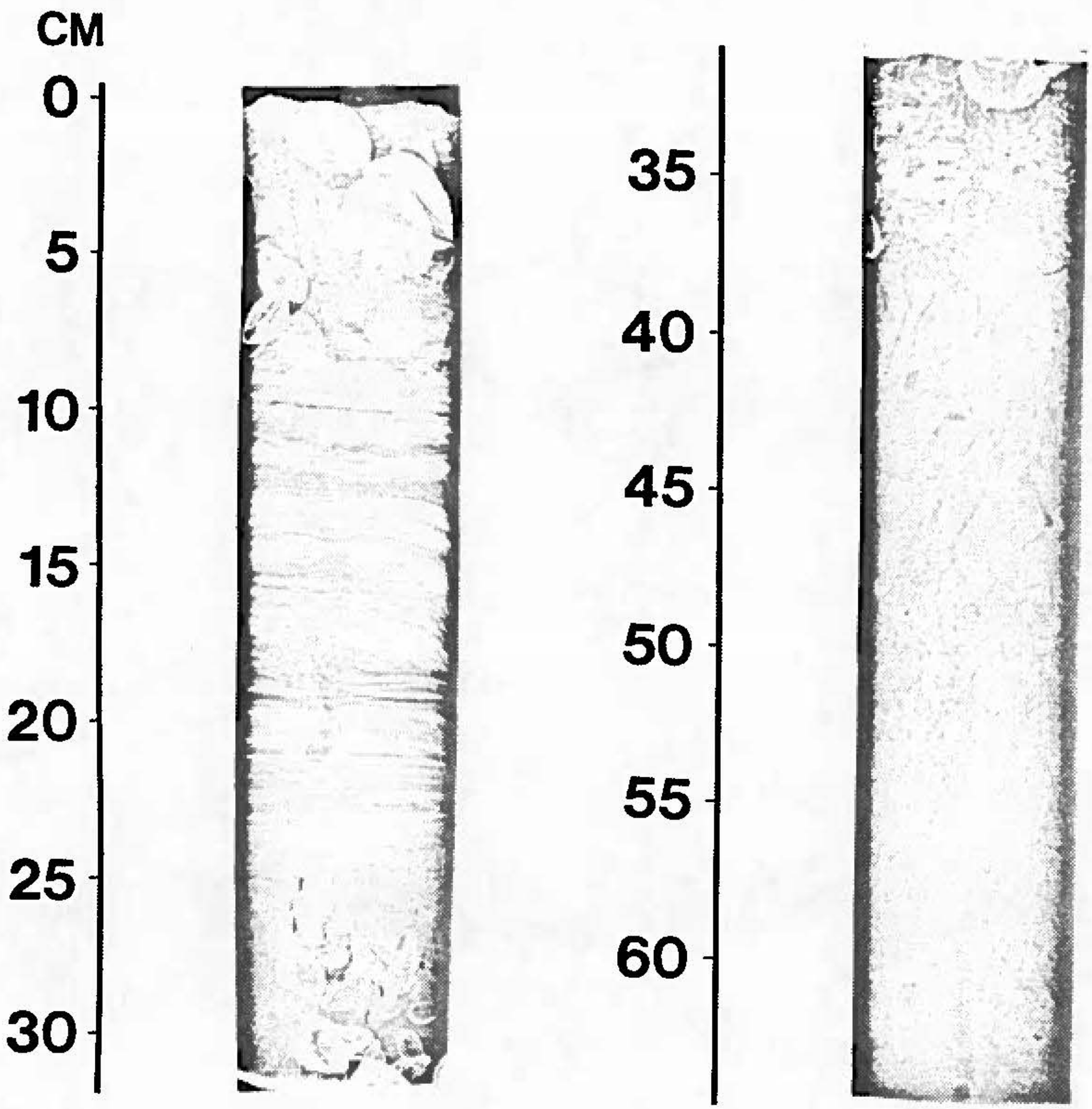


Figure A-3

BC-4

April 29, 1986

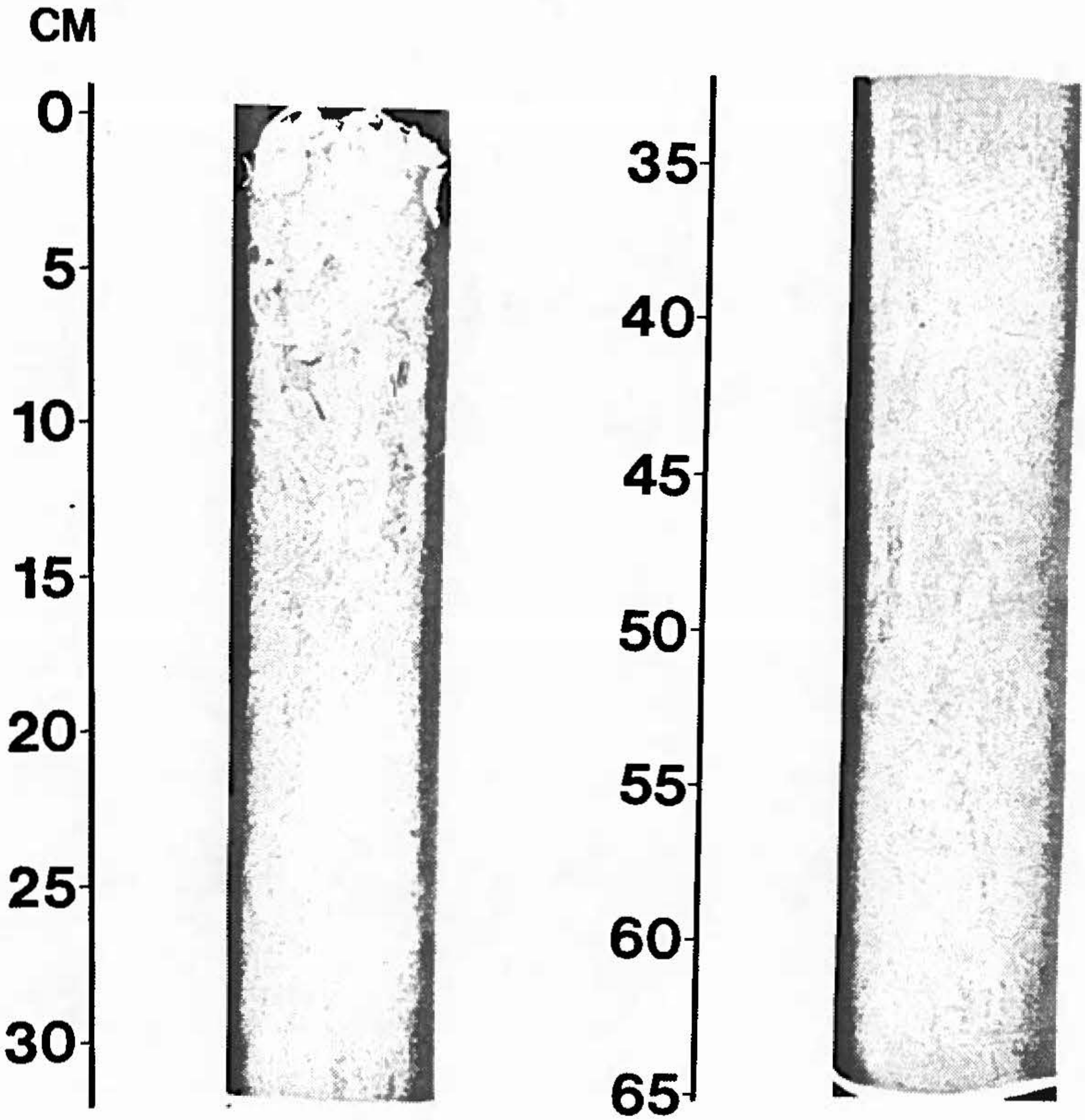


Figure A-4

BC-5

April 29, 1986

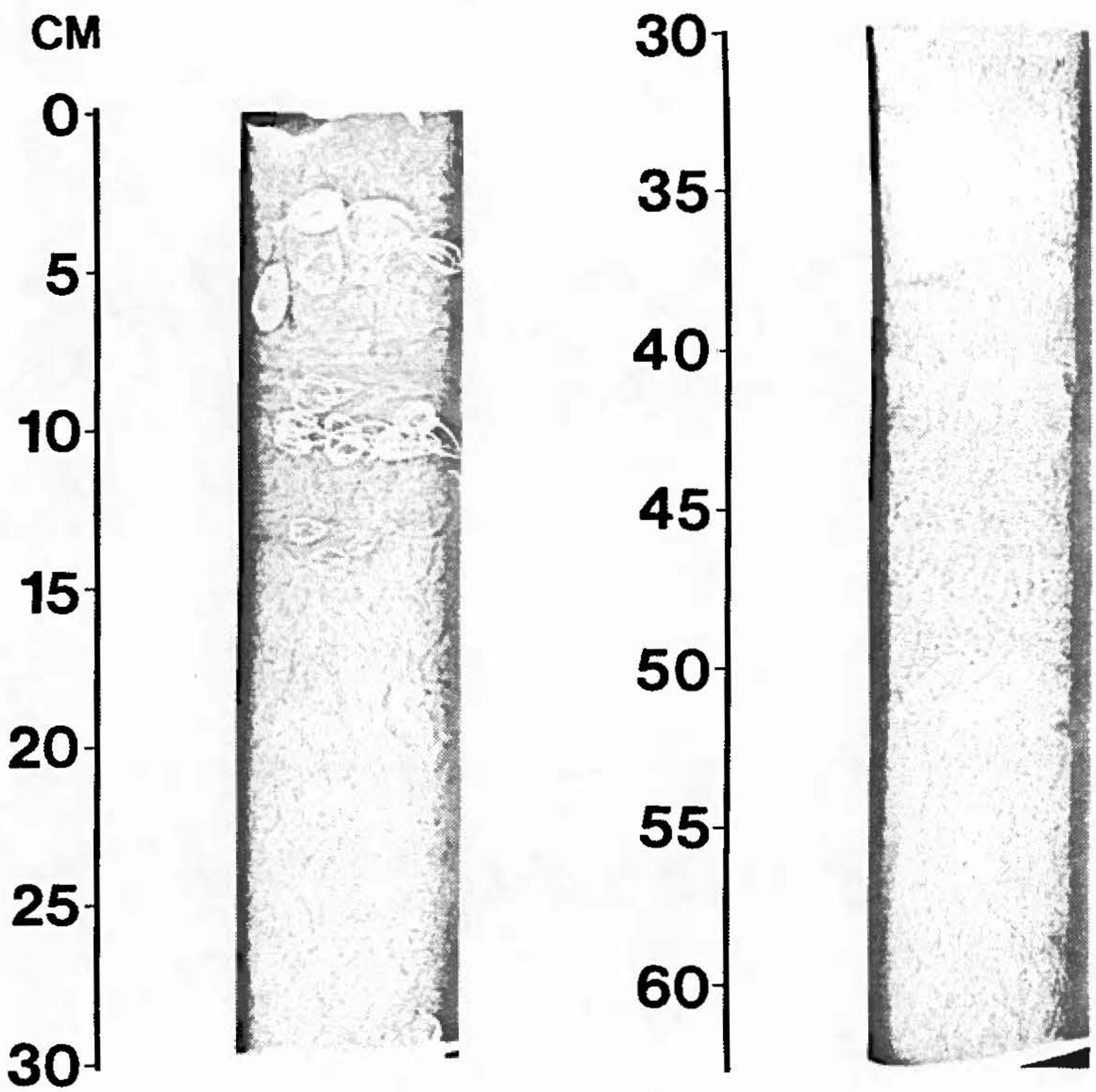


Figure A-5

BC-6

April 29, 1986

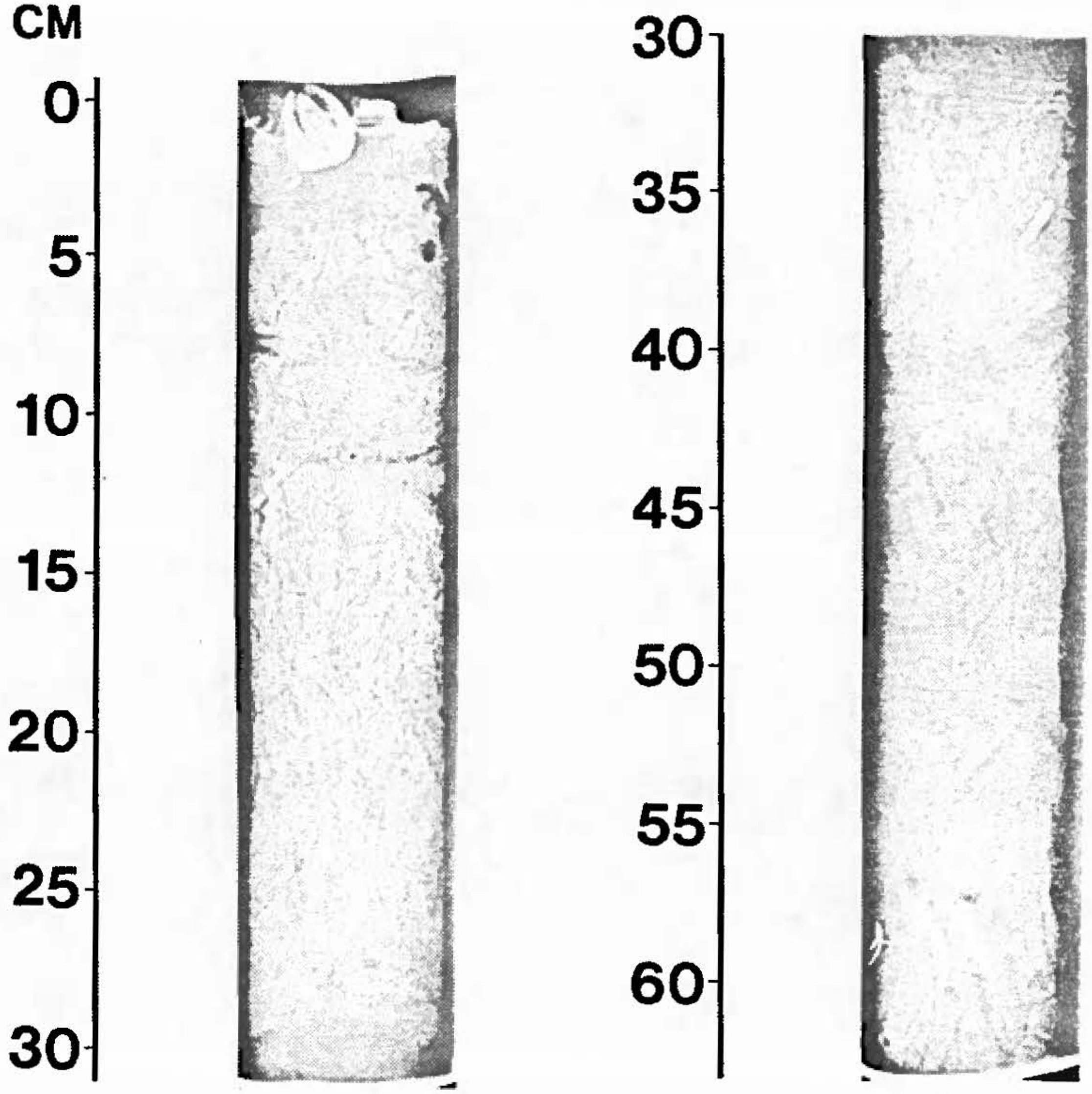


Figure A-6

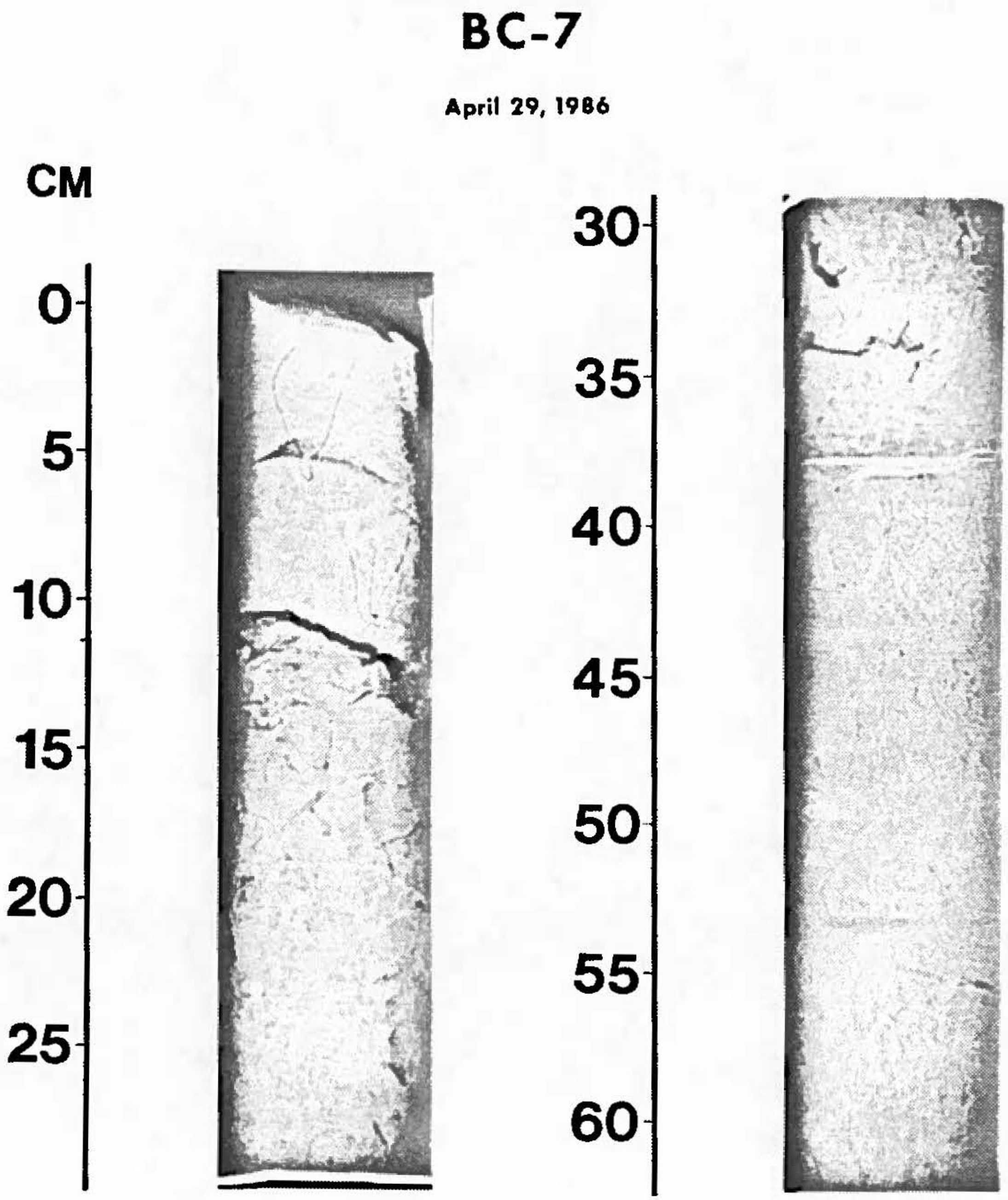


Figure A-7

21B

April 29, 1986

Figure A-8

Appendix B

Beach Contour Maps

Figures B1-B6

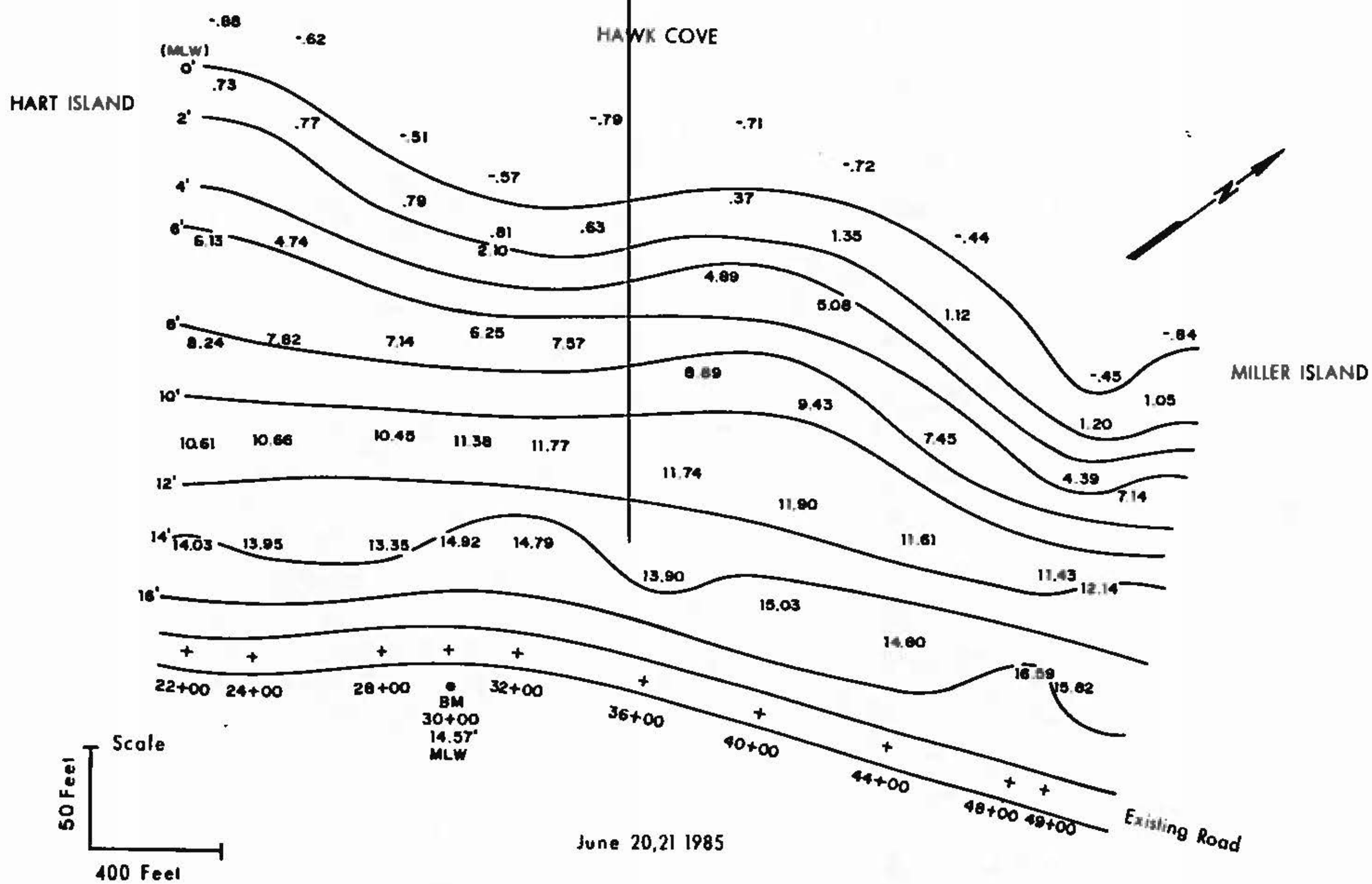

HART ISLAND
HAWK COVE
MILLER ISLAND
(MLW)
0'
2'
4'
6'
8'
10'
12'
14'
16'
22+00
24+00
28+00
BM
30+00
14.57'
MLW
32+00
36+00
40+00
44+00
48+00
49+00
Existing Road
Scale
50 Feet
400 Feet
June 20,21 1985

Figure B-1

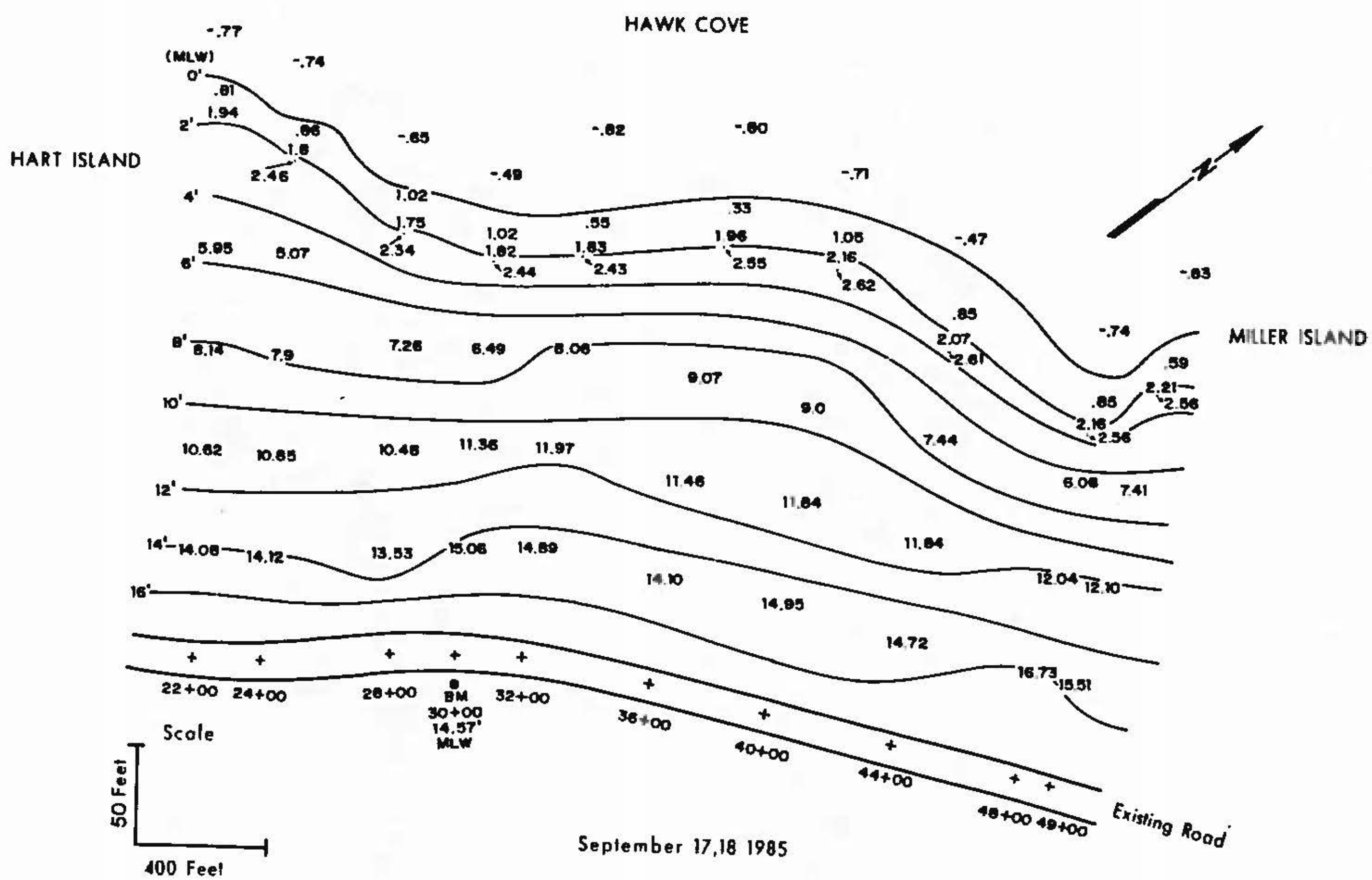

HAWK COVE
HART ISLAND
MILLER ISLAND
(MLW)
0'
2'
4'
6'
8'
10'
12'
14'
16'
N
22+00
24+00
28+00
BM
30+00
14.57'
MLW
32+00
36+00
40+00
44+00
48+00
49+00
Existing Road
Scale
50 Feet
400 Feet
September 17,18 1985

Figure B-2

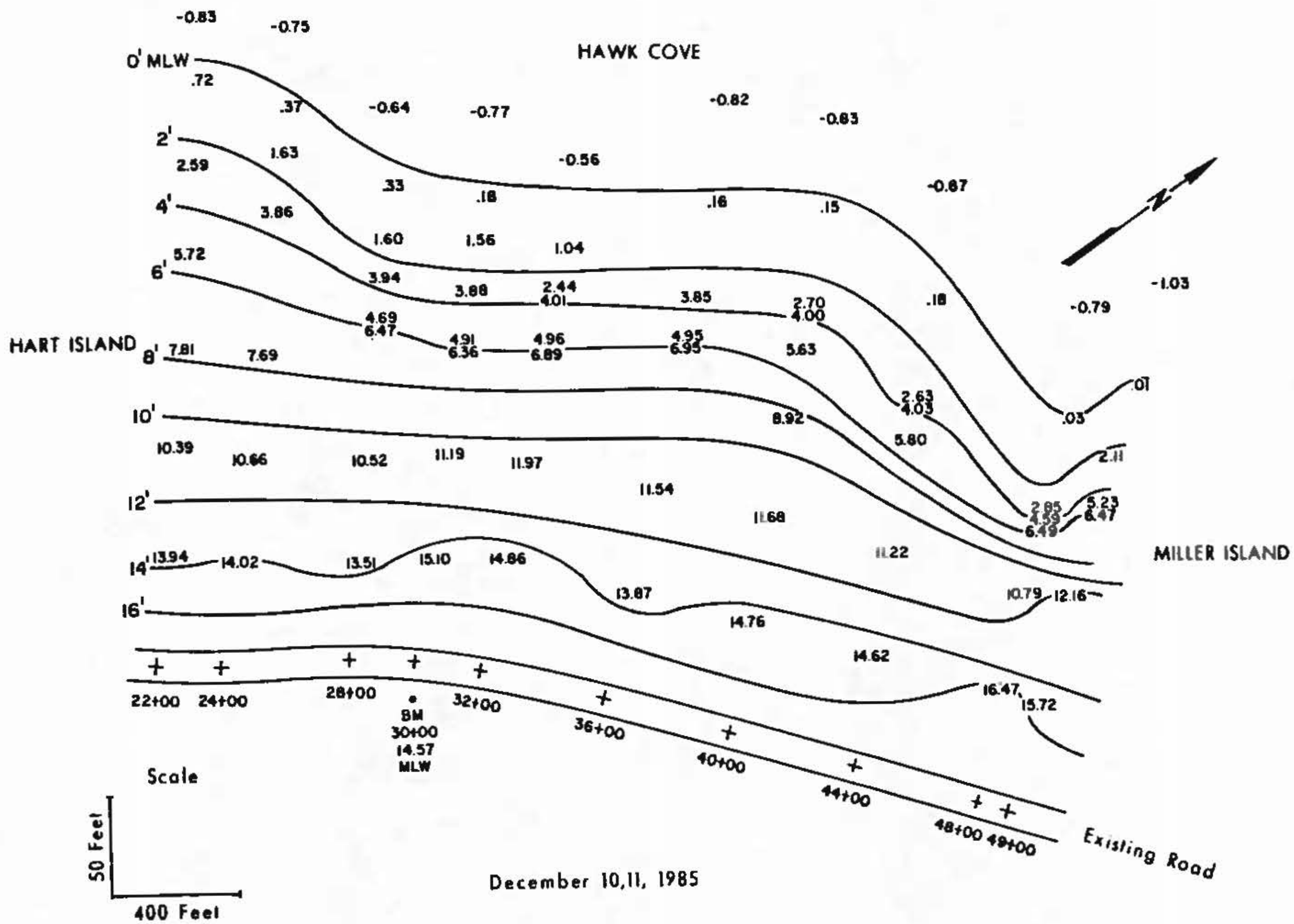

HAWK COVE
HART ISLAND
MILLER ISLAND
N
0' MLW
2'
4'
6'
8'
10'
12'
14'
16'
-0.83
-0.75
.72
.37
-0.64
-0.77
-0.82
-0.83
2.59
1.63
.33
.18
-0.56
.16
.15
-0.87
3.86
1.60
1.56
1.04
5.72
3.94
3.88
2.44
4.01
3.85
2.70
4.00
.18
-0.79
-1.03
4.69
6.47
4.91
6.36
4.96
6.89
4.95
6.95
5.63
7.81
7.69
2.63
4.03
.03
.01
8.92
5.80
10.39
10.66
10.52
11.19
11.97
2.11
11.54
11.68
5.23
6.47
6.49
13.94
14.02
13.51
15.10
14.86
11.22
13.87
10.79
12.16
14.76
14.62
16.47
15.72
22+00
24+00
28+00
BM
30+00
14.57
MLW
32+00
36+00
40+00
44+00
48+00
49+00
Existing Road
Scale
50 Feet
400 Feet
December 10,11, 1985

Figure B-3

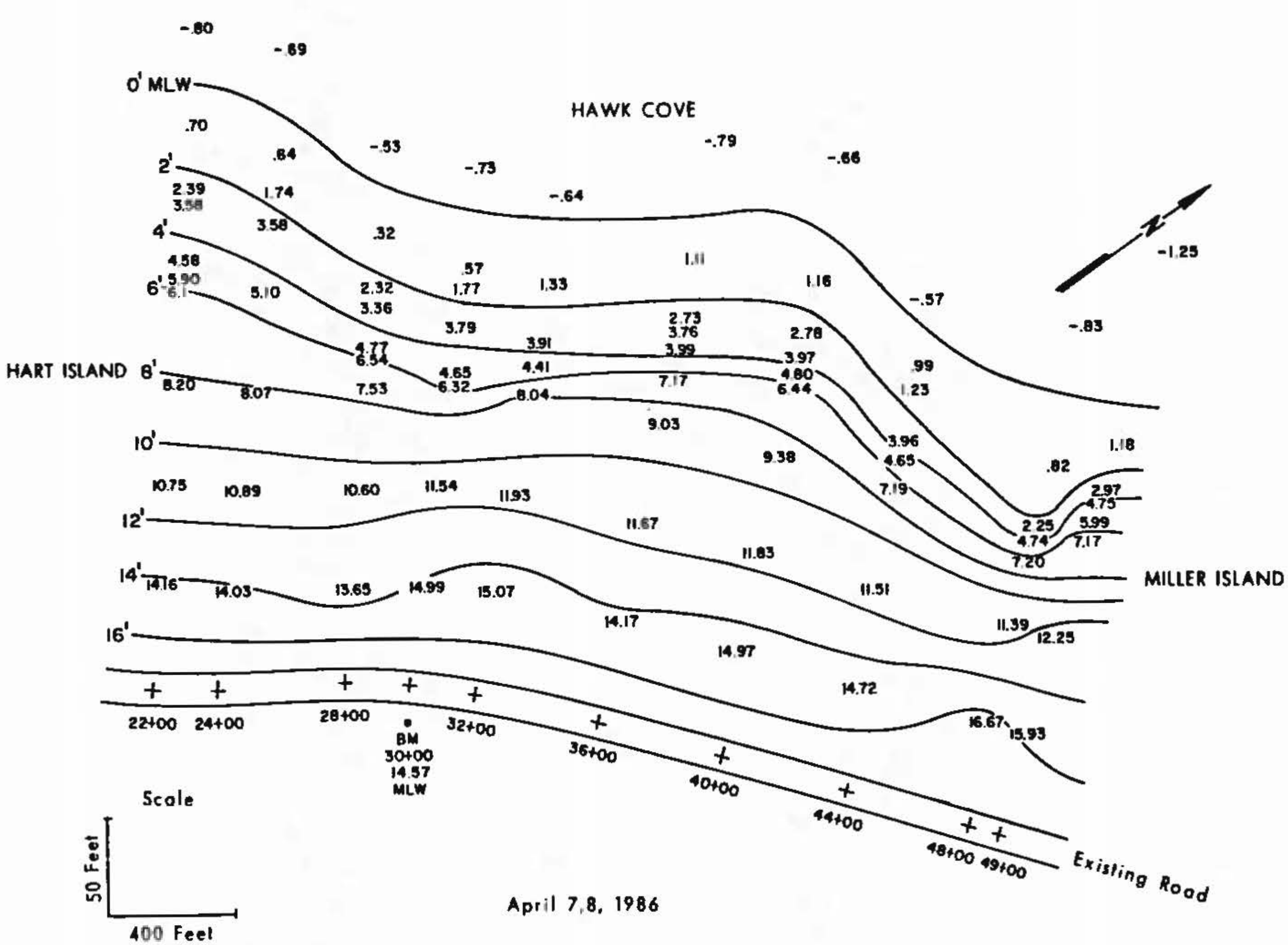

HAWK COVE
HART ISLAND
MILLER ISLAND
0' MLW
2'
4'
6'
8'
10'
12'
14'
16'
22+00
24+00
28+00
BM
30+00
14.57
MLW
32+00
36+00
40+00
44+00
48+00
49+00
Existing Road
Scale
50 Feet
400 Feet
April 7,8, 1986

Figure B-4

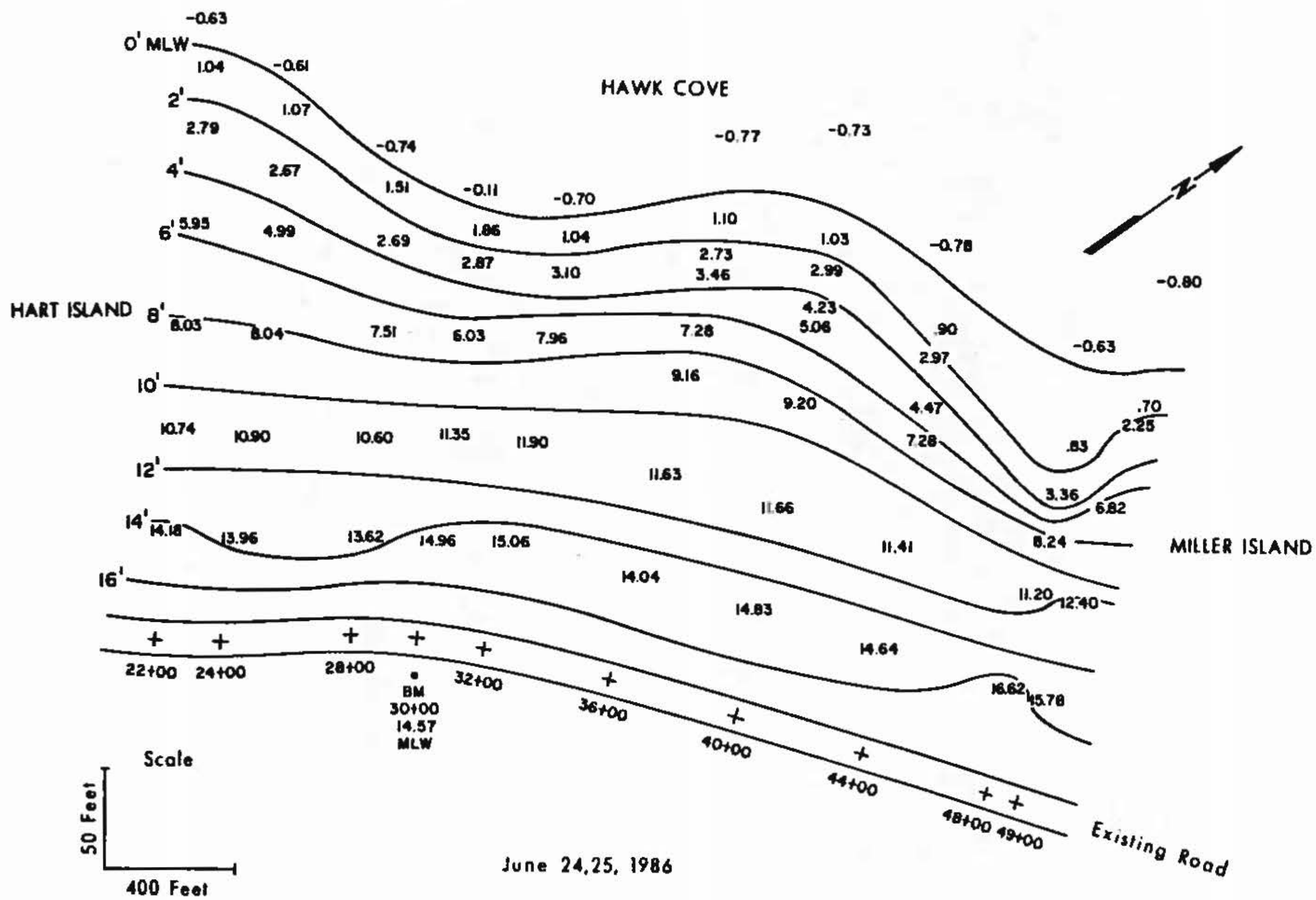

HAWK COVE
HART ISLAND
MILLER ISLAND
0' MLW
2'
4'
6'
8'
10'
12'
14'
16'
-0.63
1.04
-0.61
1.07
2.79
-0.74
2.67
1.51
-0.11
-0.70
-0.77
-0.73
5.95
4.99
2.69
1.86
1.04
1.10
1.03
-0.78
-0.80
2.87
3.10
2.73
3.46
2.99
4.23
5.06
8.03
8.04
7.51
6.03
7.96
7.28
.90
2.97
-0.63
9.16
9.20
4.47
7.28
.70
2.25
10.74
10.90
10.60
11.35
11.90
.83
11.63
3.36
6.82
11.66
14.18
13.96
13.62
14.96
15.06
11.41
8.24
14.04
11.20
12.40
14.83
14.64
16.62
15.78
22+00
24+00
28+00
BM
30+00
14.57
MLW
32+00
36+00
40+00
44+00
48+00
49+00
Existing Road
Scale
50 Feet
400 Feet
June 24,25, 1986

Figure B-5

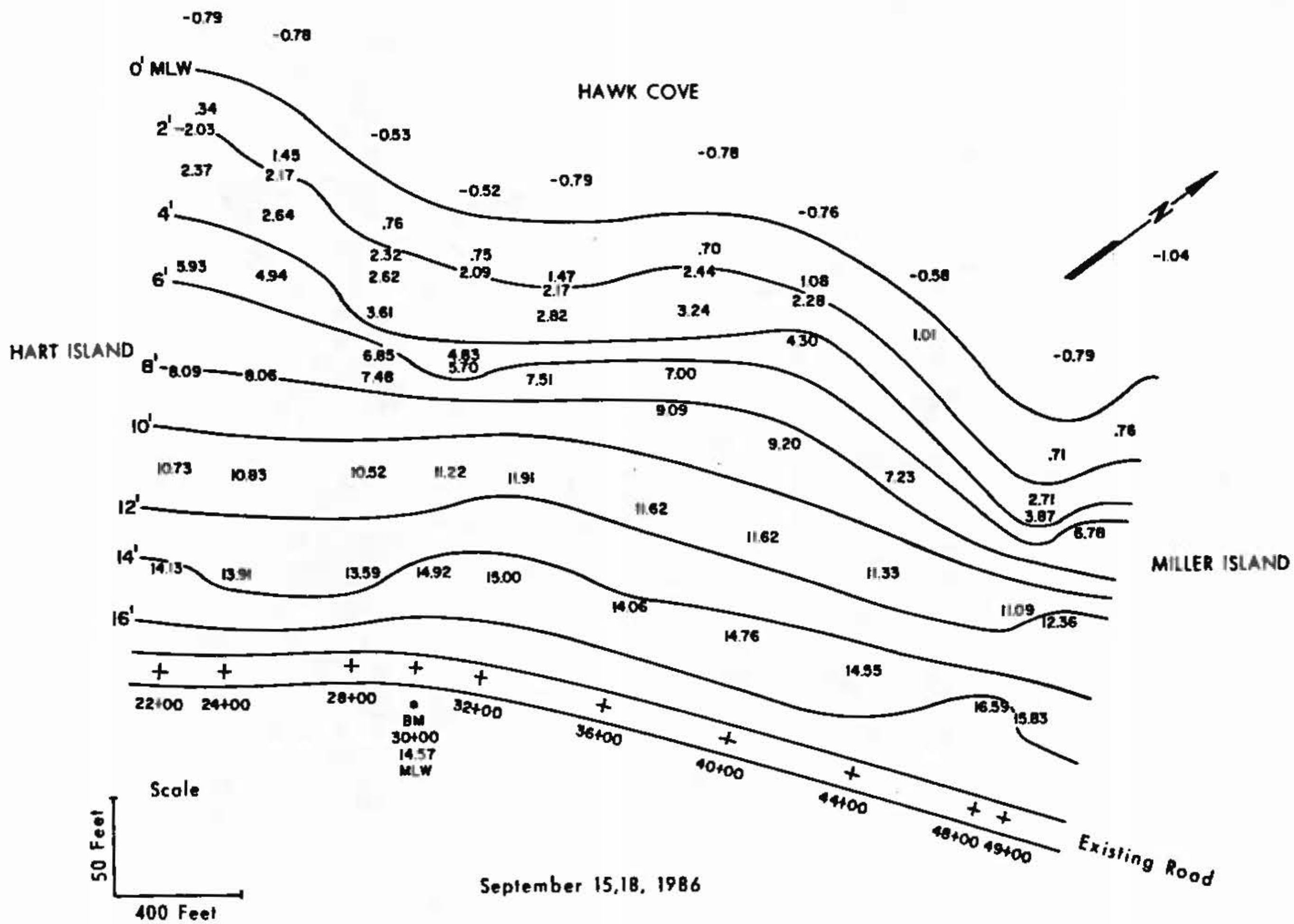

HAWK COVE
HART ISLAND
MILLER ISLAND
0' MLW
2'
4'
6'
8'
10'
12'
14'
16'
22+00
24+00
28+00
BM
30+00
14.57
MLW
32+00
36+00
40+00
44+00
48+00
49+00
Existing Road
Scale
50 Feet
400 Feet
September 15,18, 1986

Figure B-6

Contour Maps and Crossectional Profiles
of the Recreational Beach

Figures B7-B26

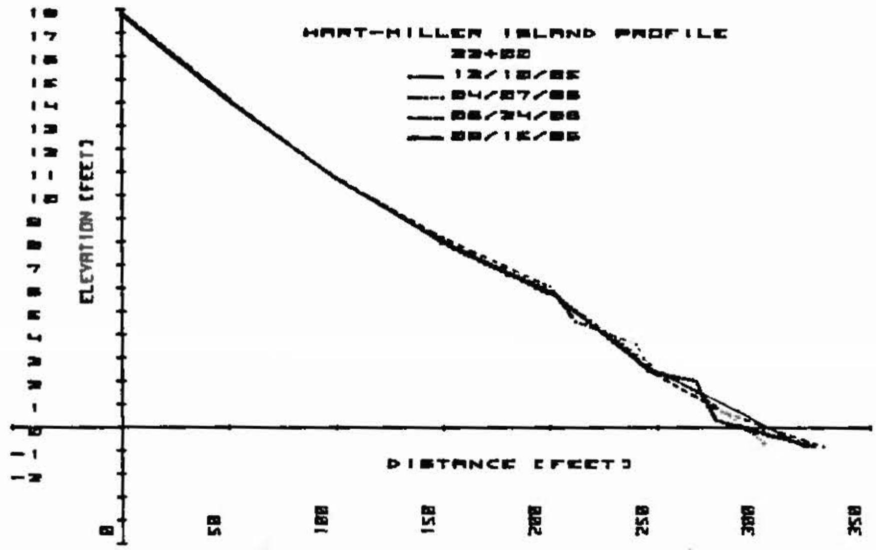


Figure B-7

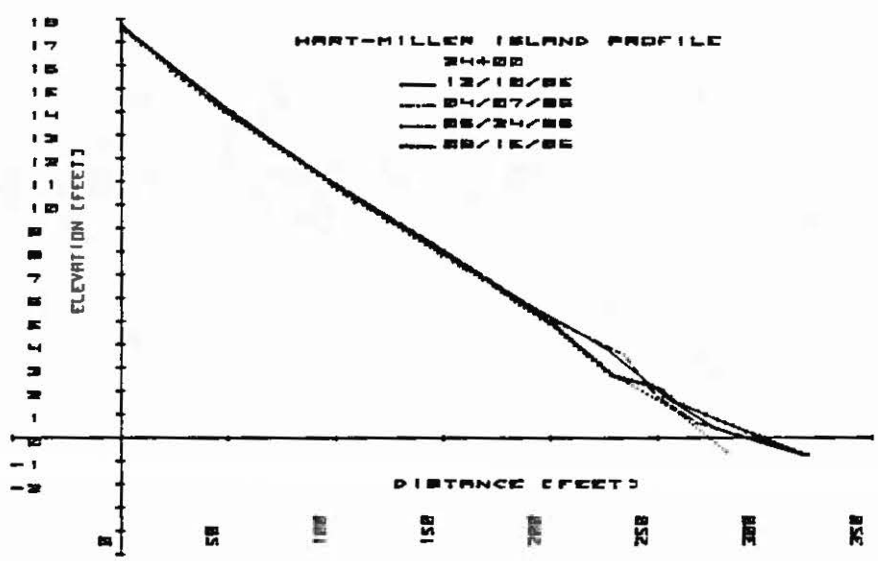


Figure B-8

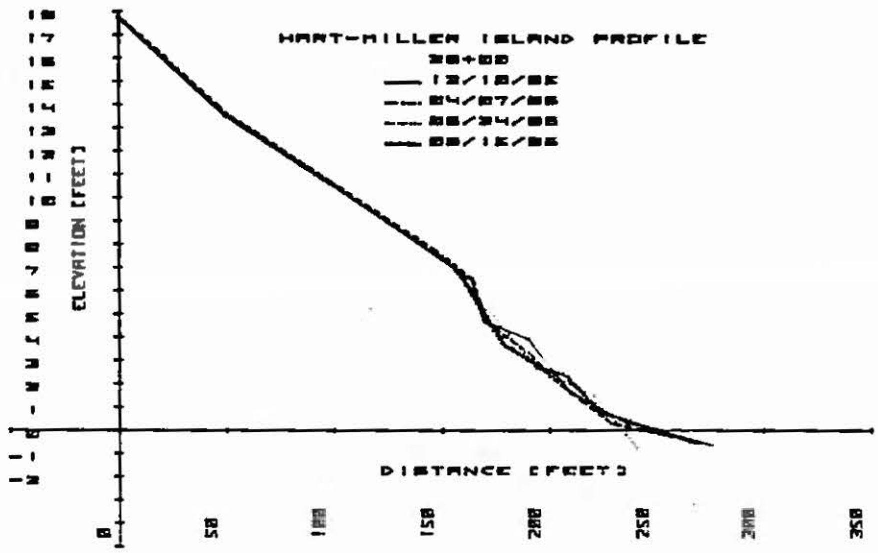


Figure B-9

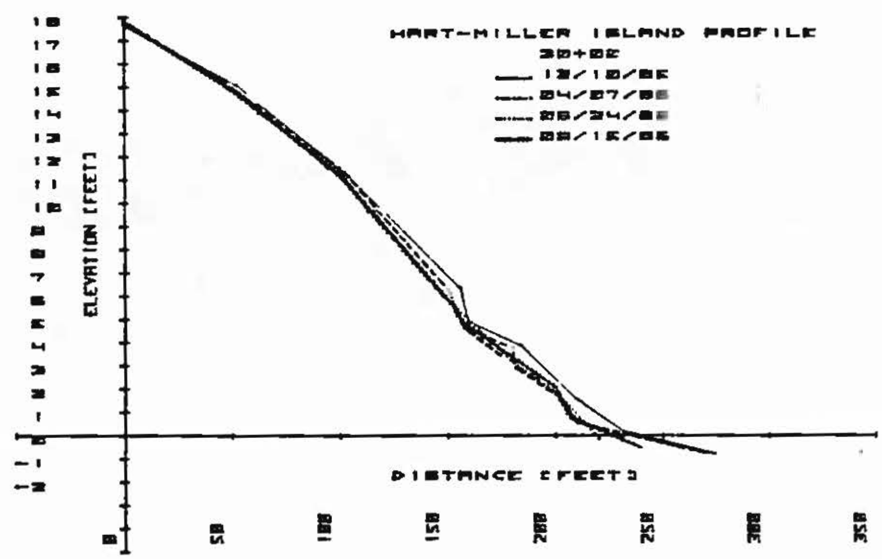


Figure B-10

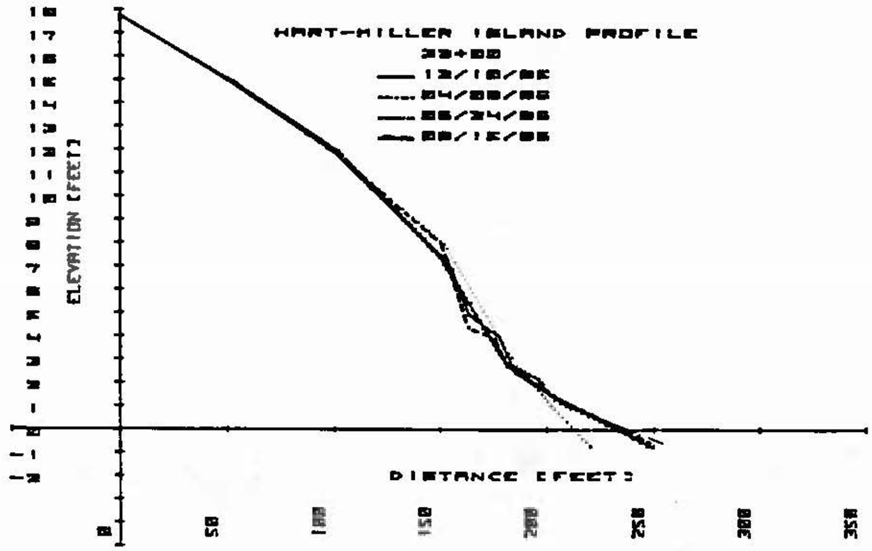


Figure B-11

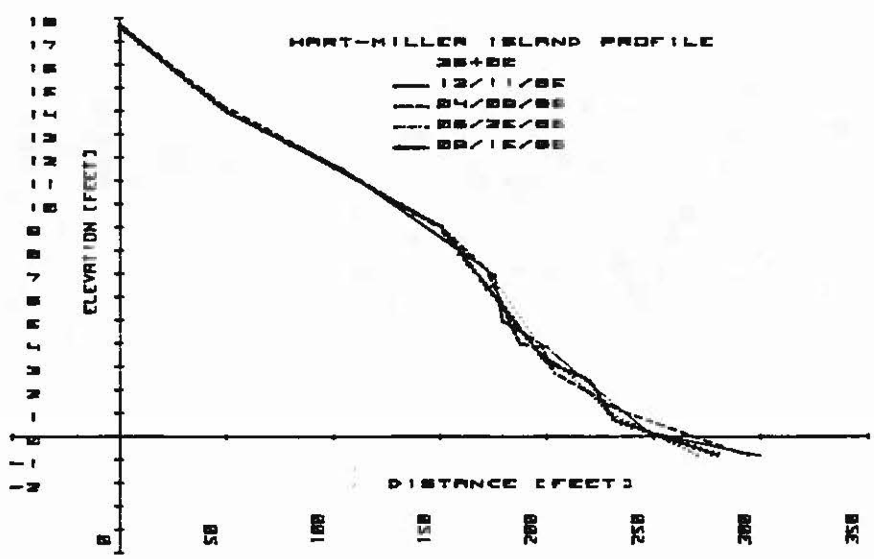


Figure B-12

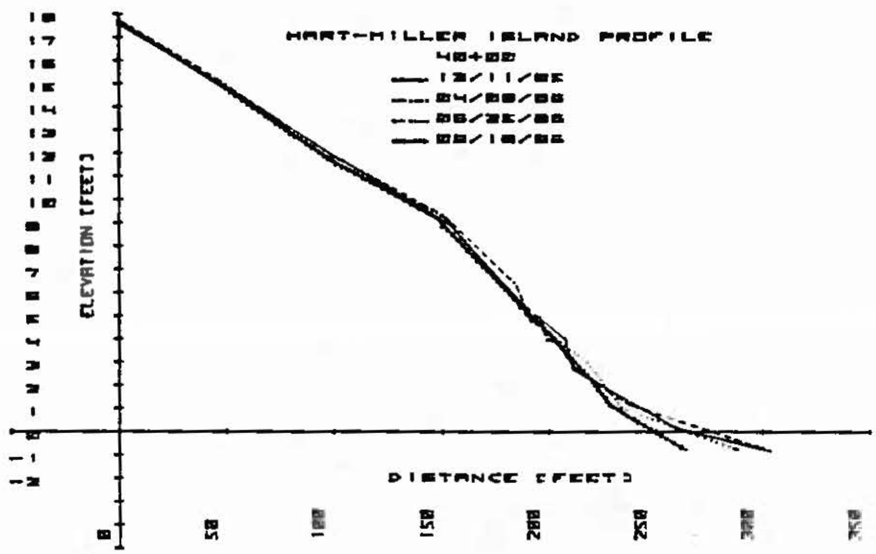


Figure B-13

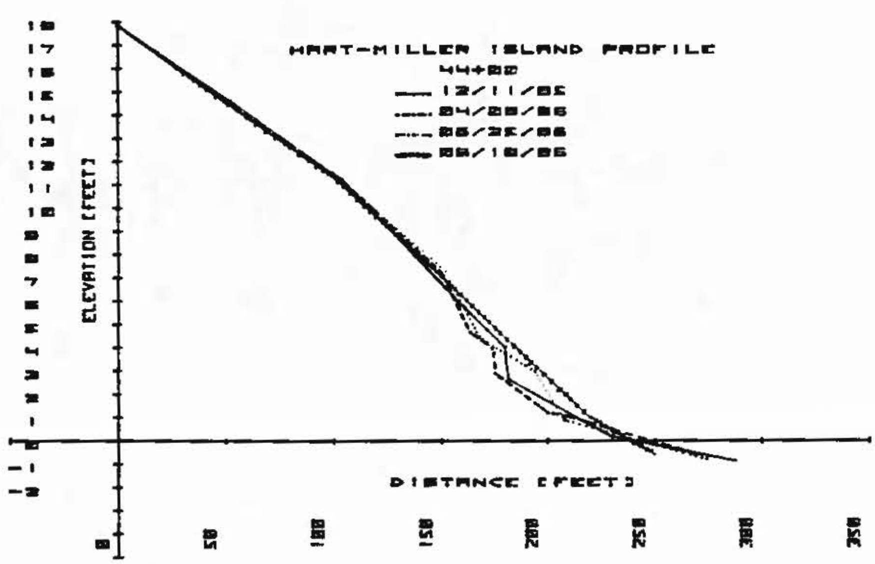


Figure B-14

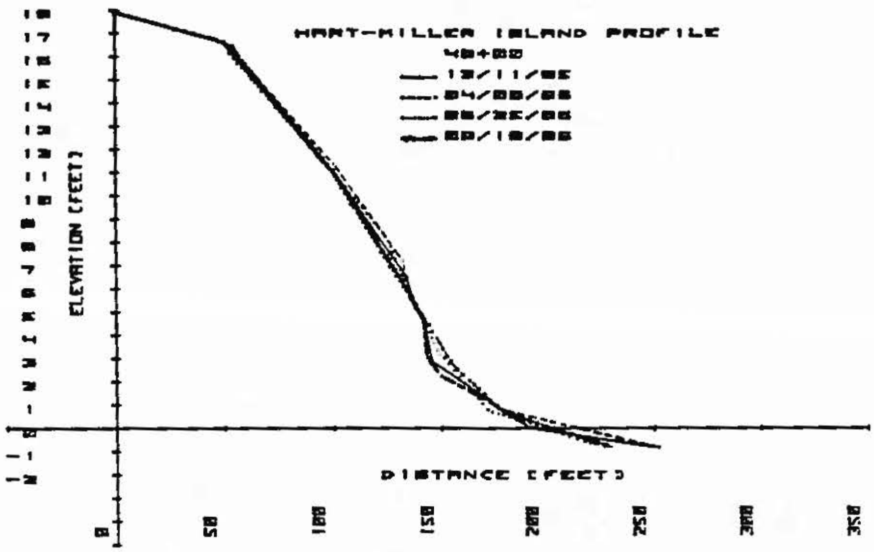


Figure B-15

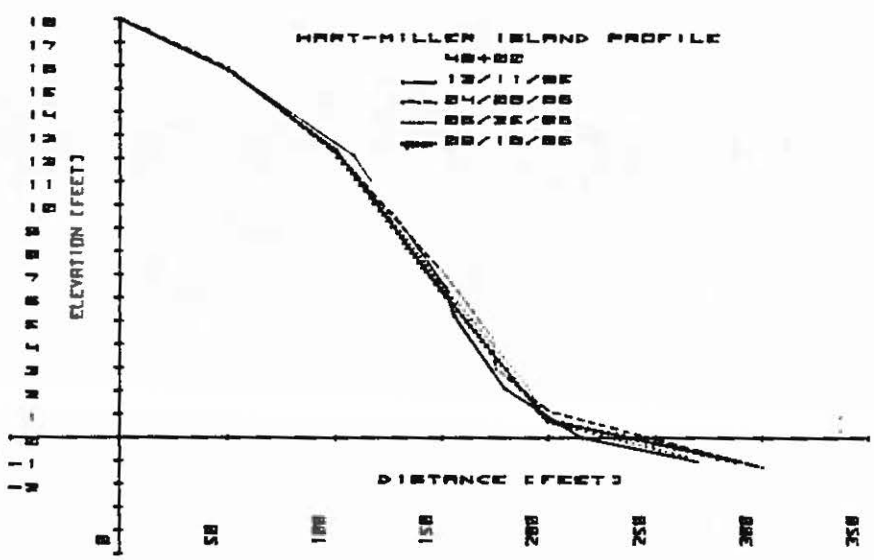


Figure B-16

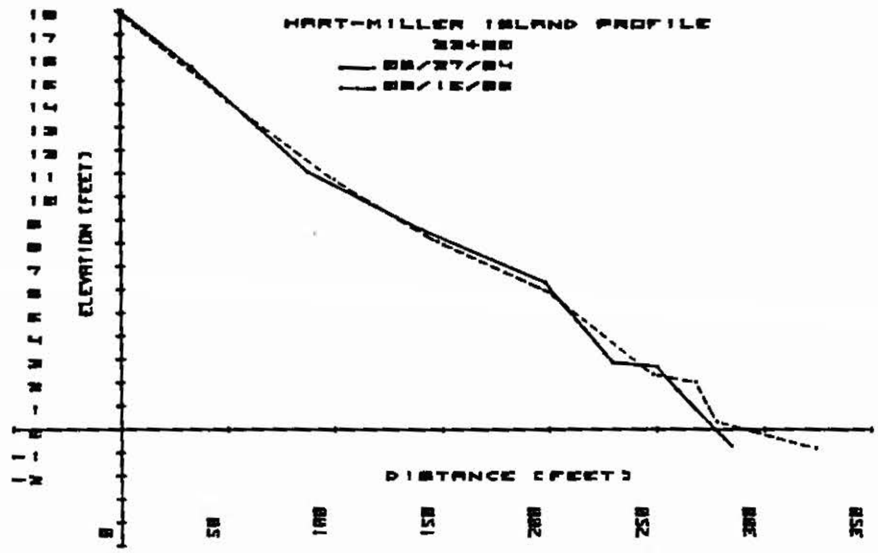


Figure B-17

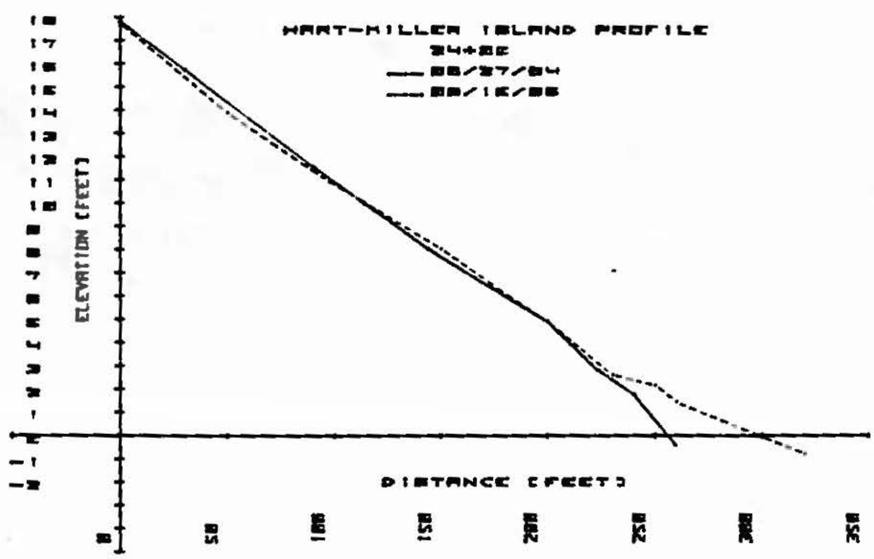


Figure B-18

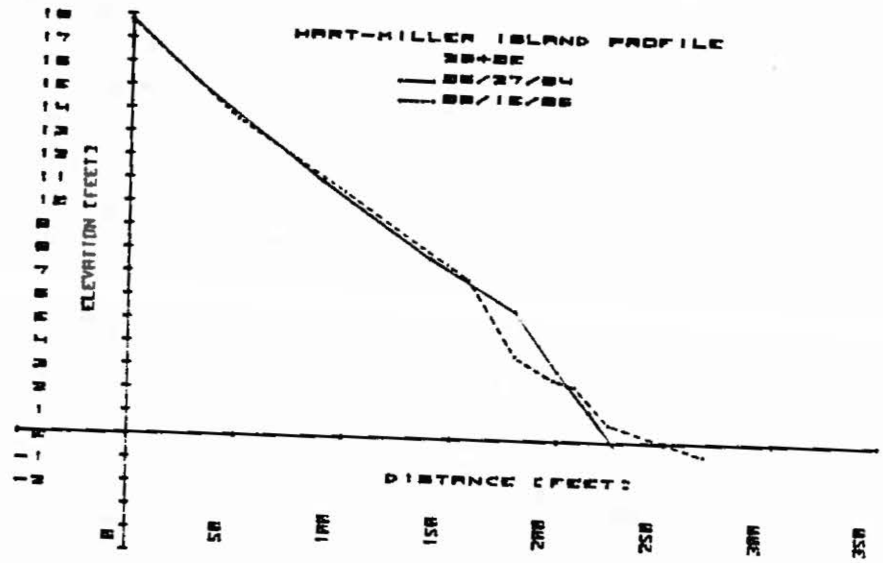
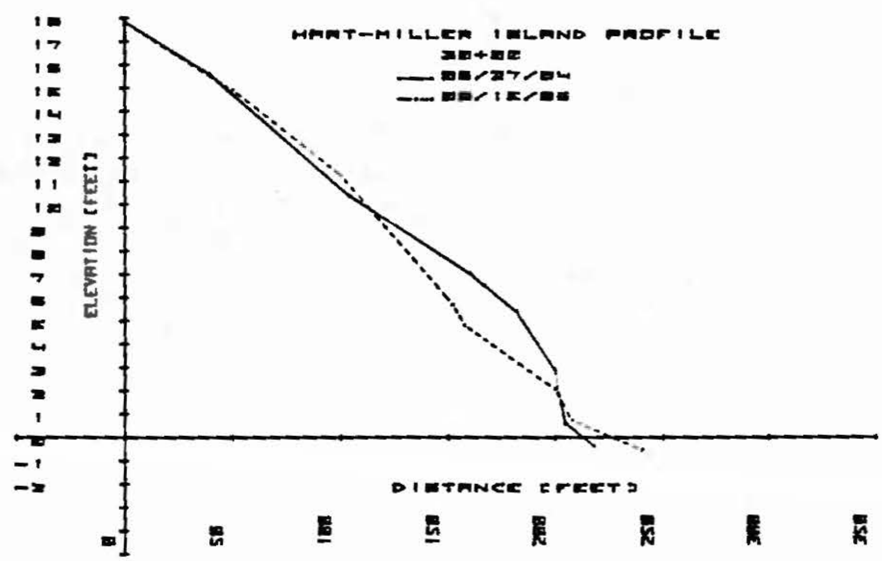


Figure B-19



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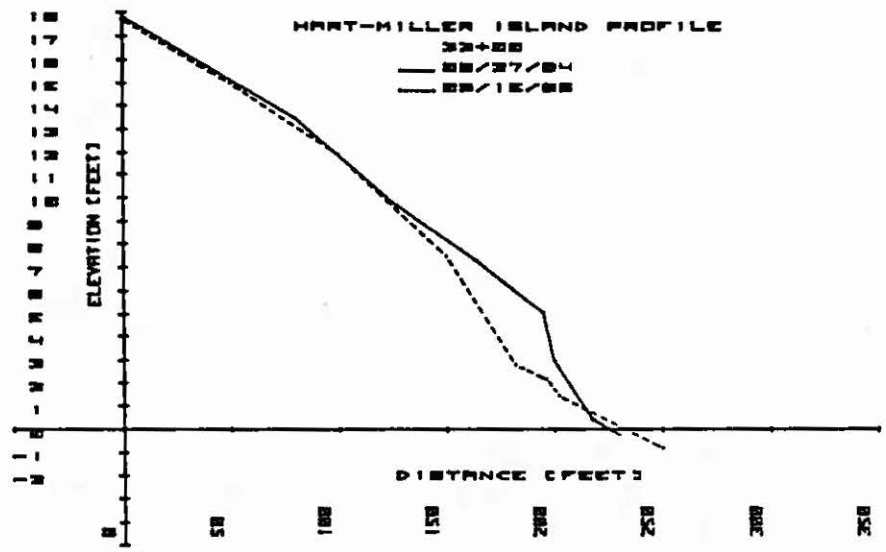

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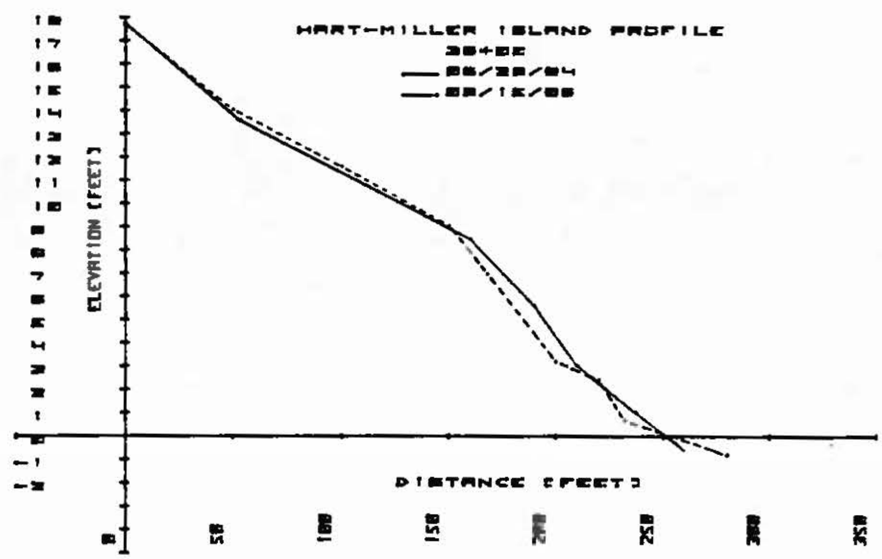
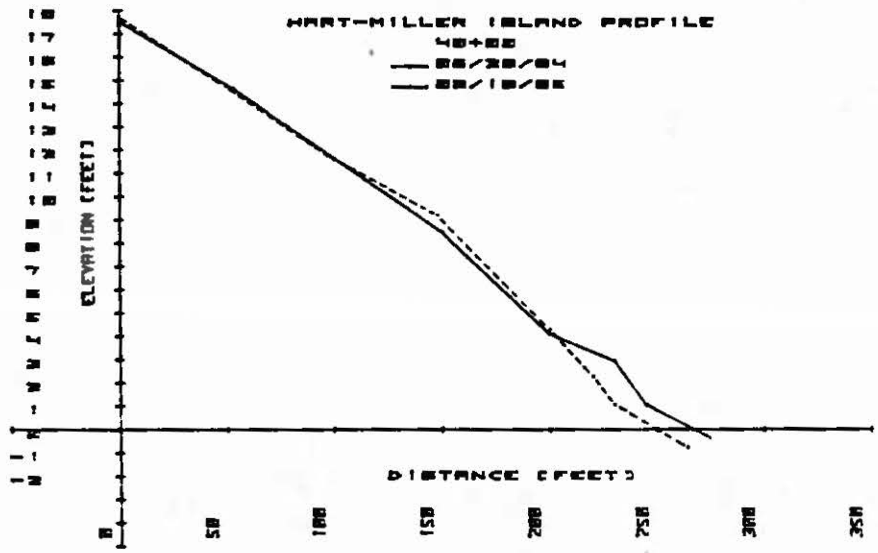


Figure B-22



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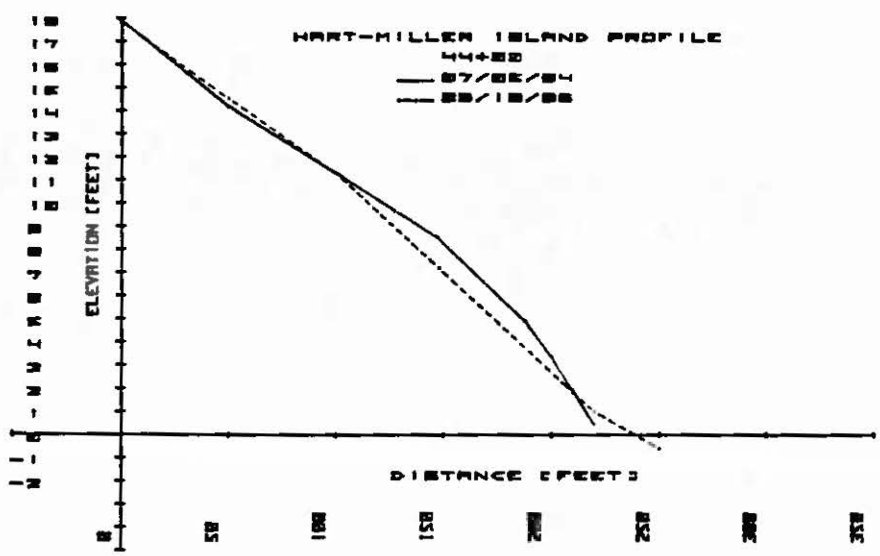

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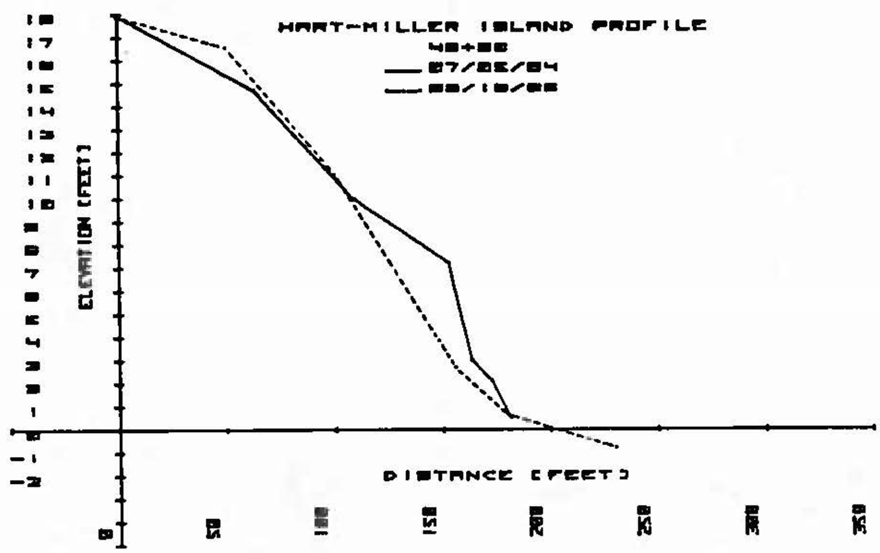

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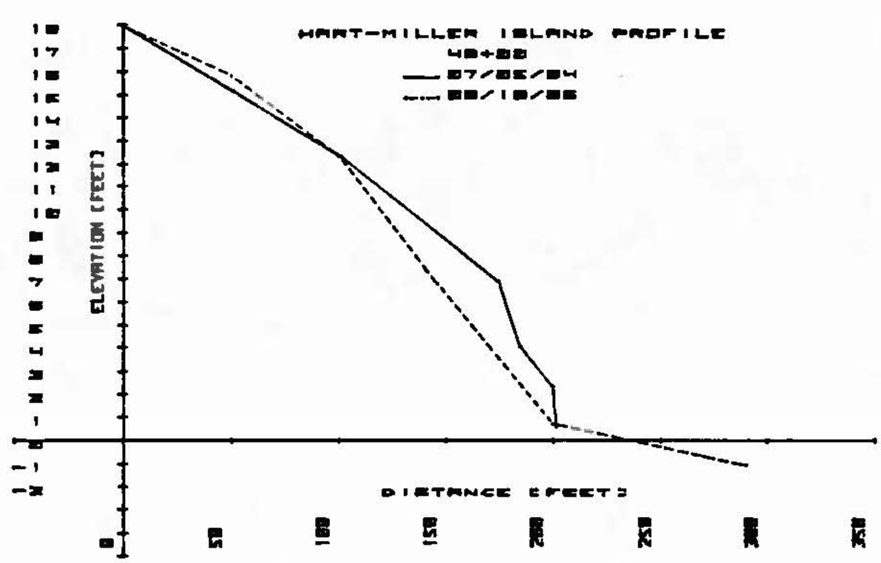

Figure B-26

Project III-Part 1
Benthic Studies

Maryland Department of Natural Resources
Tidewater Administration

University of Maryland
Center for Environmental and Estuarine Studies
Chesapeake Biological Laboratory

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ACKNOWLEDGEMENTS

Appreciation for assisting in this year's monitoring program is extended to Timothy Mulligan for help with the field collection and laboratory processing of the samples. Stanley Ostazeski and David Jenkins donated much of their personal time and SCUBA equipment in the collection of the epibenthic samples.

ABSTRACT

The benthic invertebrate population at Hart and Miller Islands in the upper Chesapeake Bay was monitored for possible effects from the recently constructed, now operational dredged material containment facility. Nearfield infaunal and epifaunal samples were taken along with reference samples in December 1985 and April and August 1986. A total of 26 species were collected from ten silt-clay stations, two oyster shell stations and one sand substrate station. A discussion on the role of the five dominant species and their year-to-year variability is included. The dominant species are the annelids *Scolecolepides viridis* and *Heteromastus filiformis*, the crustaceans *Leptocheirus plumulosus* and *Cyathura polita*, and the clam *Rangia cuneata*.

Species diversity (H') values were evaluated at each station. The highest diversity was found in August; the period of the year when predation on dominant benthic species was greatest. The highest diversity was at the oyster shell substrate stations. The length-frequencies of *R. cuneata* were compared at the nearfield and reference stations. Observations were also made on the clams *Macoma balthica* and *Macoma mitchelli*, which were not as abundant. Cluster analyses of the three sampling periods usually associated stations in response to bottom type. Recruitment and sampling variations could explain why some specific stations did not form tight groupings. An analysis of species diversity indicated that two nearfield stations were significantly different in August, presumably because of their sand and oyster shell substrates. During August and December significant differences were found at two stations surrounding the island. These stations, one with sand substrate and the other at the rehandling pier where tug traffic was concentrated, were low in total abundance. Faunal disruption at the latter station had occurred since 1984, when dredged material began to be unloaded at the facility.

Epifaunal populations followed the same seasonal pattern as in previous years. During the winter, populations at the 0-1 m depth were eliminated by ice movement and/or desiccation by exposure at low tide. The repopulation period in April was initiated by species capable of movement, not colonial species.

The results of the current monitoring effort suggest once again that only localized and temporary effects on the benthos are a result of the containment facility. These effects were limited to the area where dredged material was transferred from barges into the facility. They were believed to be caused by a washing-away of the bottom by the props of the tug boats. Discharge of effluent from the facility did not occur during this sampling year.

INTRODUCTION

This report represents the fifth year of consecutive benthic sampling for baseline and monitoring studies at Hart and Miller Island. Estuarine areas such as this, with wide seasonal salinity changes and vast shallow soft-bottom shoals, are important to protect because of the nursery feeding capabilities they provide to many commercial and non-commercial species of migratory fish and invertebrates.

Since it is an area that is environmentally unpredictable from year to year, it is important to maintain as complete a record as possible on all facets of the ecosystem. Holland (1985) completed an eleven-year study of a more stable mesohaline area farther down-Bay and found all macrobenthic species showed significant year-to-year fluctuations in abundance, primarily as a result of slight salinity changes. Based on that study, one can expect even greater fluctuations in this highly variable oligohaline portion of the bay.

Dredging-related activities at Hart and Miller Islands during the current monitoring year were concentrated at the rehandling piers where dredged material from barges was unloaded into the containment facility. The volume of material inside the dike had not reached a sufficient level for treated effluent to be discharged. It is anticipated that discharge will occur during the next sampling year.

METHODS

This year we sought to establish a network of stations surrounding the disposal area (Figure 1), instead of concentrating the sampling stations in two specific areas: the rehandling pier and the effluent spillway. Six nearfield stations were located along the eastern side of the dike, extending within 90 m from the northern end to the southern end. A station was also located about 180 m from the effluent pipes and another station was located about the same distance from the rehandling piers. Four reference areas were resampled during the year. They were HM16, a soft-bottom station located about 1.9 km southeast of the island; HM9, located on an oyster shell bottom about 36 m northeast of the island; HM22, a soft-bottom station located about 3.7 km north of the island; and HM7, located on soft bottom about 35 m northwest of the island. Station HM26, located at the mouth of Back River, was resampled this year as a monitoring check

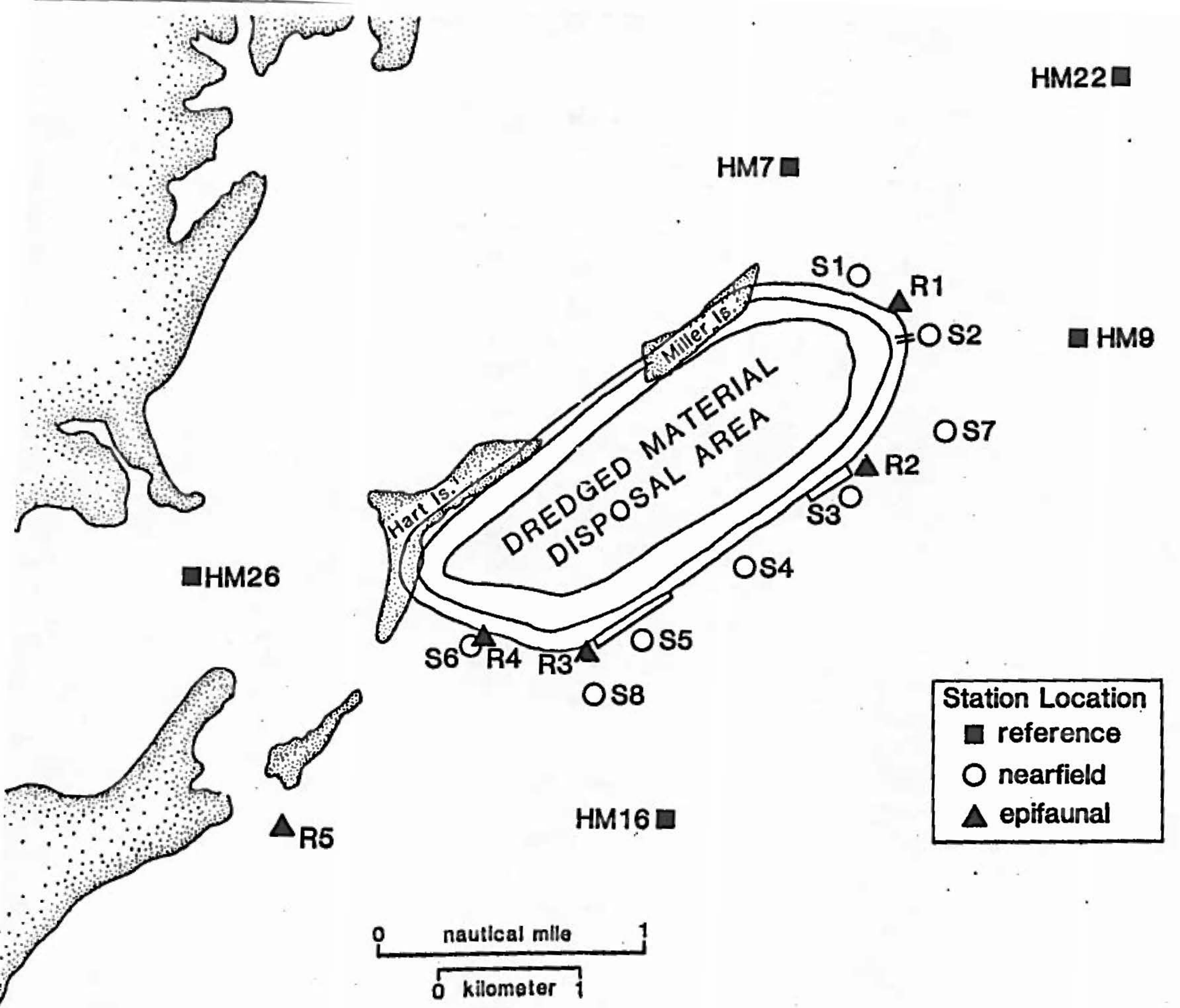


Figure 1. Benthic and epibenthic sampling station locations at Hart and Miller Islands.

of that critical area and its influences on the fauna to the west of the island. Epifaunal samples were obtained from pilings located about 25 m from the dike, at depths of 1 m and 3 m below the surface of the water. Finally, an epifaunal reference station, located on a navigational beacon at the Pleasure Island channel, was sampled this year.

These stations were sampled in December 1985, and in April and August 1986. Three replicate grabs were taken with a 0.05 μm Ponar grab at each benthic station for each sampling period. The samples were washed separately on a 0.7 mm screen, fixed in 10% formalin and later transferred to 70% ethyl alcohol. Each organism was removed, identified, and enumerated. Length-frequency measurements were made on mollusks.

Approximately 10 cm^2 was scraped from the pilings at the epifaunal stations by a SCUBA diver and treated similar to the infaunal benthic samples. A relative estimate of abundance was made for each species.

Stations were located with the research vessel's radar and LORAN C. Depths and bottom profiles were recorded from the ship's fathometer. Water temperature and salinity were measured at the surface and near the bottom of the water column at selected stations with an induction salinometer.

Since this was primarily monitoring and not an experimental investigation, qualitative comparisons with past studies prove to be as important and meaningful as numerical analysis. A method of rank analysis was used again to determine dominant species (Fager, 1957). The Shannon Wiener (H') diversity index was calculated for each station after data conversion to $base_2$ logarithms (Pielou, 1966). Stations were grouped according to numerical similarity of the fauna by cluster analysis (BMDP-77 Biomedical Computer Programs P-Series; Dixon and Brown, 1977). Analysis of variance and the Student-Neuman-Keuls multiple range test were used to determine differences in faunal abundance between stations (Nie et al. 1975). Friedman's non-parametric test (Elliott 1977) was used to compare mean numbers of species between several benthic samples.

RESULTS AND DISCUSSION

Since the beginning of the project in 1981, the dominant species have remained relatively stable in the different bottom types (Table 1). Soft bottoms have been preferred by *S. viridis* and the crustaceans *L. plumulosus* and *C. polita*. While the most common inhabitants of the predominately old oyster shell substrates were the barnacle, *Balanus* sp. the worm *Nereis succinea*, and the crustaceans *Melita nitida* and *Gammarus* sp.

This sampling year was no exception: only two other species, the clam *R. cuneata*, and the worm *H. filiformus*, were found in abundance during the annual high salinity period in August. *R. cuneata* does not prefer high salinities, but sudden freshwater inflows during the spring spawning period favored recruitment success, and the individuals reached sufficient size (5 mm) by August to be captured in the samples. If high salinities (>10 o/oo) persist throughout the winter, then large mortalities of this clam occur (Cain, 1975). The worm *H. filiformis* has a preference for the higher mesohaline area of an estuary. It is an opportunist with the ability to rapidly increase its progeny as favorable saline conditions arise. It also has been acknowledged as a nitrate enrichment indicator (Dean and Haskins, 1964), therefore large resident populations probably exist in nearby Back River. Station HM26, at the mouth of this river, had a large number of this species in April and also had the most diverse annelid fauna.

Table 1. Abundances of the three major species since inception of monitoring project. Based on reference station data only after Feb., May 1983.

Major Species	Aug. Nov. 1981	Feb. May, Aug.,Nov. 1982	Feb., May 1983	Sep. 1983 Mar. 1984	Oct. 1984 Apr. 1985	Dec. 1985 Apr., Aug. 1986
Scolecolepides						
Range/m²	0-1825	0- 286	0- 264		11-153	7-1287
Avg./m²	229	121	69	546	92	398
Leptochierus						
Range/m²	0-2960	0-5749	7-6626		20-441	7-1293
Avg./m²	832	1459	2259	614	272	308
Rangia						
Range/m²	0-46	0-99	0-135		0-75	0-273
Avg./m²	9	9	22	455	27	102

The worm *S. viridis* was the most numerically abundant organism at most stations, including, on occasion, the hard bottom stations where shells are interspersed with silt (Table 1). Over the course of these monitoring studies, *S. viridis* has alternated with the crustacean *L. plumulosus* as the foremost dominant species. It appears that slight modifications in the salinity patterns during the important seasonal recruitment period (late spring) play an important role in determining dominance. *L. plumulosus* becomes more abundant during the low salinity years while *S. viridis* prefers slightly higher salinities, as exemplified by a dry spring in the Susquehanna drainage, which favored *S. viridis.*

Occasionally, *C. polita* becomes one of the three dominants (Table 2). It appears to coincide with the abundance of *L. plumulosus*, since it also prefers low salinity and silt-clay substrates. It is more stable in population densities at all seasons than the other dominants and therefore does not score high on the Fager (1957) index. This species is tolerant of physical and chemical disturbances and repopulates areas such as dredged material disposal piles more quickly than other species (Pfitzenmeyer 1985).

All of the dominant species, with the exception of *R. cuneata*, brood their young. This is an advantage in an area of unstable and variable environmental conditions such as the upper Chesapeake Bay. Organisms released from their parents as juveniles are less susceptible to minor chemical and physical variations than gametes released into the water. Futhermore, there is evidence that a brooding adult may delay release of juveniles until near optimal conditions exist (Scheltema 1956).

Table 2. List of the three numerically dominant benthic species taken in each area and bottom type.

	DECEMBER 1985	APRIL 1986	AUGUST 1986
NEARFIELD			
SOFT BOTTOM			
	1. Scolecolepides viridis	1. Leptochierus plumulosus	1. Scolecolepides viridis
	2. Leptochierus plumulosus	2. Scolecolepides viridis	2. Leptochierus plumulosu
	3. Cyathura polita	3. Cyathura polita	3. Heteromastus filiformi
SHELL BOTTOM			
	1. Balanus improvisus	1. Scolecolepides viridis	1. Balanus improvisus
	2. Nereis succinea	2. Balanus improvisus	2. Melita nitida
	3. Melita nitida	3. Gammarus tigrinus	3. Nereis succinea
REFERENCE			
SOFT BOTTOM			
	1. Scolecolepides viridis	1. Scolecolepides viridis	1. Leptochierus plumulosu
	2. Cyathura polita	2. Leptochierus plumulosus	2. Rangia cuneata
	3. Leptochierus plumulosus	3. Cyathura polita	3. Cyathura polita
SHELL BOTTOM			
	1. No sample taken	1. Scolecolepides viridis	1. Balanus improvisus
	2.	2. Balanus improvisus	2. Melita nitida
	3.	3. Melita nitida	3. Heteromastus filiform
BACK RIVER REFERENCE			
SOFT BOTTOM			
	1. No sample taken	1. Scolecolepides viridis	1. Leptochierus plumulos
	2.	2. Heteromastus filiformis	2. Heteromastus filiform
	3.	3. Leptochierus plumulosus	3. Rangia cuneata

The endemic fauna are adapted to disturbance, and thus far they have shown no adverse effects from the containment facility. When there is a controlled disturbance such as a release of dredged material in the designated areas, a minimal time usually exists before benthic repopulation occurs. Repopulation begins almost immediately but the rate is dependent upon the season of disposal.

Observations at dredge sites throughout the Chesapeake region by Pfitzenmeyer (1981) showed that it takes about twelve months for most areas to recover if dredging takes place in the spring, as opposed to five months if dredging takes place in the early autumn.

Twenty-six species were collected at the nearfield stations (Table 3) compared to twenty-three species at the reference stations (Table 4). More intensive sampling in the nearfield area probably was responsible for the capture of three additional species. Moreover, the average number of individuals sampled at each station near the containment facility was greater; $140/m^2$ compared to an average of $1573/m^2$ at each reference station (Tables 3 and 4). Two nearfield stations, S4 and S5, which were close to the rehandling pier where most vessel activity was located, had the lowest population densities. Conversely, shell bottoms are known to have high diversities and high densities of individuals (Wells, 1961). Two of the shell stations were in the nearfield array as opposed to only one shell substrate reference station, which would effect the total number of individuals sampled. Additionally, the new fine substrates which are abundant near the containment facility (Wells et al. 1984), are attractive to detritus feeders, the predominant type of benthic population in this area. Sampling factors may have also contributed to lower observed faunal density at the reference stations.

Table 3. List of species and number per square meter of individuals collected at the nearfield stations for the three sampling periods.

	S1 5710			S2 5406			X1F4811 S3			X1F4715 S4			X1F4420 S5			X1F4327 S6			S7 X165405			X1F4124 S8		
	DEC 85	APR 86	AUG 86	DEC 85	APR 86	AUG 86	DEC 85	APR 86	AUG 86	DEC 85	APR 86	AUG 86	DEC 85	APR 86	AUG 86	DEC 85	APR 86	AUG 86	DEC 85	APR 86	AUG 86	DEC 85	APR 86	AUG 86
RHYNCHOCOELA (Ribbon worm)																								
Micrura leidyi			7			13	33	60	67	7	60	60		13	33	33	27	47			20	40	13	20
ANNELIDA (Worms)																								
Heteromastus filiformis		40	27	13	27	160		7	87	27		153	53		93	360	273	473	7	13	1047	33	53	67
Nereis succinea				167	7	260	93	27		73				20		80	27		813	13	20		7	
Eteone heteropoda										20			7			13								
Polydora ligni						7		7																
Scolecolepides viridis	60	6920	47		1707		447	2513	353	227	447	220		533	60	480	1093	433	7	867	1247	107	1427	113
Streblospio benedicti				20																				
Capitella capitata	7				13					7						7								
MOLLUSCA (Mollusks)																								
Ischadium recurvus						13														7				
Congeria leucophaeta						13															7			
Macoma balthica						13	7		13	20		7			7	27	13	160				13		27
Macoma mitchelli							20	7	13	20		13	27	13		80	93	27			20	27	60	20
Rangia cuneata	7		53			13	133	213	153	307	220	180		13	73	7		93			140	27		13
ARTHROPODA (Crustaceans)																								
Balanus improvisus				693	20	2453													693	993				
Balanus subalbidus				40		20													7					
Cyathura polita	20	13	20	13	53	13	87	73	133	127	113	133	73	87	180	187	120	153	20	7	120	207	127	100
Cassidinidea lunifrons						93														87				
Edotea triloba					7		13	20	7	7	7		7		7	53	20	20				7	13	7
Leptocheirus plumulosus		140	167		13		287	260	147	127	487	140	7	973	33	2880	1940	373			147	260	1513	220
Corophium lacustre		7	7	7	27	7		20		13				13		13				20	53		7	
Gammarus daiberi									33															
Gammarus tigrinus				7	220			53						7			20			73				
Melita nitida			13	60	20	220								13			7		260	287	7		33	
Chirodotea almyra		13	33						7															
Chironomid sp.			7		20																			
Rithropanopeus harrisi					13	153	7								7				107	60				
TOTAL	7608			6618			5393			3220			2359			9632			7169			4561		

Table 4. List of species and number of per square meter of individuals collected at the reference station for the three sampling periods.

	HM16			HM7			HM22			HM9			HM26		
	DEC 85	APR 86	AUG 86	DEC 85	APR 86	AUG 86	DEC 85	APR 86	AUG 86	DEC 85	APR 86	AUG 86	DEC 85	APR 86	AUG 86
HYMCHOCOELA (Ribbon worm)															
Micrura leidyi	13	27	27		13	20			27	7	7	33		27	47
ANNELIDA (Worms)															
Heteromastus filiformis	33	27	53		7	20	27	7	7			327		947	100
Nereis succinea	40	7		13			40	7		7	27	93		153	40
Eteone heteropoda	7														
Scolecolepides viridis	20	667	40	33	1220	7	340	1287	107	273	720	67		3507	34
Streblospio benedicti										7					
Capitella capitata	47									80					
MOLLUSCA (Mollusks)															
Macoma balthica	80	20	13	7			7								34
Macoma mitchelli	67	20	7		7	13	40			13				33	67
Rangia cuneata		7	13	213	120	180	273	160	153	67		40		13	93
Congera leucophaeta												7			
ARTHROPODA (Crustaceans)															
Balanus improvisus											387	1120			
Balanus subalbidus											7				
Cyathura polita	233	173	93	27	127	93	107	140	73	287	27	67		40	87
Cassidinidea lunifrons											20	107			
Edotea triloba		7			7		13			7				27	27
Leptocheirus plumulosus	1293	247	47	7	227	267	680	733	120	67	13			927	660
Corophium lacustre	7							7		7	33				
Gammarus daiberi											33				
Gammarus tigrinus											67				
Melita nitida	7							20			60	327			
Chironomid sp.						7	27	7			7				
Rithropanopeus harrisi											67	287			
TOTAL	3342			2635			4529			4772			6863		

These samples were from more varied bottom substrate and water depths, and were more widely distributed geographically. An unexplained low count in December contributed to HM7 having the lowest population density estimate of the reference stations.

Table 5 compares the densities of three numerically major species since sampling began in 1981. The range and average densities of individual species has varied considerably. Presently, *S. viridis* is the most numerous, but during the past sampling year, *L. plumulosus* was numerically dominant. *R. cuneata* is still considered to be a major species, because it has the capacity to completely dominate faunal abundance. However, not since the years 1974 to 1976 has it appeared in large numbers (Pfitzenmeyer and Millsaps, 1984). The low salinity conditions immediately following hurricane Agnes in 1972 made conditions favorable for *R. cuneata.*

Salinity at the three sampling periods during the past year is shown in Table 6. Periods of drought, which contribute to increased salinity, were characteristic of the year. While salinities at the time of sampling were similar to past observations, the generally higher salinities at critical times of the year were reflected in an increase in some benthic populations, e.g., *S. viridis.*

Species diversity values must be interpreted carefully in analyzing benthic data from the upper Bay. High diversity values generally reflect a healthy, stable fauna, with the number of all species in the population somewhat equally distributed and no obvious dominance by one or two species. However, in this area of the Chesapeake, studies indicate that the normal condition is for one species out of three to assume complete numerical dominance. This dominance is variable from year to year depending on environmental factors, primarily the

Table 5. Abundances of the three major species since inception of monitoring project. Based on reference station data only after Feb., May 1983.

Major Species	Aug. Nov. 1981	Feb. May, Aug., Nov. 1982	Feb., May 1983	Sep. 1983 Mar. 1984	Oct. 1984 Apr. 1985	Dec. 1985 Apr., Aug. 1986
<u>Scolecolepides</u>						
Range/m²	0-1825	0- 286	0- 264		11-153	7-1287
Avg./m²	229	121	69	546	92	398
<u>Leptochierus</u>						
Range/m²	0-2960	0-5749	7-6626		20-441	7-1293
Avg./m²	832	1459	2259	614	272	308
<u>Rangia</u>						
Range/m²	0-46	0-99	0-135		0-75	0-273
Avg./m²	9	9	22	455	27	102

Table 6. Bottom water salinities and temperatures recorded during the three sampling periods.

Stations	Dec. '85		Apr. '86		Aug. '86	
	Bottom Sal °/oo	Bottom Temp °C	Bottom Sal °/oo	Bottom Temp °C	Bottom Sal °/oo	Bottom Temp °C
NEARFIELD						
S1			.2			
S3					6	
S5	5.3	6.4			6	
S6	5.3	5.9				
R2			.2			
REFERENCE						
HM 7	3.5	5.3	.2			
HM 9	4.0	5.6			6	
HM16					7	
HM22	4.0	5.7	.5			
HM26			.4			

amount of freshwater entering the Bay from the Susquehanna River. Because of the overwhelming numerical dominance of a few species, diversity values are low in this productive area of the Bay when compared to values obtained elsewhere.

Again this year, the highest species diversity (2.3971) was found during the summer, specifically in August (Table 7). As postulated in the First Interpretive Report (Pfitzenmeyer, Johnston, and Millsaps, 1982), predator populations (fish and crabs) were highest in summer. This would result in a reduction of the most abundant food species, which in turn would reduce prey dominance. Food organisms are easiest for predators to obtain in soft bottoms. However, on shell bottoms, the prey species are less susceptible to predation. Therefore, the number of individuals remained comparatively high in August.

More species are also found on shell bottoms because of the diverse niches, but dominance by one or two species still keeps diversity values lower than normally could be expected. In spring, diversity values are lowest, probably because of the effects of predation and the rigors of winter (Table 8).

During April only one area (S1), north of the containment facility, indicated some stress in the population structure. Samples taken in December 1985 at this station revealed only seven individuals, in two replicates, and zero in a third (Table 9). Subsequent samples in December and August showed more normal populations, although the species diversity value was comparatively low for April (0.2390). This resulted from the overwhelming dominance of the worm *S. viridis* in six of the samples. This area (S1) is shallow (1.5 m) with an unstable sand substrate (Wells, Conkwright, and Hill, 1985). Populations of benthic invertebrates have always been variable here (Pfitzenmeyer et al. 1984), and therefore are not the result of the containment facility activities.

Table 7. Number of species and individuals per 3 grabs (.05 m each) found at corresponding stations for August 1986. Also shown are bottom substrate, species diversity (H'), and dominance factor (S.I.).

	SUBSTRATE	NO. SPECIES	NO. INDIVIDUALS	SPECIES DIVERSITY (H')	DOMINANCE S.I.
NEARFIELD					
S1	Sand	10	63	2.5715	.2305
S2	Shell	15	533	1.7503	.4948
S3	Silt/Clay	10	151	2.6748	.1984
S4	Silt/Clay	8	136	2.6162	.1770
S5	Silt/Clay	10	75	2.6090	.2099
S6	Silt/Clay	9	267	2.6184	.1932
S7	Shell	11	424	1.9822	.3390
S8	Silt/Clay	9	88	2.5130	.2249
REFERENCE					
HM16	Silt/Clay	8	44	2.6307	.1911
HM 7	Silt/Clay	8	91	2.0455	.3078
HM22	Silt/Clay	6	73	2.2288	.2340
HM 9	Shell	11	401	2.6044	.2341
BACK RIVER REFERENCE					
HM26	Silt/Clay	10	178	2.3301	.3358
AVERAGE		10	194	2.3971	.2592

Table 8. Number of species and individuals per 3 grabs (.05 m each) found at corresponding stations for April 1986. Also shown are bottom substrate, species diversity (H'), and dominance factor (S.I.).

	SUBSTRATE	NO. SPECIES	NO. INDIVIDUALS	SPECIES DIVERSITY (H')	DOMINANCE S.I.
NEARFIELD					
S1	Sand	6	1070	.2390	.9415
S2	Shell	13	322	1.2665	.6439
S3	Silt/Clay	12	489	1.3657	.6063
S4	Silt/Clay	6	200	2.0300	.2820
S5	Silt/Clay	10	253	1.5864	.4361
S6	Silt/Clay	11	545	1.8168	.3832
S7	Shell	11	364	2.0646	.3120
S8	Silt/Clay	10	488	1.5903	.4109
REFERENCE					
HM16	Silt/Clay	10	180	1.9093	.3734
HM 7	Silt/Clay	8	259	1.4295	.5268
HM22	Silt/Clay	9	355	1.6595	.3997
HM 9	Shell	14	221	2.3117	.3154
BACK RIVER REFERENCE					
HM26	Silt/Clay	9	851	1.6150	.4374
AVERAGE		11	428	1.6612	.4668

Table 9. Number of species and individuals per 3 grabs (.05 m each) found at corresponding stations for December 1985. Also shown are bottom substrates, species diversity (H'), and dominance factor (S.I.)

	SUBSTRATE	NO. SPECIES	NO. INDIVIDUALS	SPECIES DIVERSITY (H')	DOMINANCE S.I.
NEARFIELD					
S1	Sand	4	14	1.4299	.4693
S2	Shell	9	153	1.5990	.4945
S3	Silt/Clay	10	181	2.4503	.2319
S4	Silt/Clay	13	177	2.7454	.1900
S5	Silt/Clay	6	26	2.0061	.3018
S6	Silt/Clay	14	634	1.7289	.4874
S7	Shell	8	287	1.8329	.3337
S8	Silt/Clay	9	108	2.4139	.2431
REFERENCE					
HM16	Silt/Clay	12	283	1.7414	.4913
HM 7	Silt/Clay	6	48	1.5587	.4792
HM22	Silt/Clay	10	233	2.2738	.2772
HM 9	Silt/Clay	11	124	2.3861	.2527
BACK RIVER REFERENCE					
HM26	No sample taken.				
AVERAGE		9	189	2.0079	.3543

Three species of mollusks were measured to the nearest mm in shell length to determine if any growth differences were noticeable between the reference and nearfield areas (Figure 2). The most abundant clam was *R. cuneata* which possesses two cohorts in the Hart and Miller Islands Region. The largest and most numerous clams had a length of 36 mm (mode) in December and April. By August the mode increased to 39 mm. It is believed that this cohort is made up of several year classes which are near the maximum size of *R. cuneata* in this area of the Bay. The smallest size group of *R. cuneata* in December and April, which represented the previous summer's spawning, was less than 5 mm. No differences between reference and nearfield areas could be observed from the frequency distributions. The slightly smaller total number of individuals collected at the reference stations was because less stations were sampled.

Several consecutive years of above normal salinities during the summer spawning season resulted in a larger population of *M. mitchelli* than *M. balthica*. Not enough specimens were collected in the samples for any critical appraisals to be made. However, the observed range of *M. mitchelli* was from 1 to 15 mm. This would indicate that several year classes fall in this wide range of individuals. *M. balthica* was less numerous than *M. mitchelli* at all areas except the nearfield stations during August. This 4-10 mm cohort represented the summer 1986 recruitment.

Cluster analysis was employed again this year to study relationships among groups of stations, based upon the numerical distribution of the numbers of species and individuals. Stations with faunal similarity (based on chi-square statistics derived from the differences between the values of the variables for two stations), are linked by horizontal connections in the dendrogram (Figs. 3-5). Initially, each station was considered to be a cluster of its own. At each

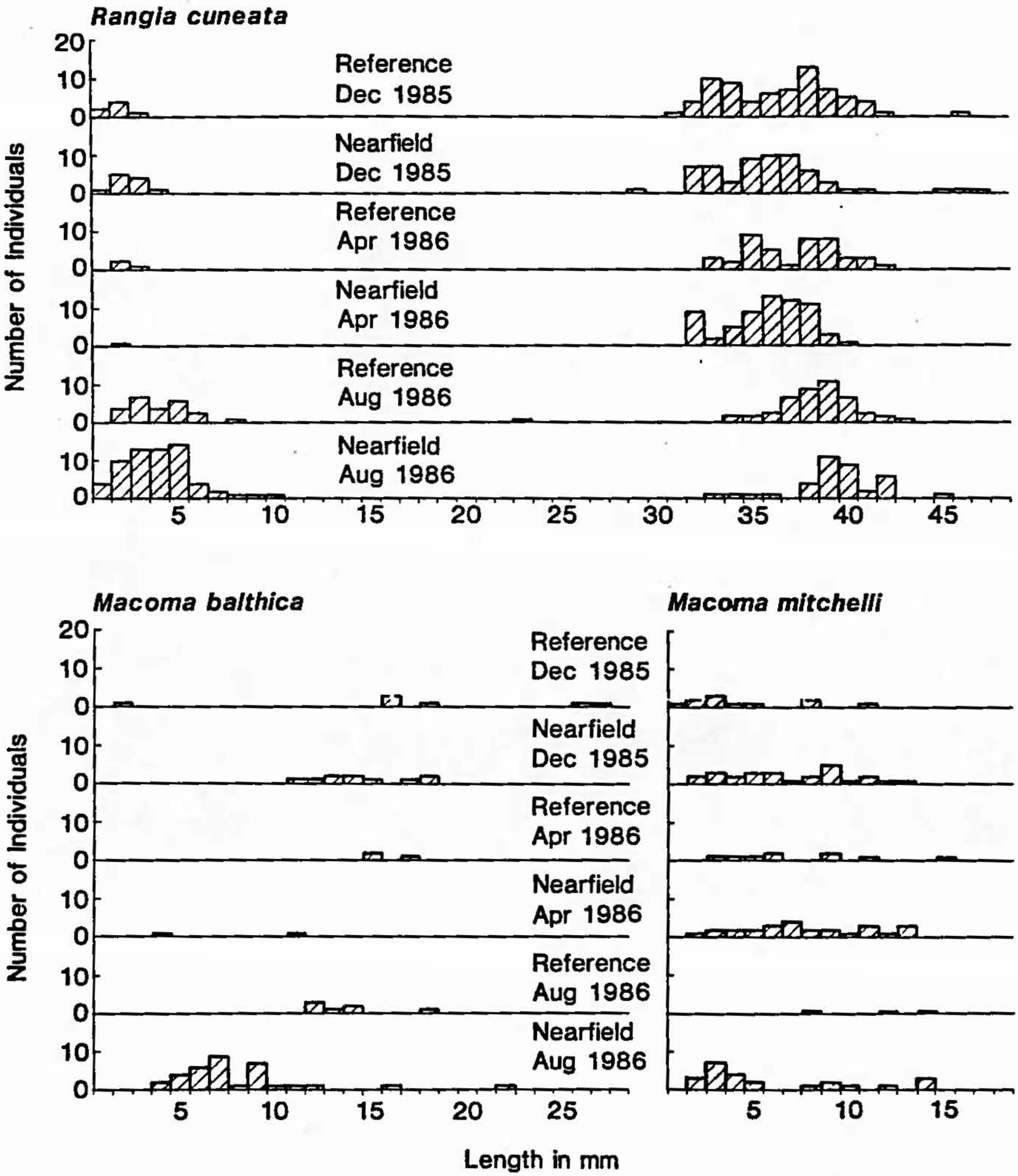


Figure 2. Length frequencies of the three major molluscan species sampled in December, April and August.

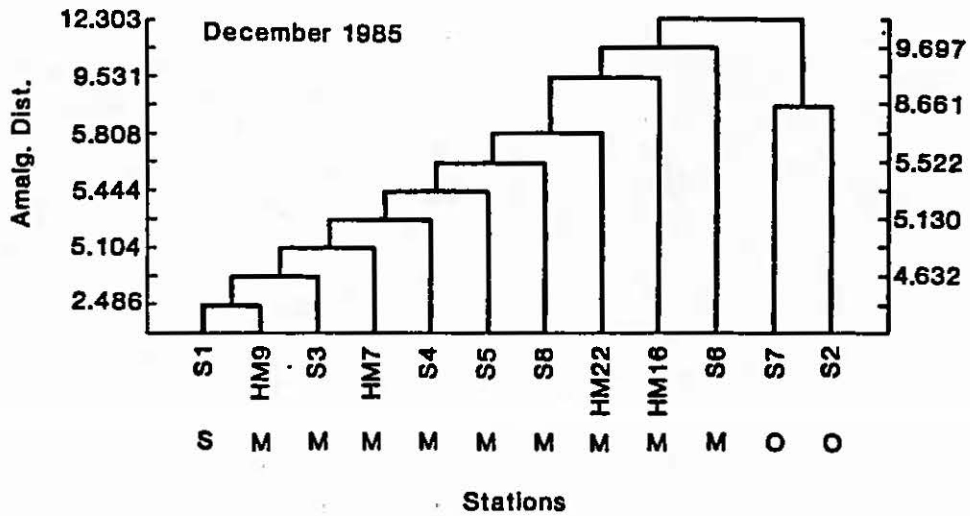


Figure 3. Cluster analysis for December 1985.

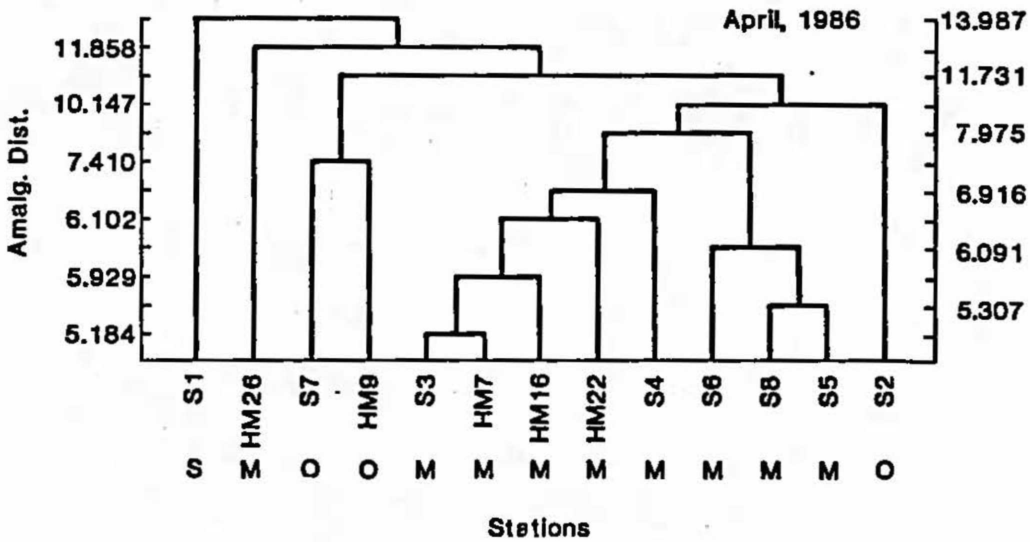


Figure 4. Cluster analysis for April 1986.

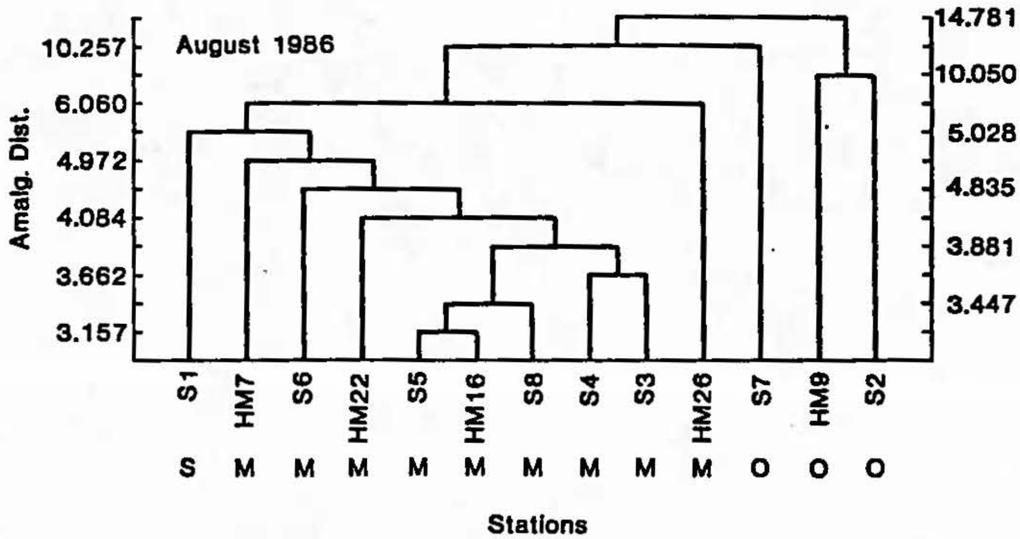


Figure 5. Cluster analysis for August 1986.

step (amalgamated distance), the clusters with the shortest distance between them were combined (or amalgamated) and treated as one cluster. This progression of combining clusters continued until all the stations were combined into one cluster. Unusual or close groupings and the relationships of stations can be explained most of the time through experience and familarity with the area under study. When it can not be explained, then extraneous influences must be investigated further.

In December, the relationships for eight stations were close and formed a step-wise progressive dendrogram, (Figure 3). A grouping of two stations (S7 and S2), both shell bottom, interrupted this progression. Both of these shell bottom stations had fauna similar to each other, but decidedly different from the basic grouping of soft bottom stations. They were the last group to be added on the dendrogram. Two stations, HM16 and S6, connected the two disparate groups to form a single tree. These connecting stations were related in that they had the highest number of species as well as a similar faunal makeup. Based on this analysis for December, there was no unexplainable or unusual station arrangement or connection. Therefore, the fauna surrounding the containment facility appeared to have normal patterns of abundance and distribution.

In April, the basic grouping was formed by a joining of nearfield and reference stations (Figure 4). This similarity is desirable and is an indication of no anomalous activity. It also indicates an appropriate selection of reference stations. Shell bottom stations (S7 and HM9) formed a tight cluster and joined the basic grouping just after S2, another shell station. Station HM26 at the mouth of Back River was not selected as a reference station, but selected out of interest for its occasionally unusual faunal distribution. Station HM26 was the next-to-last to join the dendrogram. The last station, S1, retained its unusual characteristics in April. It has less than the average number of species, but more than twice the average number of individuals. This was due to one species, the worm *S. viridis*. As pointed out in the description of diversities, this station was different due to bottom type (sand) and depth (1.5 m) which often results in an unstable and unusual faunal composition.

August represented the season of recruitment for most of the benthic species, but also represented a period of stress from predation, high salinity, and high water temperatures. These stresses probably had a moderating effect on the dominant species, keeping their populations in check. Again, a mixture of nearfield and farfield soft bottom stations formed the shortest amalgamated distances in the dendrogram (Figure 5). Station S1, with the sand substrate discussed above, was the last to join this grouping. The Back River station (HM26), known for its unusual fauna, then joined the dendrogram, even though the station has soft sediments. The inherent characteristics of this station were probably the result of Back River water quality, which influenced the faunal composition and kept it separate from the other stations.

Last to join the cluster, were the shell substrate stations (S7, HM9, and S2). These stations were a large amalgamated distance from the soft bottom stations. The cluster formed during this sampling period represented a normal grouping with no isolated stations. These clusters were consistent with earlier studies which primarily grouped stations according to bottom type. If these fauna were affected by some extraneous force it would definitely appear in the groupings, and no such indications were found during the three sampling periods.

The Student-Neuman-Keuls multiple range test was used to determine if a significant difference could be detected when population means of benthic invertebrates were compared at the various sampling stations. The total number of individuals of each species was transformed ($\log_2$) before the analysis was performed. Subsets of groups, the highest and lowest means of which do not differ by more than the shortest significant range for a subset of that size, are listed as homogenous subsets.

In April 1986, the station most significantly different ($p<0.05$) from the greatest number of other stations (10) was HM26, the station at the mouth of Back River (Table 10). The probable cause for this was the large number of three species: the worms *H. filiformis* and *S. viridis*, and the crustacean *L. plumulosus*. Station HM26 was most similar to HM7 and HM22. Both were soft-bottom reference stations with similar fauna. The only reference station that HM26 did not have a close relationship to was HM9, the shell substrate station. HM9 was more similar to the nearfield stations. Based on this analysis for April, it appears that there are two groups of stations--the nearfield and the reference stations. No one station was isolated from the others. Even though there appeared to be two groups, the stations within the groupings were inter- related. The one-way analysis of variance, F-test, did not indicate significant differences between stations.

In August, reference stations HM22 and HM16 were significantly different from the rest of the stations (Table 11). Station S8 was the only nearfield station grouped with the remaining reference stations. Nearfield station S1, which had a sand substrate, and S2, which had a shell substrate, were significantly different from all other nearfield stations. The remaining stations formed a separate group. As in April, reference stations and nearfield stations formed discernable groups, with only nearfield station S8 not significantly different from HM9. In the analysis of variance for this sampling period, there was no significant differences between or within groups of stations.

Table 10. The Student-Neuman-Keuls test of significance among means of individuals per station for April. Subsets show grouping of stations not significantly different (P <0.05). Stations in a vertical column and row by themselves are significantly different from others.

APRIL 1986

SUBSET	STATION NUMBERS												
1	S2	S3	S1	S5	S6	S7	HM9						
2		S3	S1	S5	S6	S7	HM9	S4					
3			S1	S5	S6	S7	HM9	S4	S8				
4					S6	S7	HM9	S4	S8	HM16			
5								S4	S8	HM16	HM7	HM22	
6											HM7	HM22	HM26

ANALYSIS OF VARIANCE

SOURCE	D.F.	SUM OF SQ.	MEAN SQ.	F.	F PROB
Between gps.	12	95088.5	7924.0	11.9	.00
Within gps.	26	17274.0	664.4		
TOTAL	38	112362.5			

Table 11. The Student-Neuman-Keuls test of significance among means of individuals per station for August. Subsets show grouping of stations not significantly different (P <0.05). Stations in a vertical column and row by themselves are significantly different from others.

AUGUST 1986

SUBSET	STATION NUMBERS										
1	S1										
2		S2									
3			S3	S5							
4				S5	S4						
5					S4	S6					
6						S6	S7				
7							S8	HM9			
8								HM9	HM7		
9									HM7	HM26	
10										HM16	
11											HM22

ANALYSIS OF VARIANCE

SOURCE	D.F.	SUM OF SQ.	MEAN SQ.	F.	F PROB.
Between gps.	12	45658.4	3804.9	113.4	.00
Within gps.	26	872.5	33.6		
TOTAL	38	46530.9			

Analysis of the December 1985 data by this method did not indicate anything unusual (Table 12). Reference stations HM7 and HM22 were significantly different ($p<0.05$) from the rest, and only nearfield stations S7 and S8 were connected to HM9 and HM16. Stations S7 and S8 are located 100 meters from the dike and, therefore, in about the same depth of water as HM9 and HM16. The analysis of variance for this period did not indicate any significant difference between or within groups.

For the three sampling periods only one station (S1) stood out from the others. This station, which is located north of the island, is the only one in shallow water (1.5 m) and with a sand substrate. Because of these differences, its population could be expected to vary somewhat.

Friedman's test for differences in the means of samples taken in similar bottom types for nearfield and reference areas was calculated. The results of this non-parametric test are presented in Table 13. Significant differences ($p<0.05$) were found at stations surrounding the island during the December and August sampling periods. During these two periods, two stations (S1 and S5), had low numbers of individuals. The uniqueness of station S1 due to sand sediments and shallowness was discussed earlier. Station S5 also had a lower number of individuals than the other stations, except during the April sampling period. This station is located near the rehandling pier. An unusual flocculent layer of detritus over a clay substrate was observed at Station S5 in December. Barge and tug activity prior to the sampling period at this area may have affected the fauna. Faunal distribution has occurred at this station since 1984 (Pfitzenmeyer et al. 1985).

Table 12. The Student-Neuman-Keuls test of significance among means of individuals per station for December. Subsets show grouping of stations not significantly different (P <0.05). Stations in a vertical column and row by themselves are significantly different from others.

DECEMBER 1985

SUBSET	STATION NUMBERS										
1	S1	S2	S3								
2		S2	S3	S4							
3					S6	S5					
4							HM9	HM16	S8	S7	
5											HM22	
6												HM7

ANALYSIS OF VARIANCE

SOURCE	D.F.	SUM OF SQ.	MEAN SQ.	F.	F PROB
Between gps.	11	28320.5	2574.6	92.4	.00
Within gps.	24	668.7	27.9		
TOTAL	35	28989.2			

Table 13. Results of Friedman's non-parametric test for differences in abundances of selected dominated species between stations.

	SOURCE	D.F.	X^2	$X^2(.05)$
DECEMBER				
	Nearfield	5	22.2*	11.07
	Reference	3	3.6	7.82
	Nearfield & Reference	8	22.5*	15.51
APRIL				
	Nearfield	5	7.8	11.07
	Reference	2	3.6	5.99
	Nearfield & Reference	8	10.3	15.51
AUGUST				
	Nearfield	5	14.4*	11.07
	Reference	3	2.4	7.82
	Nearfield & Reference	8	22.3*	15.51

* Significant difference at 5% level.

There were no significant differences between the three reference stations of similar bottom type (HM16, HM7 and HM22). However, when the reference stations and the nearfield stations were tested together there was a significant difference for December and August. This is probably a result of the two stations, S1 and S5, since no difference was indicated in April. At that time, all nearfield and reference stations were statistically equivalent.

The affected area of fauna at these two stations was relatively small, since neighboring stations did not indicate any reduction. The difference at station S1 is not the result of the containment facility, but the result of an environmentally different area. The other area (S5) becomes disturbed with barge activity which washes the bottom and redistributes the fauna. As shown, the area becomes recolonized with animals when barge activity lessens.

The same scenario was found again this year with regard to the densities and distribution of epifaunal species on the pilings. The results of this study are presented in Table 14. By spring (April), species begin to recolonize the first meter of depth on the piling which was scoured by ice formation and desiccated by low tides during the winter. Species found in this upper zone in April were all individuals capable of movement on their own. Colonial and sedimentary species were found at the 1.5 m level in spring. No species were found at the 0.5 m depth on the reference piling, R5. This is located in an area more exposed to wind and wave action than the pilings surrounding the containment area. Four species were found at the 1.5 m depth at this sampling time.

By August and also in December, the growth and development of epifaunal species was almost evenly distributed along the pilings. The same eleven species were found this year as last year. The most abundant and wide-spread species was the amphipod, *Corphium lacustre*. This tiny crustacean is very opportunistic and

Table 14. Species in descending order of density and depth found on the pilings surrounding the containment facility and reference area for the three sampling periods.

DECEMBER 1985

Stations R1 - R4		Reference R5	
.5 m	1.5 m	.5 m	1.5 m
Corophium	Corophium	Corophium	Corophium
Nereis	B. improvisus	Nereis	Nereis
Polydora	Nereis	Polydora	Poldora
B. improvisus	Polydora	B. improvisus	B. improvisus
Scolecolepides	B. subalbidus	B. subalbidus	B. subalbidus
Victorella	Victorella	Victorella	Victorella

APRIL 1986

.5 m	1.5 m	.5 m	1.5 m
Corophium	Corophium	0	Corophium
Gammarus	B. subalbidus		B. improvisus
Nereis	Scolecolepides		Chironomid
Scolecolepides	Nereis		Nereis
Chironomid	Chironomid		
	Cordyolphora		

AUGUST 1986

.5 m	1.5 m	.5 m	1.5 m
Corophium	Corophium	Corophium	Corophium
Victorella	Cordylophora	Victorella	Victorella
Cordylophora	Victorella	B. subalbidus	B. subalbidus
B. subalbidus	B. subalbidus	Nereis	Nereis
Nereis	B. improvisus	B. improvisus	Polydora

is protected on the pilings by living in tubules formed from detritus. It is not limited to pilings, but also lives on shells or other hard surfaces on the bottom. It was also the most abundant species found in previous years. Once again, no zonation of species was evident on these pilings. The same species found at the first meter were found at 1.5 m surrounding the containment facility. Because the area is relatively shallow, restrictions to specific depth should not be expected. This also is a factor worth noting should any spill or leakage from the facility occur.

CONCLUSIONS AND RECOMMENDATIONS

From a population of 26 species, five species remain numerically dominant on soft bottoms. They are the annelids *S. viridis* and *H. filiformis*, the crustaceans *L. plumulosus* and *C. polita*, and the clam, *R. cuneata*. On the limited oyster shell substrates, the crustaceans *Balanus* sp., *M. nitida*, and *Gammarus* sp., and annelids *S. viridis* and *N. succinea* are the most abundant. Yearly, as well as seasonal variations in salinity determine the position of dominance of these species.

The average number of individuals per square meter was greater at the nearfield stations then the reference stations. This is believed to be a result of substrate differences, more specifically, the recent finer sediments close to the dike.

The highest average species diversity values were found during the August sampling period. Predation is greatest at this summer period. The most abundant benthos, which are important food organisms, are consumed, resulting in more even populations among the benthic species.

Length frequencies and cohorts among molluscan species living close to the containment facility were comparable to populations at the reference stations.

A cluster analysis grouped stations of similar faunal composition in response to sediment type. Stations in the three diagrams which were isolated from their common grouping were not due to facility-related causes. The Back River station was consistently separated from other station groupings.

The Student-Neuman-Keuls multiple range test indicated significant differences in fauna at stations with the sand and oyster shell substrates.

Friedman's non-parametric test indicated significant differences at near-field stations with unusual bottom types as well as at one station at the rehandling pier. This station was located in the area of heavy barge and tug activity and was the only measured Facility-related effect on the benthic fauna.

Epifaunal species were absent on some pilings and sparse on others in the 0-1 m depth zone in April. It is believed that ice movement and dehydration during low winter tides contributed to this loss. By August, repopulation was uniform along the pilings.

It is recommended that the infauna and epifauna continue to be sampled at the established locations in the following year. This should be the first year for the complete operation of the designed containment facility, and its effects on the fauna should be monitored. Station locations and sampling techniques should be kept the same as in the previous year, to eliminate as much variation as possible.

Project III-Part 2- Fish Studies

Department of Natural Resources
Tidewater Administration
Tidal Fisheries Division

James Casey

INTRODUCTION

Major engineering projects in both tidal and non-tidal waters can considerably alter the natural ecosystem over a wide area. Such projects can have both positive and negative effects on the local biota. Significant amounts of data must be collected to document these effects. This data can then be interpreted and used to formulate management strategies that will minimize the adverse effects and enhance the positive effects. Data for this report was collected both prior to and during construction of the Hart and Miller Islands Facility, as well as during its operation as a containment facility. Use of the area by finfish and crabs is considerable; the structure may function as a artificial reef, although induced currents along the south and east faces may reduce its use by some desirable species.

METHODOLOGY

Three gear types were used during the 1985-1986 sampling period: trawls, seine and eel pots. Although fish traps were used during previous sampling periods, they were dropped from the 1985-1986 sampling period because they rarely caught a representative sample of species available and they were frequently lost to boat traffic. Trawl catches were more representative and the problem of "ghost" pot fishing could also be avoided.

Salinity, temperature depth and bottom type were recorded at each site. Biometric data were recorded for striped bass, *Morone saxatilis*; white perch, *Morone americana*; yellow perch, *Perca flavescens*, and channel catfish, *Ictalurus punctatus*, whenever possible.

This year, only six eel pots were deployed instead of the 20 eel pots that were used last year. This was due to a very low eel catch and also due to the loss of eel pots to boating traffic. The six pots used this year were sufficient to monitor the presence of eels in the area.

Bottom Net Trawls

Trawl samples were taken from the R\V Miss Kay at eight of the original ten stations used by Tsai & Millsaps (1982; Figures 1 and 2; Table 1). A similar trawl (7.5 m width, 0.5 cm mesh cod end) was used at five additional stations (Figure 3). These five stations were generally within 35 m of the rock revetment, while the other stations were considerably farther offshore. Target species were measured for length, and tissue samples of white perch and blue crab, *Callinectes sapidus*, were taken for analysis of toxic organics and heavy metals. The following data was recorded for each station:

1. Catch number by species;
2. Catch per unit effort, by species (CPUE);
3. Diversity index by station;
4. Salinity and temperature.

Haul Seine Sites

The seine sites sampled (Figure 2) were the only suitable ones remaining after completion of the structure. One site, HMS-2, had undergone severe shore erosion and resultant shoaling. This is in the public access beach area and is heavily used by local residents during the summer.

A standard beach seine (61 m long by 1.8 m deep, 591 m^2) was set from a boat and paid out in a semi-circle with one end anchored on shore. The net was brought in by hand. The catch was recorded as outlined below:

1. Number of species and aggregate weight of catch by species (with

Figure 2

THE HART - MILLER ISLAND CONTAINMENT FACILITY

SAMPLE SITE LOCATIONS

- seine & inshore trawl sites only -

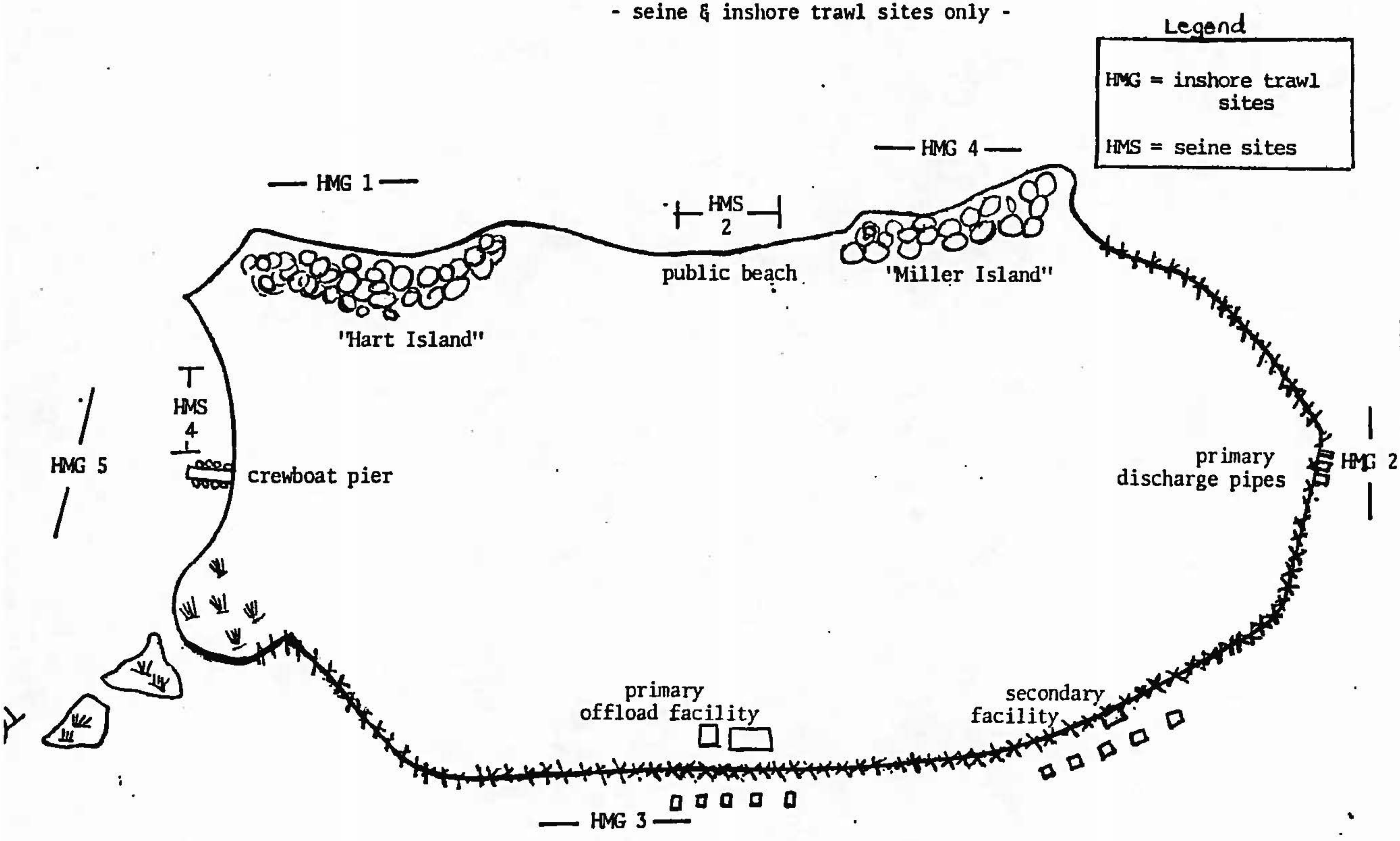


Table 1 LORAN C SITES- OFFSHORE TRAWLS

Station No.	Begin Run Latitude-Longitude	End Run Latitude-Longitude
10	39°12'44" 76°24'27"	39°13'03" 76°23'49"
9	39°12'28" 76°23'17"	39°12'52" 76°22'39"
2	39°14'06" 76°22'23"	39°14'16" 76°21'43"
1	39°14'17" 76°22'03"	39°14'31" 76°21'29"
4	39°14'24" 76°20'20"	39°14'47" 76°20'00"
6	39°15'45" 76°20'00"	39°16'13" 76°20'04"
5	39°15'32" 76°20'32"	39°15'56" 76°20'46"
7	39°15'37" 76°22'36"	39°15'32" 76°23'05"

Table 6 BEACH SEINE May 1986

Station	HMS2		HMS4		HMS5	
Species	No.	CPUE	No.	CPUE	No.	CPUE
Spot	1	17	2	34	13	220
Yellow perch					2	34
White perch			1	17	27	56
Brown bullhead					1	17
Atlantic silverside	80	1351	166	2804	66	1115
Striped killifish	3	51				501
Banded killifish	11	186				
Bay anchovy			3	51		2
Menhaden			30	507	19	321
Blue crab			1	17		2
Pumpkinseed			1	17		
Gizzard shad					2	34
Pipefish					2	34
Grass shrimp	12	203				
TOTAL	107		204		179	
		$\bar{d}$=1.21		$\bar{d}$=.92		$\bar{d}$=2.33

The offshore trawl sites were located a minimum of several hundred meters from the rock revetment. Approximately 45% of all trawl-caught species were taken at the open water offshore trawl sites. Altogether, a total of 5,784 individuals representing 13 species were collected at the offshore trawl sites. This catch was more than double that of the 1984-85 sampling season. The bulk of the catch, 79%, was made in the May 1986 sample. Although the spring samples of 1985 and 1986 were taken within two weeks of each other, the early spring warming trend in 1986 left the waters an average of 4.0°C warmer. Table 7 lists the catch by species for the two sampling periods. The respective CPUE and diversity determinations are listed in Table 8.

There was little consistency when this year's catches were compared with catches of previous years. For example, the catch of white perch increased from 227 in 1983-84 to 1,883 in 1984-85 and then declined to 119 for the 1985-86 season. Similarly, no bay anchovy were taken in the 1984-85 sample period, while 5,176 (90% of the catch) were taken in the 1985-86 period. Other species, as illustrated below, also fluctuated.

Species	1983-84	1984-85	1985-86
White perch	227	1,883	119
Bay anchovy	493	0	5,173
Blue crab	101	200	201
Spot	564	666	206
Harvestfish	0	1	44
Striped bass	10	9	3

Table 7 **OFFSHORE TRAWLS: CATCH BY STATION** OCTOBER 1985

STATION	HMT1	HMT2	HMT4	HMT5	HMT6	HMT7	HMT9	HMT0	Totals
Species									
White perch			6						6
Spot	22	23	8	38	2	16	11	85	205
Hogchoker	1								1
Bay anchovy	32	37	19	100	29	300	57	250	824
Blue crab	24	10	6	12	17	6	11	32	118
Harvestfish	2							42	44
Striped bass			1						1
Bluefish				1				1	2
Carp				1					1
Sea trout					1		1	1	6
Totals	81	70	40	152	49	322	80	414	1208

OFFSHORE TRAWLS: CATCH BY STATION May 1986

STATION	HMT1	HMT2	HMT4	HMT5	HMT6	HMT7	HMT9	HMT0	Totals
Species									
White perch	4	10		19	5	19	8	48	113
Spot			1						1
Hogchoker	1								1
Bay anchovy	365	667	524	704	719	542	301	530	4352
Blue crab	7	8	7	3	8		20	30	83
Menhaden			1		9			4	14
Striped bass			1			2			2
Yellow perch				1	1				2
Silverside				1					1
Carp					1				1
Brown bullhead						5		1	
Totals	377	685	533	728	743	568	329	613	4576

Table 8 OFFSHORE TRAWLS: CPUE and DIVERSITY October 1985

STATION	HMT1	HMT2	HMT4	HMT5	HMT6	HMT7	HMT9	HMT0	Totals
Species									
White perch	4	10	18						
Spot	66	69	24	114	6	48	33	254	
Hogchoker	3								
Bay anchovy	96	111	57	300	87	897	170	748	
Blue crab	72	30	18	36	51	18	33	96	
Harvestfish	6							126	
Striped bass			3						
Bluefish				3				3	
Carp				3					
Sea trout					3		3	12	
						5		1	
	d-1.77	d-1.42	d-1.93	d-1.28	d-1.28	d-.42	d-1.21	d-1.61	

OFFSHORE TRAWLS: CPUE and DIVERSITY May 1986

STATION	HMT1	HMT2	HMT4	HMT5	HMT6	HMT7	HMT9	HMT0
Species								
White perch	12	30		57	15	57	24	143
Spot			3					
Hogchoker	3							
Bay anchovy	1091	1994	1567	2105	2150	1621	900	1585
Blue crab	21	24	21	9	24		60	90
Menhaden			3		27			396
Striped bass						6		
Yellow perch				3	3			
Silverside				3				
Carp					3			
Brown bullhead						15		3
	d-.24	d-.20	d-.16	d-.24	d-.27	d-.32	d-.49	d-.74

These fluctuations in abundance may reflect temporary local conditions, variations in sampling times, or random variability. A five year comparison of fall catches by offshore trawl is shown in Table 9.

Inshore trawls

Sampling at the inshore trawl sites (within 35 m of the revetments toe) was clearly the most productive of the sampling methods. A total of 12,164 individuals representing 25 species were caught. This represented an almost three-fold increase in individuals and a 40% increase in species. As with the offshore trawl sites, the majority (50%) of the catch came in the spring samples.

The most obvious difference was in the species catch of the October samples. In October 1984, 12 species were caught, while in October 1985, 23 species were caught. Table 10 outlines the catch by species by site for October and Table 11 indicates the CPUE ranges for the same period.

The most common of the many species caught were spot, white perch, bay anchovy and blue crab. Together, these made up 92% of the October sample. Bay anchovy was the most abundant species, comprising 60% of the October sample and 93% of the May sample.

Catch varied considerably from site to site. In October, HMG-1 and HMG-5 yielded the most species and individuals. This was expected because these two sites were relatively protected from strong currents and seas. In May, the sites with the most abundant catches were HMG-2 and HMG-5. These two sites were also protected. Site HMG-1 experienced heavy growth of filamentous green algae, which matted the bottom and may have contributed to the reduction in catch for that site. Tables 12 and 13 illustrate the May 1986 catch by site and CPUE ranges, respectively.

Table 10 INSHORE TRAWL CATCH, BY SITE October 1985

Station	HMG1	HMG2	HMG3	HMG4	HMG5
Species					
Spot	21-0	75-9	162-21	102-0	191-0
White perch	72-0		102-0	27-0	356-57
Bay anchovy	186-0	458-6	422-15	1740-45	598-36
Banded killifish	39-0				
Summer flounder			3-0	3-0	
Winter flounder	3-0		3-0	3-0	3-0
Striped bass	3-0	6-0	3-0		
Weakfish		3-0	9-0		3-0
Croaker		15-0	6-0	18-0	3-0
Blue crab	84-33	78-21	24-9	9-0	153-0
Yellow perch	6-0				
Atl. silverside	6-0		6-0	27-0	
Tide. silverside	3-0				
Bluegill	3-0				
Brown bullhead	9-0				120-0
Carp		3-0			3-0
Grass shrimp	72-0				36-0
Naked goby					6-0
Menhaden			3-0		3-0
Hogchoker			18-0	3-0	15-0
Pumpkinseed	3-0				
Pipefish	6-3		3-0		6-0
Gizzard shad		3-0			3-0

Table 11 **INSHORE TRAWL CATCH BY SITE: CPUE RANGE** October 1985

Station	HMG1	HMG2	HMG3	HMG4	HMG5
Species					
Spot	21-0	75-9	162-21	102-0	191-0
White perch	72-0		102-0	27-0	356-57
Bay anchovy	186-0	458-6	422-15	1740-45	598-36
Banded killifish	39-0				
Summer flounder			3-0	3-0	
Winter flounder	3-0		3-0	3-0	3-0
Striped bass	3-0	6-0	3-0		
Weakfish		3-0	9-0		3-0
Croaker		15-0	6-0	18-0	3-0
Blue crab	84-33	78-21	24-9	9-0	153-0
Yellow perch	6-0				
Atl. silverside	6-0		6-0	27-0	
Tide. silverside	3-0				
Bluegill	3-0				
Brown bullhead	9-0				120-0
Carp		3-0			3-0
Grass shrimp	72-0				36-0
Naked goby					6-0
Menhaden			3-0		3-0
Hogchoker			18-0	3-0	15-0
Pumpkinseed	3-0				
Pipefish	6-3		3-0		6-0
Gizzard shad		3-0			3-0

The offshore trawl sites were located a minimum of several hundred meters from the rock revetment. Approximately 45% of all trawl-caught species were taken at the open water offshore trawl sites. Altogether, a total of 5,784 individuals representing 13 species were collected at the offshore trawl sites. This catch was more than double that of the 1984-85 sampling season. The bulk of the catch, 79%, was made in the May 1986 sample. Although the spring samples of 1985 and 1986 were taken within two weeks of each other, the early spring warming trend in 1986 left the waters an average of 4.0°C warmer. Table 7 lists the catch by species for the two sampling periods. The respective CPUE and diversity determinations are listed in Table 8.

There was little consistency when this year's catches were compared with catches of previous years. For example, the catch of white perch increased from 227 in 1983-84 to 1,883 in 1984-85 and then declined to 119 for the 1985-86 season. Similarly, no bay anchovy were taken in the 1984-85 sample period, while 5,176 (90% of the catch) were taken in the 1985-86 period. Other species, as illustrated below, also fluctuated.

Species	1983-84	1984-85	1985-86
White perch	227	1,883	119
Bay anchovy	493	0	5,173
Blue crab	101	200	201
Spot	564	666	206
Harvestfish	0	1	44
Striped bass	10	9	3

Table 7 OFFSHORE TRAWLS: CATCH BY STATION OCTOBER 1985

STATION	HMT1	HMT2	HMT4	HMT5	HMT6	HMT7	HMT9	HMT0	Totals
Species									
White perch			6						6
Spot	22	23	8	38	2	16	11	85	205
Hogchoker	1								1
Bay anchovy	32	37	19	100	29	300	57	250	824
Blue crab	24	10	6	12	17	6	11	32	118
Harvestfish	2							42	44
Striped bass			1						1
Bluefish				1				1	2
Carp				1					1
Sea trout					1		1	1	6
Totals	81	70	40	152	49	322	80	414	1208

OFFSHORE TRAWLS: CATCH BY STATION May 1986

STATION	HMT1	HMT2	HMT4	HMT5	HMT6	HMT7	HMT9	HMT0	Totals
Species									
White perch	4	10		19	5	19	8	48	113
Spot			1						1
Hogchoker	1								1
Bay anchovy	365	667	524	704	719	542	301	530	4352
Blue crab	7	8	7	3	8		20	30	83
Menhaden			1		9			4	14
Striped bass			1			2			2
Yellow perch				1	1				2
Silverside				1					1
Carp					1				1
Brown bullhead						5		1	
Totals	377	685	533	728	743	568	329	613	4576

Table 8 **OFFSHORE TRAWLS: CPUE and DIVERSITY** October 1985

STATION	HMT1	HMT2	HMT4	HMT5	HMT6	HMT7	HMT9	HMT0	Totals
Species									
White perch	4	10	18						
Spot	66	69	24	114	6	48	33	254	
Hogchoker	3								
Bay anchovy	96	111	57	300	87	897	170	748	
Blue crab	72	30	18	36	51	18	33	96	
Harvestfish	6							126	
Striped bass			3						
Bluefish				3				3	
Carp				3					
Sea trout					3		3	12	
						5		1	
	d-1.77	d-1.42	d-1.93	d-1.28	d-1.28	d-.42	d-1.21	d-1.61	

OFFSHORE TRAWLS: CPUE and DIVERSITY May 1986

STATION	HMT1	HMT2	HMT4	HMT5	HMT6	HMT7	HMT9	HMT0
Species								
White perch	12	30		57	15	57	24	143
Spot			3					
Hogchoker	3							
Bay anchovy	1091	1994	1567	2105	2150	1621	900	1585
Blue crab	21	24	21	9	24		60	90
Menhaden			3		27			396
Striped bass						6		
Yellow perch				3	3			
Silverside				3				
Carp					3			
Brown bullhead						15		3
	d-.24	d-.20	d-.16	d-.24	d-.27	d-.32	d-.49	d-.74

These fluctuations in abundance may reflect temporary local conditions, variations in sampling times, or random variability. A five year comparison of fall catches by offshore trawl is shown in Table 9.

Inshore trawls

Sampling at the inshore trawl sites (within 35 m of the revetments toe) was clearly the most productive of the sampling methods. A total of 12,164 individuals representing 25 species were caught. This represented an almost three-fold increase in individuals and a 40% increase in species. As with the offshore trawl sites, the majority (50%) of the catch came in the spring samples.

The most obvious difference was in the species catch of the October samples. In October 1984, 12 species were caught, while in October 1985, 23 species were caught. Table 10 outlines the catch by species by site for October and Table 11 indicates the CPUE ranges for the same period.

The most common of the many species caught were spot, white perch, bay anchovy and blue crab. Together, these made up 92% of the October sample. Bay anchovy was the most abundant species, comprising 60% of the October sample and 93% of the May sample.

Catch varied considerably from site to site. In October, HMG-1 and HMG-5 yielded the most species and individuals. This was expected because these two sites were relatively protected from strong currents and seas. In May, the sites with the most abundant catches were HMG-2 and HMG-5. These two sites were also protected. Site HMG-1 experienced heavy growth of filamentous green algae, which matted the bottom and may have contributed to the reduction in catch for that site. Tables 12 and 13 illustrate the May 1986 catch by site and CPUE ranges, respectively.

Table 9 TOTAL CATCH BY SPECIES IN OFFSHORE BOTTOM TRAWLS

Species	August 1981[1]	August 1982[2]	September 1983[3]	October 1984[4]	October 1985[5]
Spot	6840	697	564	666	593
Bluefish	1	4	7		2
Croaker			78		19
Hogchoker	311	25	13	5	20
Anchovy	366	72	493	3075	
White perch	468	81	9	953	501
Summer flounder	17		11		2
Striped bass	1	3	4	5	8
Gizzard shad			2		2
Menhaden	24	2	10	5	2
Blue crab	3	3	199	99	472
American eel	118				
Channel catfish	12	42		3	
Brown bullhead		1			105
Sea trout	82				15
Winter flounder	3				5
Pipefish	1				10
Naked goby		1			3
Harvestfish				1	44
Yellow perch					3
Grass shrimp					57
Atlantic silverside					15
Tidewater silverside					1
Bluegill					1
Pumpkinseed					1
Banded killifish					20
Carp					3

1. Ysai, 1982
2. CRC publ. #114, 1984
3. 3rd Interpretive Report, 1984
4. 4th Interpretive Report, 1985
5. Present Data

Table 10 INSHORE TRAWL CATCH, BY SITE October 1985

Station	HMG1	HMG2	HMG3	HMG4	HMG5
Species					
Spot	21-0	75-9	162-21	102-0	191-0
White perch	72-0		102-0	27-0	356-57
Bay anchovy	186-0	458-6	422-15	1740-45	598-36
Banded killifish	39-0				
Summer flounder			3-0	3-0	
Winter flounder	3-0		3-0	3-0	3-0
Striped bass	3-0	6-0	3-0		
Weakfish		3-0	9-0		3-0
Croaker		15-0	6-0	18-0	3-0
Blue crab	84-33	78-21	24-9	9-0	153-0
Yellow perch	6-0				
Atl. silverside	6-0		6-0	27-0	
Tide. silverside	3-0				
Bluegill	3-0				
Brown bullhead	9-0				120-0
Carp		3-0			3-0
Grass shrimp	72-0				36-0
Naked goby					6-0
Menhaden			3-0		3-0
Hogchoker			18-0	3-0	15-0
Pumpkinseed	3-0				
Pipefish	6-3		3-0		6-0
Gizzard shad		3-0			3-0

Table 11 INSHORE TRAWL CATCH BY SITE: CPUE RANGE October 1985

Station	HMG1	HMG2	HMG3	HMG4	HMG5
Species					
Spot	21-0	75-9	162-21	102-0	191-0
White perch	72-0		102-0	27-0	356-57
Bay anchovy	186-0	458-6	422-15	1740-45	598-36
Banded killifish	39-0				
Summer flounder			3-0	3-0	
Winter flounder	3-0		3-0	3-0	3-0
Striped bass	3-0	6-0	3-0		
Weakfish		3-0	9-0		3-0
Croaker		15-0	6-0	18-0	3-0
Blue crab	84-33	78-21	24-9	9-0	153-0
Yellow perch	6-0				
Atl. silverside	6-0		6-0	27-0	
Tide. silverside	3-0				
Bluegill	3-0				
Brown bullhead	9-0				120-0
Carp		3-0			3-0
Grass shrimp	72-0				36-0
Naked goby					6-0
Menhaden			3-0		3-0
Hogchoker			18-0	3-0	15-0
Pumpkinseed	3-0				
Pipefish	6-3		3-0		6-0
Gizzard shad		3-0			3-0

Table 12 INSHORE TRAWL CATCH, BY SITE May 1986

Station	HMG1	HMG2	HMG3	HMG4	HMG5	Total Individuals
Species						
Spot		50	25		22	97
White perch		48	25	21	81	175
Bay anchovy	99	2723	1413	117	3630	7982
Yellow perch	5	8		3	7	23
Atlantic silverside	1			6	37	44
Blue crab	16	29	16	7	19	87
Brown bullhead		12	3		53	68
Hogchoker		10	5		6	21
Pipefish		2				2
Menhaden		5	5		14	24
American eel		1			3	4
Carp				1	3	4
Channel catfish					15	15
Pumpkinseed	1	1			18	20
Total species	5	11	7	6	13	
Total fish 8,566						

Table 13 INSHORE TRAWL CATCH BY SITE: CPUE RANGE May 1986

Station	HMG1	HMG2	HMG3	HMG4	HMG5
Species					
Spot	0	135-0	36-0		30-0
White perch	18-0	63-3	36-0	36-0	90-12
Bay anchovy	156-0	2601-36	1929-15	329-0	3738-359
Yellow perch	9-0	9-0		3-0	15-0
Atlantic silverside	3-0			7-0	42-3
Blue crab	27-0	51-0	36-0	15-0	18-0
Brown bullhead		27-0	6-0		36-3
Hogchoker		12-0	6-0		6-0
Pipefish		3-0			6-0
Menhaden		15-0	6-0		12-0
American eel		3-0			6-0
Carp				3-0	3-0
Channel catfish					12-0
Pumpkinseed	3-0	3-0			9-0
Brown bullhead	9-0				120-0
Carp		3-0			3-0
Grass shrimp	72-0				36-0
Naked goby					6-0
Menhaden			3-0		3-0
Hogchoker			18-0	3-0	15-0
Pumpkinseed	3-0				
Pipefish	6-3		3-0		6-0
Gizzard shad		3-0			3-0

Inshore Versus Offshore Sites

As in past years, the inshore sites yielded more individuals and species than the offshore sites, suggesting that the containment facility does attract fish. Table 14 compares adjacent inshore and offshore catches by site for individuals and species from fall 1984 to spring 1986.

Eel Pots

Although up to 20 eel pots were used during the 1983-84 and 1984-85 seasons, only six pots were used during the 1985-86 season, for reasons stated earlier. Nevertheless, the CPUE as represented by the average catch per pot was still low and variable (see Table 15). Eels apparently still were not using the revetment as a habitat. This may have been due to frequent rough sea conditions, such as wave and current scouring, which reduced the quality of the revetment as an eel habitat.

CONCLUSIONS AND RECOMMENDATIONS

The aquatic locale of the containment facility is a dynamic one with many types of habitat: both protected and unprotected reaches, shallow and deep water areas, currents and backwaters. While the major species may be reasonably consistent in their presence, their numbers vary considerably from year to year. The facility appears to function to a minimal degree as a fish attractant. Its physical presence resulted in the creation of more protected waters to the north and west, which may have benefited local fish and crab populations.

Unless external alterations or additions are being actively considered for the facility, only minimal monitoring is necessary.

Table 14 COMPARISON OF INSHORE TRAWL SITES WITH ADJACENT OFFSHORE TRAWL SITES

Number of Individuals

Site	Fall 1984	Fall 1985	Spring 1985	Spring 1986
HMG-3	562	440	554	1492
HMT-2	171	70	4	685
HMG-2	2880	336	393	2889
HMT-6	87	49	166	733
HMG-1	149	483	309	122
HMT-7	18	322	100	568

Number of Species

Site	Fall 1984	Fall 1985	Spring 1985	Spring 1986
HMG-3	5	12	12	7
HMT-2	6	3	4	3
HMG-2	8	9	9	11
HMT-6	5		2	6
HMG-1	11	14	11	5
HMT-7	3		2	4

HMG= inshore trawl site
HMT= offshore trawl site

TABLE 15. EEL POT CATCH COMPARISON BETWEEN 1983-84, 1984-85 and 1985-86

Station	October 1983				October 1984				October 1985			
	HMG3	HMG2	HMG1	Total	HMG3	HMG2	HMG1	Total	HMG3	HMG2	HMG1	Total
American eel	76	4	11	91	6	5	5	16	6	13		19
Blue crab	26	9	25	60	12	16	26	54	7	9	3	19
Pumpkinseed					1		11	12				
Spot					1		1	2				
Channel catfish						2	1	3				
Banded killifish												
	Average 1.3 eels/pot day				Average 0.2 eels/pot day				Average 1.75 eels/pot day			

Station	May 1984				May 1985				May 1986					
	HMG3	HMG2	HMG1	Total	HMG3	HMG2	HMG1	Total	HMG5	HMG4	HMG3	HMG2	HMG1	Total
American eel	15	13	5	33	14	43	28	85	1		3		1	5
Blue crab	18	6	22	46	40	59	17	116	4	2	1	2		9
Pumpkinseed			3	3			1	1	2					5
Spot			1	1					1					2
Channel catfish							1	2						
Banded killifish														
	Average 0.6 eels/pot day				Average 1.4 eels/pot day				Average 0.5 eels/pot day					

Project IV-Analytic Services

by

Department of Natural Resources
Tidewater Administration
Coastal Resources Division
and
Water Resources Administration

SUMMARY

Levels of 30 individual trace organic contaminants (Table 1) were analyzed in sediment samples. Biological samples (fish, blue crabs, and clams) were analyzed for concentrations of six metals: chromium, copper, iron, manganese, nickel, and zinc. Information on metals in sediment can be found in the Project II (Sedimentary Environment) section of this report (pages 17-20).

Levels of all 30 organic compounds were below detection limits in all sediment samples that were analyzed. Comparison with past data was difficult due to changes in laboratories, technology, methods, sample collection, temperature, and other factors. Concentrations of five metals (Cr, Fe, Mn, Ni and Zn) were highest in clam tissue; copper concentrations were higher in crabs than in fish or clams. There were no clear spatial patterns in tissue concentrations of the metals analyzed. Seasonal patterns could not be separated clearly from other effects. All metals analyzed except copper were highest in December, when only clams were collected for analysis.

INTRODUCTION

Selected metals and organic contaminants are analyzed in sediments and biota on a continuing basis as a part of the Hart and Miller Islands Environmental Assessment monitoring program. Contaminant levels significantly exceeding baselines established before and during construction of the containment facility could indicate undesirable environmental impacts associated with the transportation or storage of contaminated dredged material.

Baseline information (Chesapeake Research Consortium 1984) demonstrated that sediments and biota in the area surrounding the containment facility were contaminated with organic compounds before construction. Four classes of organic compounds (chlorinated pesticides, such as DDT and its degradation products; phthalates, which are solvents and plasticizers used in industry and painting materials; polynuclear aromatic hydrocarbons, or PAH's, which are by-products of combustion, and polychlorinated biphenyls, or PCB's) were detectable in sediments and biota. Levels of some of these compounds were quite high in benthic species which feed on sediment particles, reflecting bioaccumulation. These organic compounds are almost entirely products of human activity, although the specific sources of the various substances can be industrial, municipal, agricultural, maritime, or atmospheric.

Baseline data also suggested some degree of metal enrichment in biota, but data for comparative purposes were sparse, so that the observed metal concentrations could not be certainly attributed to anthropogenic contamination. The metals analyzed during the fifth monitoring year all have natural sources, so that their presence alone does not indicate anthropogenic contamination. Concentrations must be compared with baseline data, or with concentrations from physically similar areas known to be uncontaminated to be meaningful. Two of the metals measured, iron and manganese, are not toxic except at extremely high concentrations; they are monitored only as indicator substances. Zinc and copper, while toxic at high concentrations, are biologically necessary in small amounts. Only trace amounts of chromium and nickel should be detectable in organisms not exposed to contamination of their environments.

METHODOIOGY

Sampling of sediment and biota in the Hart-Miller Island area was performed in five different months: October and December of 1985, and April, May and August of 1986. The sampling was done mainly in the fall and spring to determine whether or not there was any seasonal variability in the levels of the substances tested. A total of 41 samples were examined. Data on organics in biota were not received in time for the printing of this report. The raw data will be published in the accompanying 1985-86 Data Report.

Analyses of 30 organic compounds (Table 1) were performed on each sediment sample. Gas chromatography analyses of the following classes of organic contaminants were made: herbicides, insecticides, polychlorinated biphenyls (PCBs), and polynuclear aromatic hydrocarbons (PAHs). The protocols and detection limits were recommended by the EPA/WRA laboratory to ensure consistency with previous data collected under these investigations. The WRA/EPA laboratory also planned to analyze selected biota for copper, chromium, zinc, nickel, manganese, and iron. When the WRA/EPA lab in Annapolis closed, the remaining samples were transferred to the Department of Health and Mental Hygiene's (DHMH) Environmental Chemistry Division in Baltimore for analyses.

Metals in Biota

Biota samples from Hart-Miller Island Containment Facility were submitted to the DHMH, Food Chemistry Laboratory on September 8, 1987 for the determination of six metals (copper, chromium, zinc, nickel, manganese, and iron). The samples consisted of three types: clams (*Rangia cuneata*), blue crabs (*Callinectes sapidus*), and fish (several species in composite samples). A total of 29 samples was collected: 6 crabs, 8 fish, and 15 clams. One sample, number 870601-52, was recorded as collected, but was not found by the laboratory.

Each sample was filleted (fish) or shucked (clams and crabs) and then homogenized using a Waring blender. The samples were then weighed and tested for moisture content. A portion of each sample was also weighed and digested for the six metals specified in the analysis. These portions were digested with concentrated nitric acid and brought to a final volume of 50 ml with deionized water (Barnstead Nanopure II system). The samples were then analyzed using inductively coupled plasma optical emission spectrometry (ICP). The Perkin-Elmer Plasma II simultaneous ICP with automatic background correction was used. The concentrations of all calibration standards were verified against EPA quality control check samples and EPA/ICP quality control samples.

RESULTS

Trace Organics in Sediments

Surficial sediments were collected at seven stations (Figure 1). The raw data for these stations may be found in the accompanying Data Report. Eleven samples from the MGS November cruise were analyzed at the WRA/EPA lab. Four samples were received in broken glass containers, therefore analyses were not performed on these samples. None of the stations had any constituents above detection limits.

Table 1

Hart and Miller Island Containment Facility Monitoring

Organic Contaminant Analyses

Organic Compound	Detection Limit (ppb)
3,3 - benzofluoranthene	128
4,4' DDD	2.6
4,4' DDE	1.3
4,4' DDT	2.6
PCBs, total	200
acenaphthene	128
acenaphthylene	128
aldrin	0.6
alpha - BHC	0.6
anthracene	128
benzo (a) anthracene	128
benzo (a) pyrene	128
benzo (g,h,i) perylene	128
benzo (k) fluoranthene	128
beta - BHC	1.3
chlordane	26
chrysene	128
dibenz (a,h) anthracene	128
dieldrin	0.6
endrin	1.3
fluoranthene	128
fluorene	128
heptachlor	1.3
heptachlorepoxide	0.6
indeno (1,2,3-cd) pyrene	128
lindane	0.6
naphthalene	128
phenanthrene	128
pyrene	128
toxaphene	320

Organic Compounds in Tissue

Data on organic compounds in tissue were not received from the laboratory in time to be included in this report.

Metals in Clam Tissue

Clams had higher tissue concentrations than crabs or fish of all metals analyzed except copper (Figures 1-6). Iron and nickel were particularly high in clam tissue relative to the other biota: about ten times higher for iron, and nearly 100 times higher for nickel. Differences between metal concentrations in clams at the seven stations sampled were negligible relative to the differences between taxa. Manganese, iron and chromium tissue concentrations were highest in December, zinc and nickel in April, and copper in August.

Metals in Crab Tissue

The mean concentration of copper in crab tissue was about 22 times higher than in fish tissue, and more than 5 times higher than in clam tissue. Manganese, iron and chromium concentrations were greater in crabs sampled in April than in August, and zinc, nickel and copper concentrations were greater in August. Crabs were not collected in December.

Metals in Fish Tissue

Overall, tissue concentrations of metals in fish were lower in than the other taxa sampled. Average concentrations of iron and chromium were slightly higher in fish than in crabs but considerably lower than in clams. Zinc and nickel concentrations were greater in fish tissue in August than in April; all other metal levels were higher in April than in August. Fish were not collected in December.

DISCUSSION

The failure to detect any of the organic contaminants measured in sediment samples was a positive indication that (1) the containment facility and associated transportation and unloading of dredged material had not been a source of contamination of the environment with toxic organic compounds and (2) that background levels of these compounds have continued to decline since the pre-construction sampling in the early 1980's (Chesapeake Research Consortium 1984). In the previous (fourth) monitoring year, sediment samples at several stations had detectable amounts of PCB's ranging from 12 to 162 ppb (Tidewater Administration, 1987). However, the fifth year detection limit for PCB's (200 ppb) was considerably higher than that for the fourth year analyses (10 ppb). It can only be determined that PCB concentrations in sediment did not increase drastically from the fourth to the fifth monitoring year. Detection limits for all other organic compounds analyzed were comparable between the two years.

An important determinant of metals concentrations in tissues of various species, in addition to environmental exposure, is the biology of the species. For this reason, the fish tissue data reported here are particularly weak, because species were neither separated nor identified before analysis. This problem will be rectified in subsequent monitoring.

Fish, blue crabs and brackish-water clams have very different physiology, mobility, and feeding mechanisms. Brackish-water clams are suspension (filter) feeders which collect multitudes of small particles from the water on their gills. They use organic particles such as algal cells for food, but many inorganic particles (silt, clay, fine sand) are also collected and may be ingested. This may be an explanation for the high metals concentrations observed in clam tissue. The clams' digestive tracts were not removed before analysis; they probably contained large numbers of inorganic particles which could have had high metals concentrations. Comparable nickel concentrations were found in another clam (*Macoma balthica*), a benthic amphipod (*Leptocheirus plumulosus*) and a polychaete worm (*Scolecolepides viridis*) collected from the Hart-Miller Island area before construction of the containment facility (Chesapeake Research Consortium 1984). Each of the last three animals lives in, and ingests, bottom sediments. Whether the nickel concentrations in *Rangia cuneata* were accumulated by ingestion of water column particulates or from contact with or ingestion of bottom sediments cannot be determined. Fish and crab tissues had only trace (< 1.0 ppm) amounts of nickel. Predominant sources of nickel contamination are wastewater treatment and industrial metals processing.

Blue crabs have a copper-containing respiratory pigment, hemocyanin (analogous to iron-containing hemoglobin in man and other animals). This may explain the consistently high copper concentrations found in the crab tissues analyzed. Copper levels were somewhat higher in clams and crabs in August than in April or December (clams only). Anti-fouling paints used on vessel bottoms could be an important source of copper in the Hart and Miller Islands environment. August is the height of the recreational boating season, so this source may have accounted for some of the seasonal variability in tissue copper levels.

In general, spatial and temporal patterns of metal concentrations in tissue did not show any indications that the containment facility was a source of metals contamination in the surrounding environment. The sampling regime was less than ideal for testing this hypothesis. A statistical analysis (multivariate analysis of variance) was conducted to test for overall differences in metals concentrations among species, sampling dates, and groups of sampling stations. Significant differences ($p < 0.05$) were indicated in all effects, but these results should be viewed with caution. Sampling was very unbalanced in time and space (clam stations were different from fish and crab stations and only clams were sampled in December), which led to biased, or trivial, tests of time and space hypotheses. However, the differences between taxa clearly were real.

An alternative explanation of the metals data would implicate the containment facility as a possible source of metals contamination: the least mobile species analyzed, the clam, had the highest overall levels of metals in tissue. This observation could suggest a nearby source of these contaminants. This explanation cannot be supported for the following reasons. First, metals levels observed during 1985 and 1986 were consistent with those measured in benthic species before construction of the containment facility. Second, the probable retention of inorganic particulates in the filtering and digestive organs of the clams, as discussed above, appears to be an adequate explanation for metals levels in excess of those in fish and crabs. Third, the clams live in intimate association with bottom sediments, which have high background levels of metals in the area of the containment facility.

CONCLUSIONS AND RECOMMENDATIONS

1. Of the 30 organic contaminants measured in sediment samples, none were above detection levels.

2. The observed levels of organic contaminants did not implicate the containment facility. All of the sediment contaminants were below detection limits, including station 21-B, which is located adjacent to the spillway.

3. Detection limits for organics were consistent with those from the previous year, except for total PCB's. The detection limit for PCB's in sediment (200 ppb) was too high for good comparison with the previous year's data.

4. No data were available on organics in biological tissue. These samples are currently being analyzed by the Department of Health.

5. Concentrations of six metals in fish, crab and clam tissue did not implicate the containment facility as a source of metals contamination to the surrounding Chesapeake Bay environment.

6. In future monitoring, each sample of fish for tissue analysis should be confined to one species, clearly and reliably identified.

7. Two standard groups of stations, one group close to the containment dike and one distant (reference stations) must be established and maintained for collection of samples for tissue analysis.

8. Despite problems with sampling, sample processing and analysis, a reasonably reliable baseline has been established for selected organic compounds in sediment and selected metals in sediment and biota. Data on organics in biota require further evaluation. Severe or widespread contamination associated with storage and handling of dredged material at the facility should be detectable through continued, consistent sampling and analysis of sediment and biota. The utility of this information will depend upon timely processing of samples and interpretation of data.

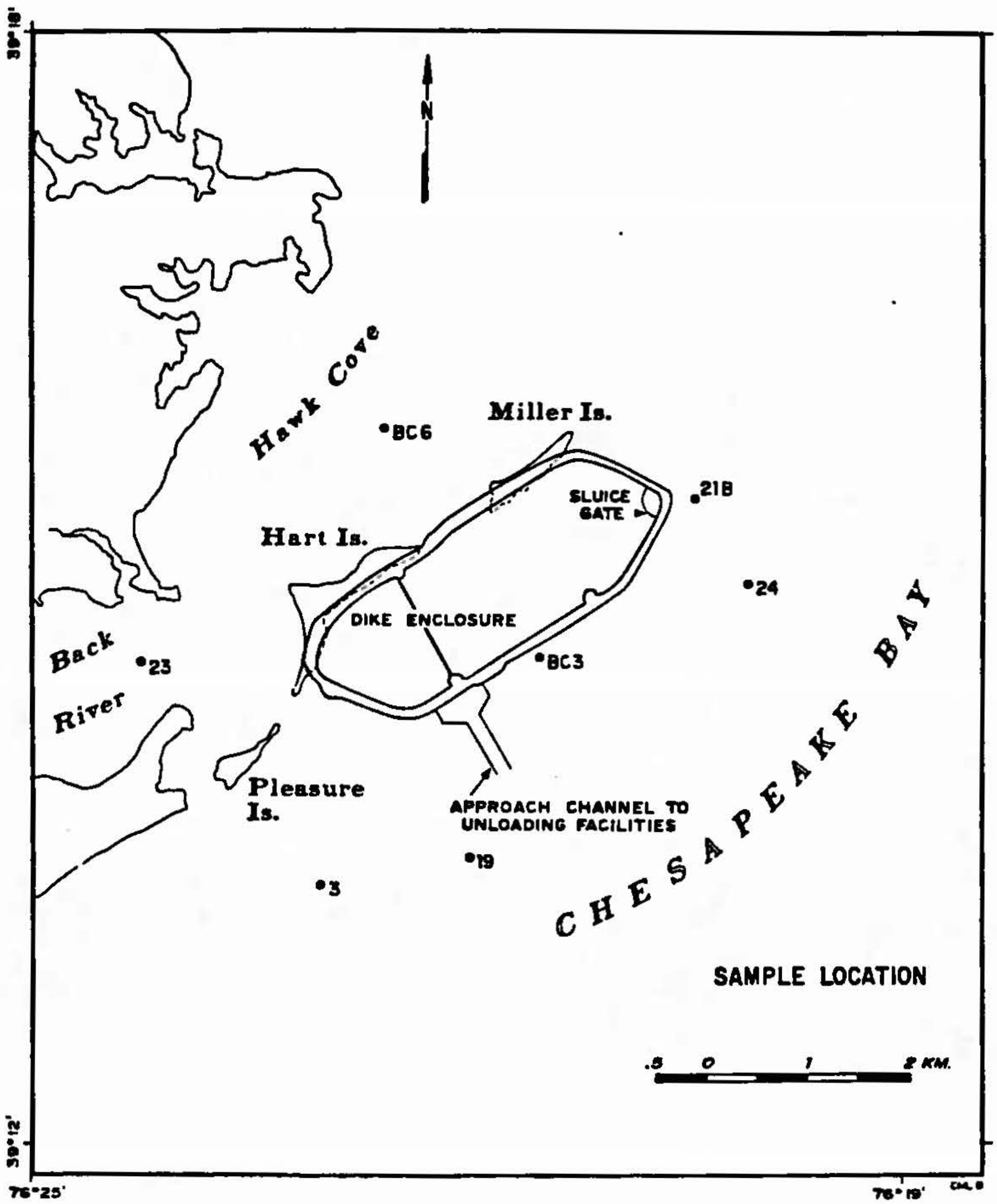
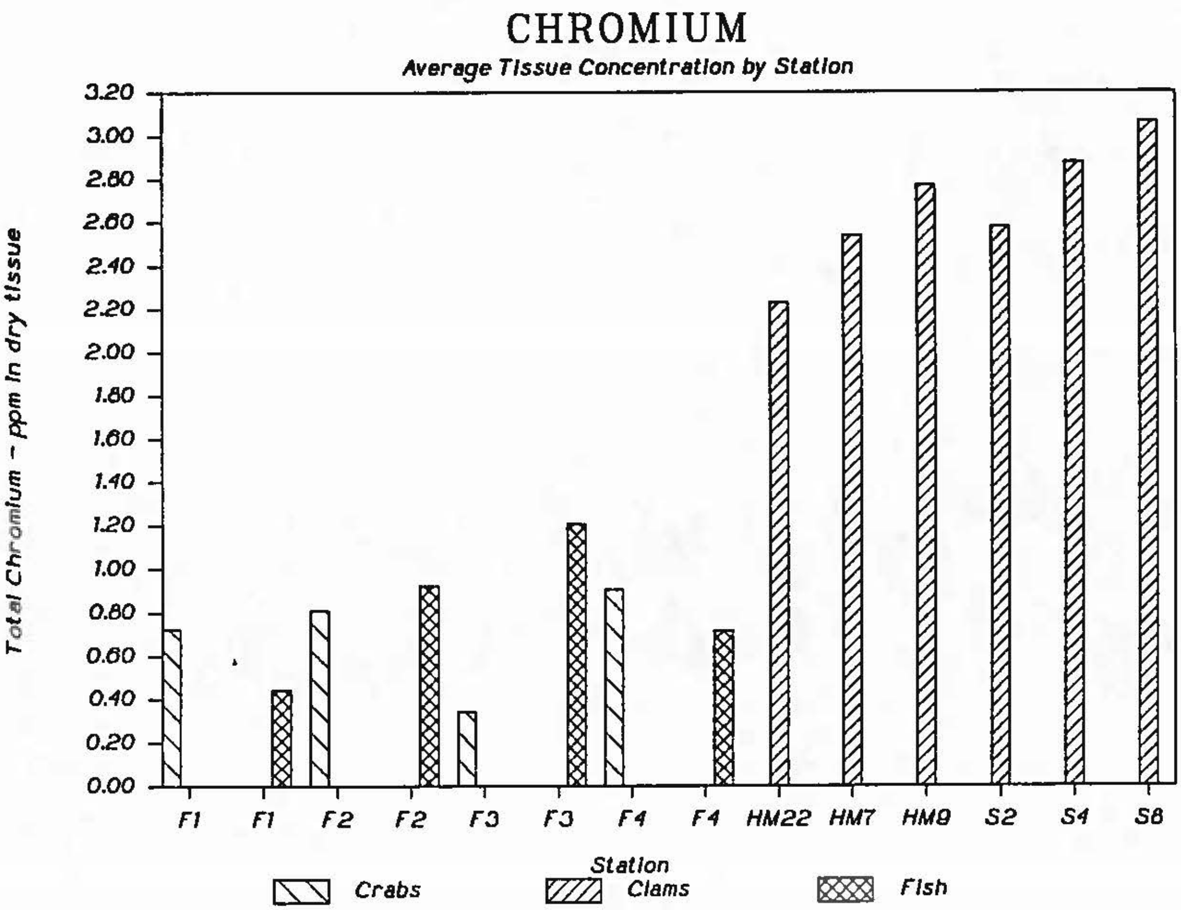
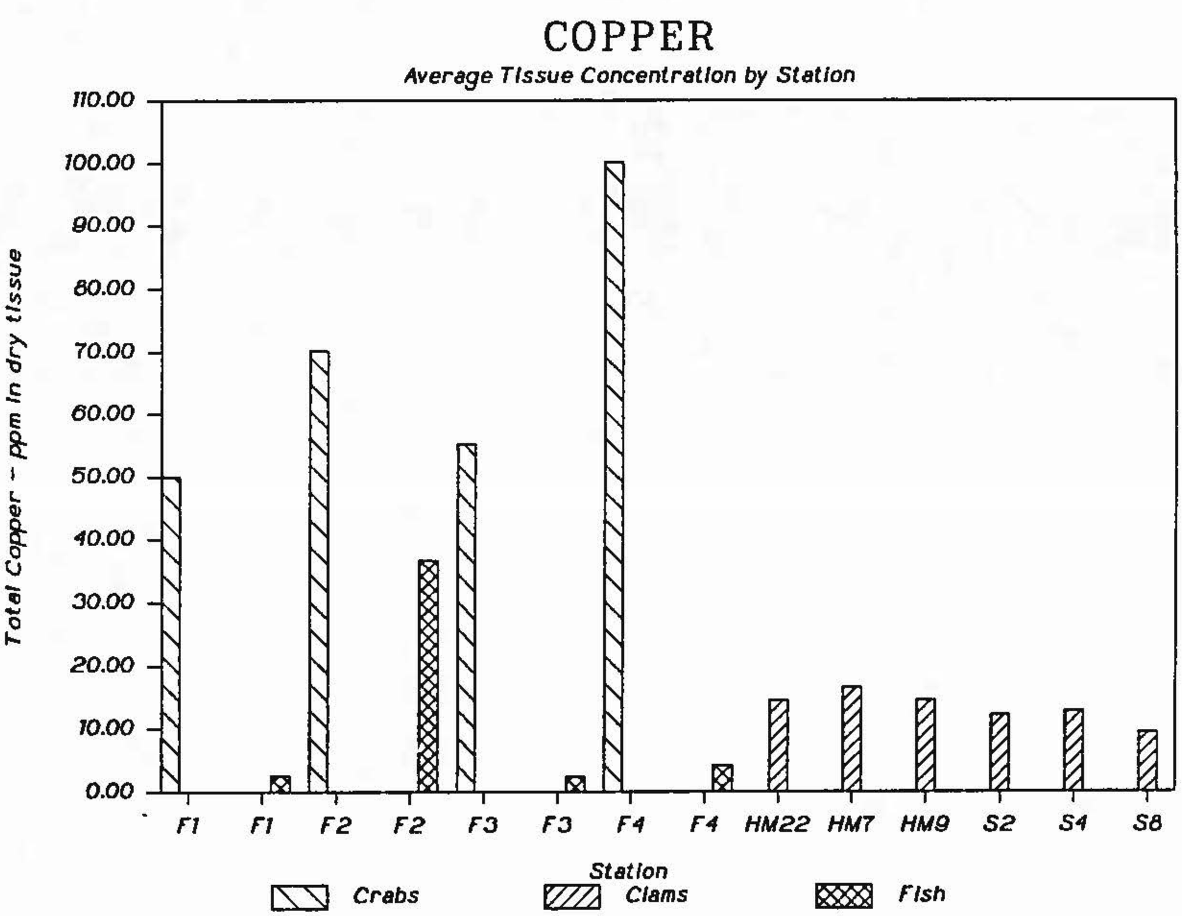
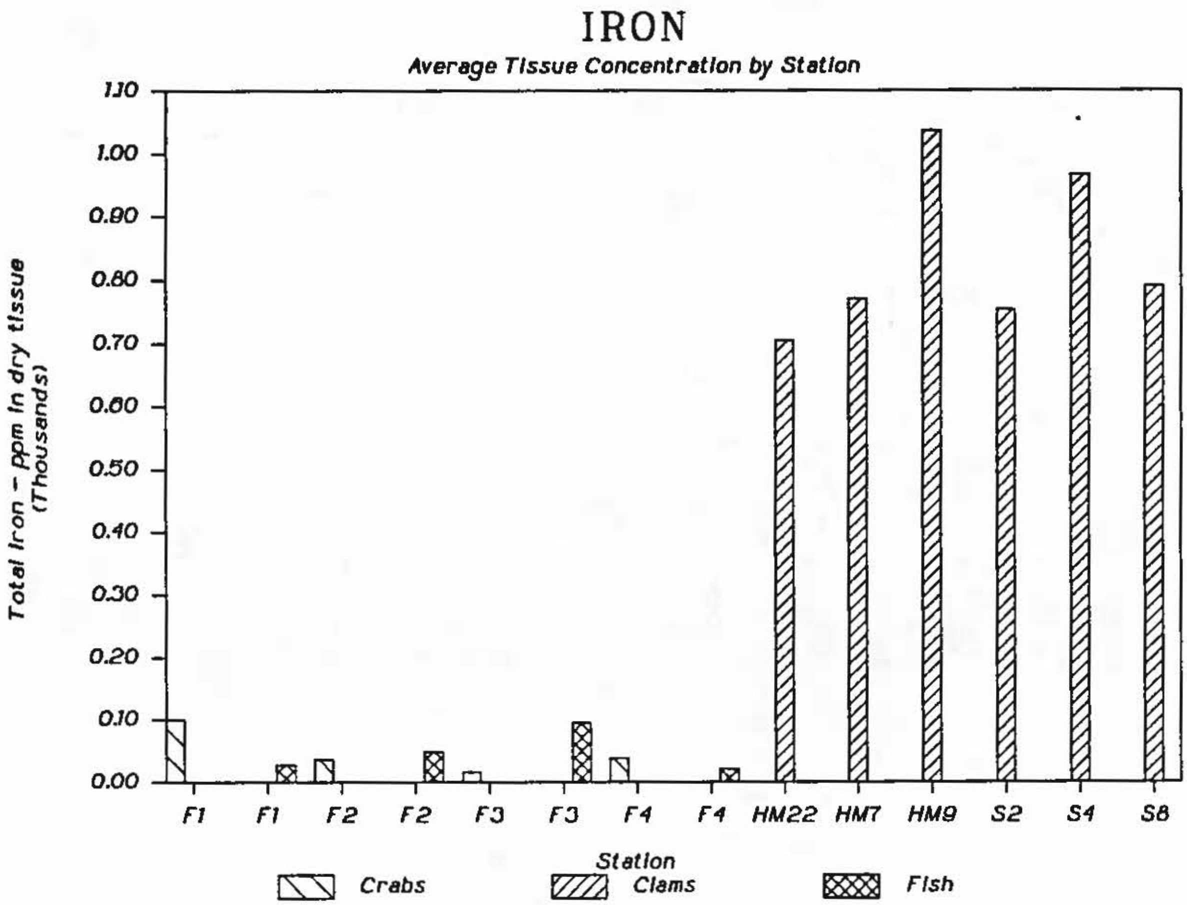
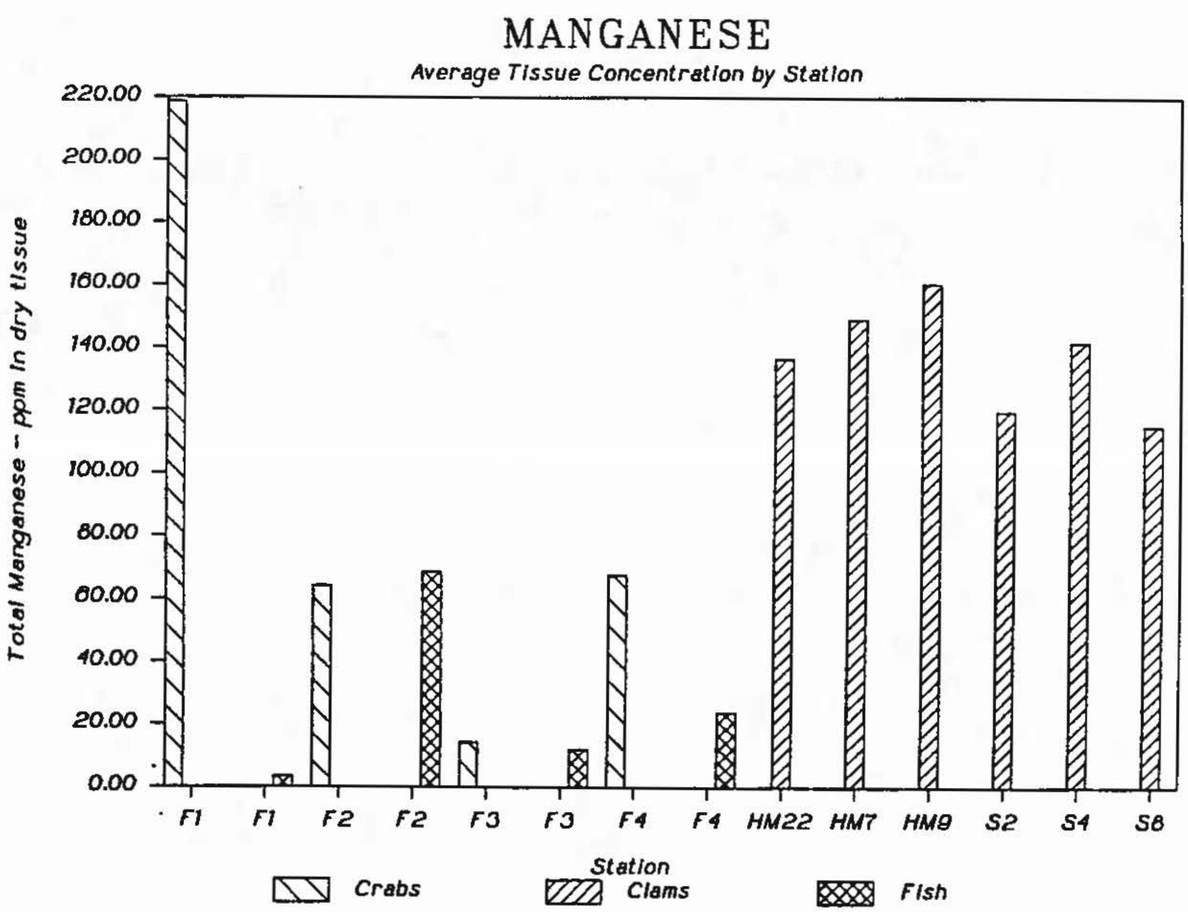


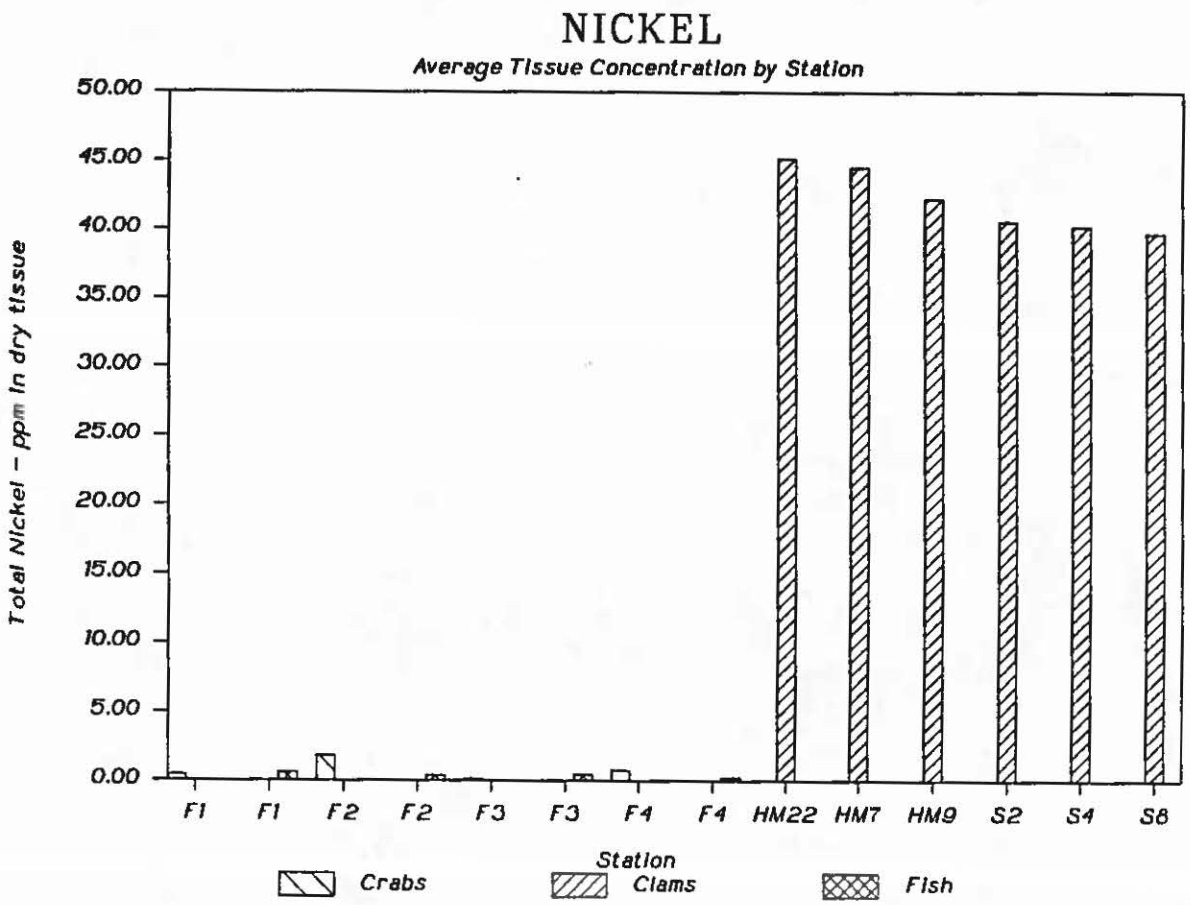
Figure 1. Map of the Hart and Miller Islands Diked Facility and vicinity, showing locations of the surficial sediments sampled during the fifth year monitoring.

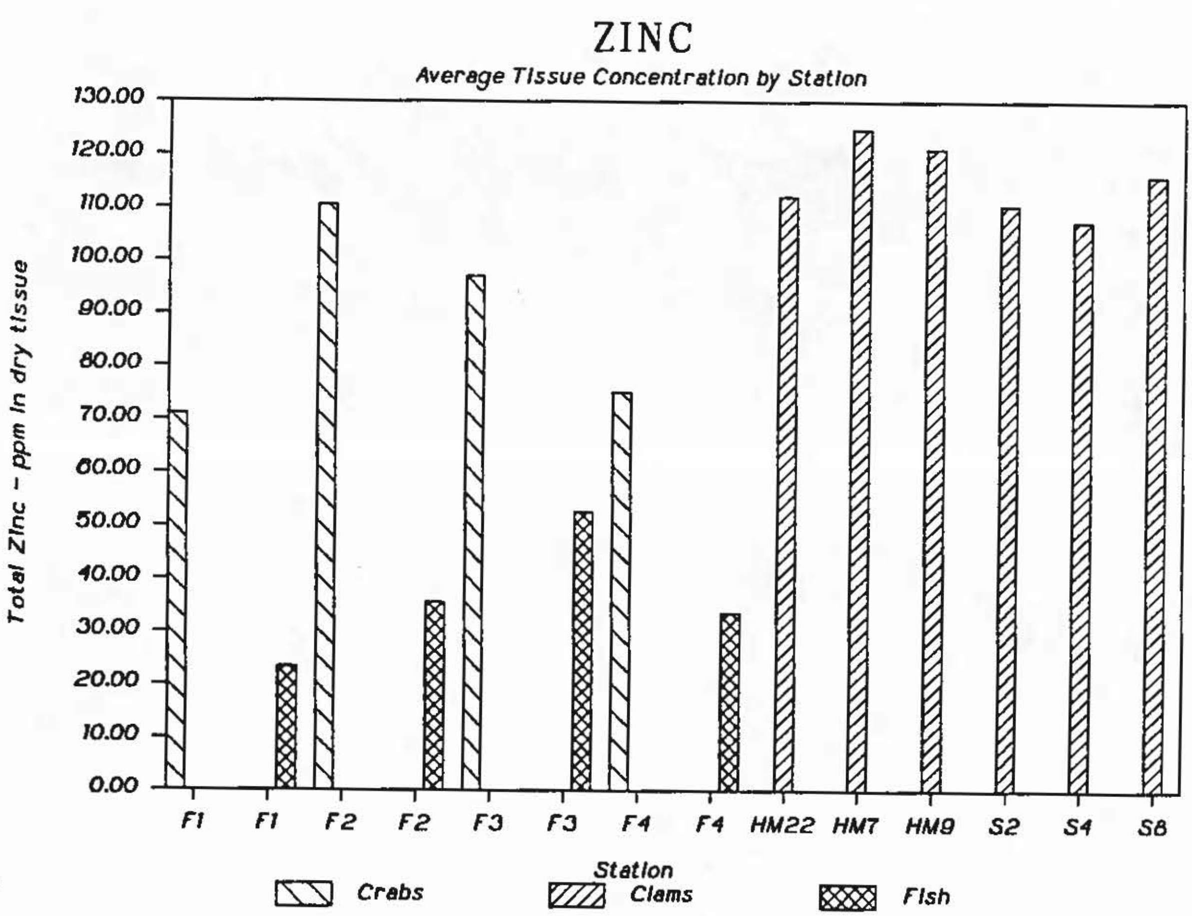

CHROMIUM
Average Tissue Concentration by Station
Total Chromium - ppm in dry tissue
3.20
3.00
2.80
2.60
2.40
2.20
2.00
1.80
1.60
1.40
1.20
1.00
0.80
0.60
0.40
0.20
0.00
F1 F1 F2 F2 F3 F3 F4 F4 HM22 HM7 HM9 S2 S4 S8
Station
Crabs
Clams
Fish


COPPER
Average Tissue Concentration by Station
Total Copper - ppm in dry tissue
110.00
100.00
90.00
80.00
70.00
60.00
50.00
40.00
30.00
20.00
10.00
0.00
F1 F1 F2 F2 F3 F3 F4 F4 HM22 HM7 HM9 S2 S4 S8
Station
Crabs
Clams
Fish


IRON
Average Tissue Concentration by Station
Total Iron - ppm in dry tissue (Thousands)
1.10
1.00
0.90
0.80
0.70
0.60
0.50
0.40
0.30
0.20
0.10
0.00
F1 F1 F2 F2 F3 F3 F4 F4 HM22 HM7 HM9 S2 S4 S8
Station
Crabs
Clams
Fish


MANGANESE
Average Tissue Concentration by Station
Total Manganese - ppm in dry tissue
220.00
200.00
180.00
160.00
140.00
120.00
100.00
80.00
60.00
40.00
20.00
0.00
F1 F1 F2 F2 F3 F3 F4 F4 HM22 HM7 HM9 S2 S4 S8
Station
Crabs
Clams
Fish


NICKEL
Average Tissue Concentration by Station
Total Nickel - ppm in dry tissue
50.00
45.00
40.00
35.00
30.00
25.00
20.00
15.00
10.00
5.00
0.00
F1
F1
F2
F2
F3
F3
F4
F4
HM22
HM7
HM9
S2
S4
S6
Station
Crabs
Clams
Fish


ZINC
Average Tissue Concentration by Station
Total Zinc - ppm in dry tissue
130.00
120.00
110.00
100.00
90.00
80.00
70.00
60.00
50.00
40.00
30.00
20.00
10.00
0.00
F1
F1
F2
F2
F3
F3
F4
F4
HM22
HM7
HM9
S2
S4
S6
Station
Crabs
Clams
Fish

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