Assessment of the Envivronmental Impacts
of the Hart-Miller Island
Containment Facility

Sixth Annual Interpretive Report
August 1986-August 1987

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by
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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 ensure 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 thank the following people for their indispensable help in the completion of this report: Patricia Matthews for typing, Lenora Dennis for data input, and Maureen Jablinske for editing.

EXECUTIVE SUMMARY

The Hart-Miller Island 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 sixth year of monitoring by the Department of Natural Resources to assess the impacts to the biological and sedimentary environment exterior to the dike. Samples of sediments and benthic populations were taken at a number of sites in the vicinity of the Hart and Miller Islands during fall 1986 and spring 1987 along with the continuation of a beach erosion study. Data collected from this and the previous five years of monitoring indicate there have been no significant changes in the environment.

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 and sediment types can be expected to change over small distances.

No significant changes were observed in the sedimentary environment surrounding the Hart-Miller Island Containment facility. Generally, the sediments around the Facility remained siltier than pre-construction sediments. The blanket of fluid mud was still very distinct after 5.5 years. Radiographic examination of the fluid mud layer revealed only a slight increase in bioturbation levels compared with the fifth year. Reworking by benthic activity is largely restricted to the upper 10-15 cm.

The distribution and range of the enrichment factor for Zn in the exterior sediments were similar to those found previously. Average enrichment factors for the fluid mud remained lower than pre-construction values. However, slight increases in enrichment factors were observed in the bioturbated zone of the fluid mud layer, indicating that benthic activity contributed to the enrichment of sediments with that metal and, by association, others as well.

The beach erosion study, initiated in the spring of 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 sixth year of monitoring, erosion of the beach increased dramatically, resulting in a steeper, more gravelly beach. A beach stabilization effort was initiated in 1988 in cooperation with the Baltimore County Soil Conservation Service. Beach grass is being planted to prevent erosion from aeolian processes.

RECOMMENDATIONS

The Hart-Miller Island Containment Facility is now fully operational. It is recommended that the Exterior Monitoring Program meet at least yearly in conjunction with the Technical Advisory Committee.

Persistent erosional problems on the recreational beach require attention. Renourishment of the beach with a suitably sized sand (medium-to coarse-grained) would not only reduce erosion by decreasing the slope of the lower dike face and foreshore, but would also increase the attractiveness of the most heavily utilized section of the beach. Sand would probably have to be replenished yearly, depending on the magnitude and frequency of storms in the Hart-Miller Island area.

Additional erosion control measures must be undertaken along the two northernmost profiles (48+00 and 49+00) to reduce the amount of sediment lost by sheet wash and gully erosion. Plans should include vegetating the beach. Diversion of drainage from that area might also be considered.

It is strongly recommended that the infaunal and epifaunal populations continue to be sampled at the established locations during this continued critical period of maximal operation to ascertain any possible effects. Station locations and sampling techniques should be maintained as close as possible to the two previous years to eliminate sampling variation and permit rapid recognition of effects resulting from the operation of the containment facility.

In future monitoring, each sample of fish for tissue analysis should be confined to one species, clearly and reliably identified. All future organics in biota data will be interpreted by the investigators for Project III- Benthic Studies. Organics in Sediment will continue to be interpreted by Project I- Scientific Coordination and Data Management investigators.

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

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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 in 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.

Flocculate - An agglomeration of particles bound by electrostatic forces.

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 adsorbent 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 the highest and lowest levels of spring tides.

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.

Supernatant - The clear fluid over a sediment or precipitate.

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.

INTRODUCTION

The Hart-Miller Island Containment Facility monitoring program was established to collect and analyze data to determine the effects of the 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 Sixth Annual Interpretive Report presents the results of the environmental monitoring of the Hart-Miller Island Containment Facility from August 1986 through August 1987.

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 52 million cubic yards (mcy) of material, most of which will be bottom sediments produced by deepening the Baltimore Harbor and its approach channels to 50'. Once the Facility is filled, it will be converted to a permanent wildlife and recreational area.

The dike is 18' 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 fine sands and silts from the dredged material would then fill the pores between the sand granules forming a semi-permeable dike wall. 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' long and contains 5,800 cubic yards of stone. The facility is divided into North and South containment cells by an interior dike approximately 4,300' long.

DREDGED MATERIAL DISPOSED

Material dredged in 1985 in the amount of 3.7 mcy was deposited into the North Cell. Of the 7.5 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.

The major 1986 dredging task was to remove material from the main shipping channel to maintain a working depth of 42'. The other projects listed for that year are mainly to remove allowing shipping companies to make better use of the 42' deep channel. Since the beginning of the project to deepen the channel to 50', shipping companies have been dredging their access channels deeper to make better use of the 50' channel depth. This represents the first of two contracts to increase the Maryland shipping channel to a depth of 50'.

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. Monitoring of the discharge is required to fulfill the State Discharge Permit #86-DP-2294.

TABLE 1
DISPOSAL OPERATIONS

YEAR	PROJECT NAME	CUT QUANTITY DISPOSED (Cubic Yards)
1984	Hart-Miller Personnel Pier	26,000
1984	42' Channel Maintenance and Brewerton Eastern Extension	3,908,000
1984	Dundalk Marine Terminal	550,000
1984	Hart-Miller Barge Unloading Pier	180,000
	TOTAL 1984	4,664,000
1985	42' Channel Maintenance	3,145,000
1985	Bethlehem Steel	596,000
	TOTAL 1985	3,741,000
1986*	42' Channel Maintenance	7,100,000
1986*	Canton-Seagirt	410,000
1986*	South Locust Point	185,000
1986*	Back River Bridge	18,000
1986*	Bethlehem Steel Ore Pier	6,000
1986*	Rukert Terminal	17,000
1986*	Hess Oil	7,000
	TOTAL 1986	7,743,000*
1987	50'Contract #1	~9,800,000**
1987	Seagirt	~3,300,000**
	Total 1987	13,182,500
	Grand Total**	29,330,500

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

** Through August 1987 (Sixth Monitoring Year)

SUMMARY OF MONITORING PROGRAMS

The State determined, as prescribed in authorizing permits for the facility, that there was a need for "a comprehensive environmental monitoring program for the Hart-Miller Containment Facility prior, during and following commencement of operations." The responsibility for the monitoring is assigned to the Water Resources Administration. The monitoring program is divided into two complementary portions: (a) monitoring to ensure compliance with federal and state laws; and (b) monitoring for environmental impacts. The operational permits requiring monitoring were issued by the Maryland Department of the Environment (MDE) (formerlly Maryland Department of Health and Mental Hygiene (DHMH)) and the Water Resources Administration (WRA) of the Department of Natural Resources (Dept. of Trans. et. al., 1979). The Maryland Environmental Service (MES) is responsible for monitoring water quality within the diked area.

This report describes studies designed to assess impacts to the biota and sediments exterior to the dike. This assessment is performed under a separate agreement between the Maryland Department of Natural Resources and the Maryland Port Administration. Liaison and coordination were maintained among all agencies having roles in site management, operations, monitoring, sampling and oversight programs related to the Hart and Miller Islands Facility, primarily through periodic meetings with the Technical Review Committee. Four projects were implemented to assess the environmental effects of construction and operation and are briefly described in the following sections.

PROJECT I: SCIENTIFIC COORDINATION AND DATA MANAGEMENT

The Tidewater Administration is responsible for maintaining a data base on the natural resources of Maryland, especially within the coastal zone. Data stored include fish, benthos, water quality, climate, sediments and hydrography. It is also responsible for conducting applied scientific investigations necessary for developing information for management purposes. The compilation, input, and long-term storage of all data related to the exterior monitoring effort is included in these responsibilities.

During the first five years of the Hart and Miller Islands environmental assessment program, data collected by the Department of Natural Resources and research institutions were stored in the Tidewater Administration's "Resource Monitoring Data Storage System" (RMDSS). This storage system makes data readily available to interested parties and also serves as a permanent repository from which baseline and trend information can be retrieved for comparison and evaluation.

The Tidewater Administration provides overall scientific planning, review and coordination of the exterior monitoring activities for the Hart and Miller Islands Facility, as well as compiling and distributing the Annual Interpretive and Data Reports. This also includes the coordination of any analyses of lab data that is not interpreted by the other principle investigators.

PROJECT II: SEDIMENTARY ENVIRONMENT

The Coastal and Estuarine Geology Program of the Maryland Geological

Survey has been involved in monitoring the physical and chemical behavior of the sediments around the Hart-Miller Containment Facility since 1981. This work has been conducted in two parts: sedimentary environment study and beach erosion study.

Monitoring and documentation of the sedimentary environment are 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 to mud ratios and the physical appearance of the surrounding sediments as well as increase the levels of trace metals and organic contaminants. In six years of monitoring however, no major changes have been detected within the sedimentary environment as a result of the operation phase of the facility. Monitoring has also provided information on a fluid mud layer that was deposited during construction. This fluid mud layer was described in the preceding exterior monitoring reports (years 1-5).

Sediment samples are collected not only at various sites around the containment facility, but also at several reference sites outside the immediate area of the facility. These samples 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 1986-87 monitoring year indicate that no major changes occurred again this year.

PROJECT III: BIOTA

PART 1. BENTHIC STUDIES

Benthic studies have been included in the ongoing monitoring program since August 1981. The primary objectives studies are to survey abundance and distribution of benthic organisms in this area and to monitor any effects of construction and operation of the diked disposal facility.

These studies have been part of the comprehensive environmental monitoring program for Hart-Miller Island containment facility for two reasons. First, many adult stages of benthic organisms live a sedentary life, either attached to hard substrates (epifauna) or buried in the sediments (infauna) and consequently they cannot readily move to avoid sudden physical and chemical changes in their environment. Thus, they are good indicators of possible adverse environmental conditions. The second reason for careful, long-term monitoring of these benthic populations is to be able to determine if any sudden change in population structure or abundance is a result of the containment facility or from natural environmental variations. The upper region of the Chesapeake Bay is a highly variable physical environment subject to sudden changes in salinity, wind-related wave action, high summer water temperatures and ice formation in the winter to name a few. As a result, the benthic populations are rarely ever stable and undergo broad seasonal and annual variations in abundance.

Since the beginning of the project in 1981, the dominant benthic species have remained relatively stable. Epifaunal populations on pilings have followed the same yearly pattern as described in previous reports. During the winter, the populations living at the upper ends of the pilings were removed by ice scour and/or desiccation at low tide. However, in the spring, the populations are re-established by larval settlement and/or recolonization by mobile species. 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 propeller wash from project tug boats.

Infaunal and epifaunal benthic populations should be monitored no less critically in the upcoming year, since supernatant from the containment island will continue. The first release of supernatant was initiated on October 25. 1986. Data from pre-construction through construction and early operation of the facility are a valuable baseline and will be essential for the assessment of possible future benthic population changes.

PART 2. FISH AND CRAB POPULATION STUDIES

This study was discontinued after the fifth monitoring year since the inherent variability in the data and the high mobility of the fish community makes such an effort difficult to design so as to function effectively as a monitoring tool (EA Engineering, 1985). Populations of fish and crabs in the vicinity of Hart and Miller Islands had been studied since 1981. The objective study was to assess the impacts of the containment facility on these populations. The extensive data collected since the beginning of the project provides a detailed description of the quantity and compositions of the populations and also provided a basis for future comparisons.

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 metals and organic contaminants. Fifth and sixth year biota (fish and crab) samples were analyzed at the Department of Health Laboratories in Baltimore. Only metals analyses of fish and clam tissue were received in time for this report. Organic analyses of biota are still in progress. A supplementary report on fifth and sixth organic analyses will be produced as soon as the analyses are complete.

Project I-Scientific Coordination and Data Management

Department of Natural Resources
Tidewater Administration

Development and implementation of a monitoring program which is sufficiently sensitive to the environmental effects of dredged material containment at Hart-Miller Island continues to be a complex and difficult undertaking. The environmental monitoring activities have evolved over the six 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 (Cronin et al., 1981-1983). Bathymetric studies were completed in the first three monitoring years to identify pre- and post-construction changes in currents and erosion.

Scientific planning, review and coordination of the monitoring activity is provided by Tidewater Administration. Sampling procedures, data analysis, and future directions of the program have been discussed with the 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 Reports are the responsibilities of the Tidewater Administration. During the first six years of the environmental assessment program, data collected by the Department of Natural Resources and research institutions were 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. The Tidewater Administration staff assumes responsibility for the long term storage of data related to the exterior monitoring program. 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 1986-1987 monitoring year is included in the Sixth Year Data Report, which is compiled and printed separately from the Interpretive Report.

Conclusion and Recommendations

It is imperative that good lines of communication be maintained between the monitoring researchers and the managers of the Hart-Miller Island, so both groups can benefit from any information acquired through the surveys they conduct. It is therefore recommended that the Exterior Monitoring Program meet at least yearly in conjunction with the Technical Advisory Committee.

Project II - Sedimentary Environment
Sixth Year Interpretive Report
(November 1986 - October 1987)

by

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ABSTRACT

The Coastal and Estuarine Geology Program of the Maryland Geological Survey has been involved in monitoring the physical and chemical behavior of near-surface sediments around the Hart-Miller Island Containment Facility as part of the State's environmental assessment of the Facility. In a separate effort, the Program's staff has also documented the erosional and depositional changes along the recreational beach between Hart and Miller Islands. The results of these studies during the sixth year of monitoring are presented in this report.

Textural and trace metal data from sediments collected around the exterior perimeter of the dike show that no major changes have occurred within the sedimentary environment as a result of operation of the Facility, although a blanket of fluid mud deposited during dike construction is still distinguishable. The top of the fluid mud layer has been reworked by benthic organisms (bioturbated). The level of activity increased slightly during the sixth year, compared to last year's observations.

The range and distribution of Zn enrichment factors in the sediments were similar to those reported previously. Generally, the average enrichment factors for Zn remain lower for the fluid muds. A slight increase in enrichment factor values, associated with the bioturbated zone of the fluid mud layer, is attributed to benthic activity.

Data collected during beach monitoring indicate that erosion has accelerated each year since the study began in June 1984. Since then, approximately 7756 yd^3 (5950 m^3) of sediment have been eroded from the beach; nearly half of that amount--3472 yd^3 (2655 m^3)--was lost this year. This is a conservative estimate as it fails to account for gully erosion, which was much greater than it has been in the past.

PART 1

SEDIMENTARY ENVIRONMENT

INTRODUCTION

The areal distribution and characteristics of esturine bottom sediments reflect the complex interaction of physical, chemical, and biological processes, acting singly or in combination. In addition to these natural processes, anthropogenic activities may produce sudden changes in the nature of bottom sediments. During construction of the Containment Facility at Hart and Miller Islands, dredging of the nearshore bottom for suitable building material and overboard disposal of that material were necessary. Those activities changed the sedimentary environment.

Documentation of construction-related changes was necessary in order to establish a baseline against which environmental changes during the operational phase of the project could be judged. Since the Facility began operating in 1983, fine-grained sediments, highly enriched in trace metals and organic carbon, have been dredged from Baltimore Harbor and its approach channels and placed inside the dike. Improper handling of this dredged material or leakage from the dike could result in detectable changes in the physical and chemical characteristics of the surrounding sediments (e.g., sand:mud ratio, appearance, trace metal and organic carbon content).

Previous Work

Changes in the sedimentary environment around the Hart-Miller Island Containment Facility were documented during the first five years of the State's monitoring project and are detailed in several reports (Kerhin et al. 1982a; Wells et al. 1984-1987). Knowledge of the physical characteristics and areal distribution of sediment types prior to the construction of the Facility was based on data collected by the Maryland Geological Survey (MGS) in 1978 (Cuthbertson, 1987). The sediments graded from nearshore sand to sand-silt-clay to silty-clay just northeast of the islands. On the Hawk Cove and southern sides of the complex, the sediments graded from nearshore sand to silty-clay. The latter were described as dark gray muds with high water content. Live bivalves, *Rangia cuneata* and *Macoma balthica*, were common (Kerhin et al. 1982b).

Radiographic examination of cores taken in the area around the islands before construction revealed low levels of bioturbation (reworking of sediments by organisms) in the Back River-Hawk Cove area and higher bioturbation levels elsewhere. Also, at several sampling locations south of the island complex, death assemblages of *R. cuneata* were found at the sediment surface.

During active construction of the dike, which began in the fall of 1981, minor changes in the relative proportions of sand, silt, and clay were detected in sediments collected at established stations around the Hart-Miller Island complex. Sediments became siltier, particularly at stations adjacent to areas of active construction. In the summer of 1982, gross changes in the physical appearance of the sediments were observed. Fine-grained sediments collected prior to the summer of 1982 were consistently described as dark gray muds. However, sediments collected in July of 1982, south of and adjacent to the dike wall, were very fluid, light gray to pink muds, resembling pre-Holocene sediments that had been 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 and Kerhin; 1983, 1985). Radiographic examination of the fluid mud accumulation revealed little or no bioturbation.

Trace metal analyses of sediment samples, presented as enrichment factors, indicated that sediments collected before and after dike construction were similar, except in the area of fluid mud accumulation. There, the enrichment factors dropped below the current regional average (see Results and Discussion).

The dike was completed in the spring of 1983. Continued monitoring has revealed little additional change in sediment characteristics. The layer of fluid mud introduced during dike construction is still evident, the only observed changes being slight color variations attributable to biogenic activity. Radiographic analyses of sediment cores taken around the dike structure have been consistent from one monitoring year to the next. Bioturbation levels in the cores taken within the fluid mud layer have increased with time. Nonetheless, enrichment factors have remained lower for the fluid mud accumulation. In areas beyond the blanket of fluid mud, enrichment factors for Zn have remained consistent with pre-construction values.

OBJECTIVES

The purpose of this year's study was to continue monitoring the vertical and areal distribution of sediments and their geochemical components. Specifically, the objectives were to:

1. Identify the sedimentological and geochemical conditions of the near-surface sedimentary column in the project area, and;

2. Provide information permitting the detection of gross environmental changes, should any occur during the life of the project.

METHODOLOGY

FIELD METHODS

Surficial sediment samples were collected twice during the sixth monitoring year, on November 20, 1986, and on April 22, 1987. Twenty-five stations were occupied during the fall cruise. Three additional stations--15, 17, and 18--were reestablished during the spring cruise to provide better control in drawing contour maps of the measured parameters. Sampling sites, shown in Figure 1-1, were located in the field by means of the LORAN-C navigational system. (LORAN-C coordinates, latitude and longitude of each station can be found in the Sixth Year Data Report).

Undisturbed samples of the upper 8-10 cm of the sediments were obtained with a dip-galvanized Petersen sampler. At least one grab sample was collected at each station for both textural and trace metal analyses. At seven stations (3, 19, 21B, 23, 24, BC-3, and BC6), a second grab sample was taken for organic contaminant analysis. At five stations (11, 21B, 24, BC-3, and BC-6), triplicate grab samples were collected.

Sediment and trace metal subsamples were collected using plastic scoops rinsed with distilled water. These samples, taken below the flocculent layer and away from the sides of the sampler to avoid possible contamination by the grab sampler, were placed in 18-oz "Whirl-Pak" bags. Samples designated for textural analysis were stored out of direct

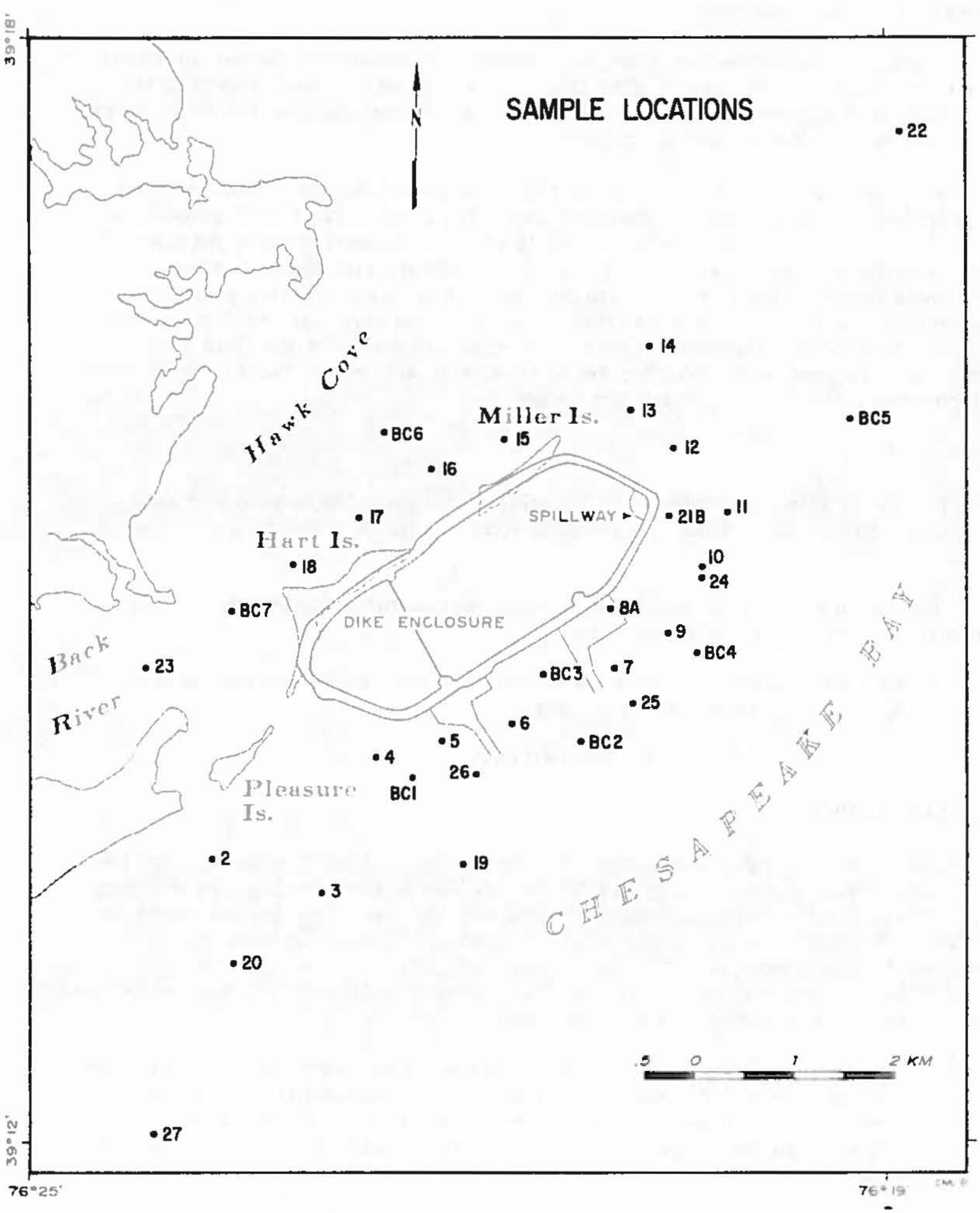


Figure 1-1: Map of the Hart-Miller Island Containment Facility and vicinity showing locations of the surficial sediment and cove stations sampled during the sixth year of exterior monitoring.

sunlight at ambient temperatures. Those intended for trace metal analysis were refrigerated and maintained at 4°C until processing.

Subsamples for organic analysis were collected with an aluminum scoop (also rinsed with distilled water), placed in pre-treated glass jars, and immediately refrigerated. They were delivered to the Water Resources Technical Services Laboratory in Annapolis for analysis.

During the April cruise, one core was collected at each of the seven box core (BC) stations and at Station 21B (Fig. 1-1) using a Benthos gravity corer (Model #2171) fitted with clean cellulose acetate butyrate (CAB) liners, 6.7 cm in diameter. Each core was cut and capped at the sediment-water interface and refrigerated until it could be X-rayed and processed in the lab.

In order to obtain an acoustical profile of the Bay floor east of the Facility, a series of eight transects, seven running east-west and one running north-south, were surveyed in April using the Datasonics DFS-210 system (Fig. 1-2). The boat path for each transect, presented in the Sixth Year Data Report, was determined using the LORAN-C navigational system. At specific time intervals during the survey, the boat's position was noted by recording LORAN-C time delays (TD's) and simultaneously marking the Datasonics' output record.

Radiographic Technique

Prior to processing, the upper 50 cm of each core were X-rayed at the Department of Radiology, Johns Hopkins Hospital, Baltimore, using a CTR kv X-ray unit (X-ray settings: 60 kV, 400 mA, 40-cm distance). A negative X-ray image of the core obtained by xeroradiographic processing. On a negative xeroradiograph, denser objects or materials, such as sand or shells, produce a lighter image. Objects of lesser density (e.g., burrows, gas bubbles) permit easier penetration of X-rays and, therefore, appear as darker features. Photographs of the xeroradiographs appear in Appendix A.

Each core was then extruded, photographed, and described (see the Sixth Year Data Report). Sediment samples for textural and trace metal analyses were taken at selected intervals from each core, on the basis of radiographic and visual observations.

Textural Analysis

In the laboratory, subsamples from both the surficial grabs and gravity cores were analyzed for (1) water content, (2) sand/silt/clay content, and (3) organic and carbonate content. Water content is calculated as the percentage of the water weight to the total weight of the wet sediment:

$$Wc = \frac{Ww}{Wt} \times 100,$$

where: Wc = water content (%)
Ww = weight of water (g)
Wt = weight of wet sediment (g).

Water weight is determined by weighing approximately 25 g of the wet sample, drying the sediment at 65°C, and reweighing it. The difference between total wet weight (Wt) and dry weight equals water weight (Ww). Bulk density was also determined from water content measurements.

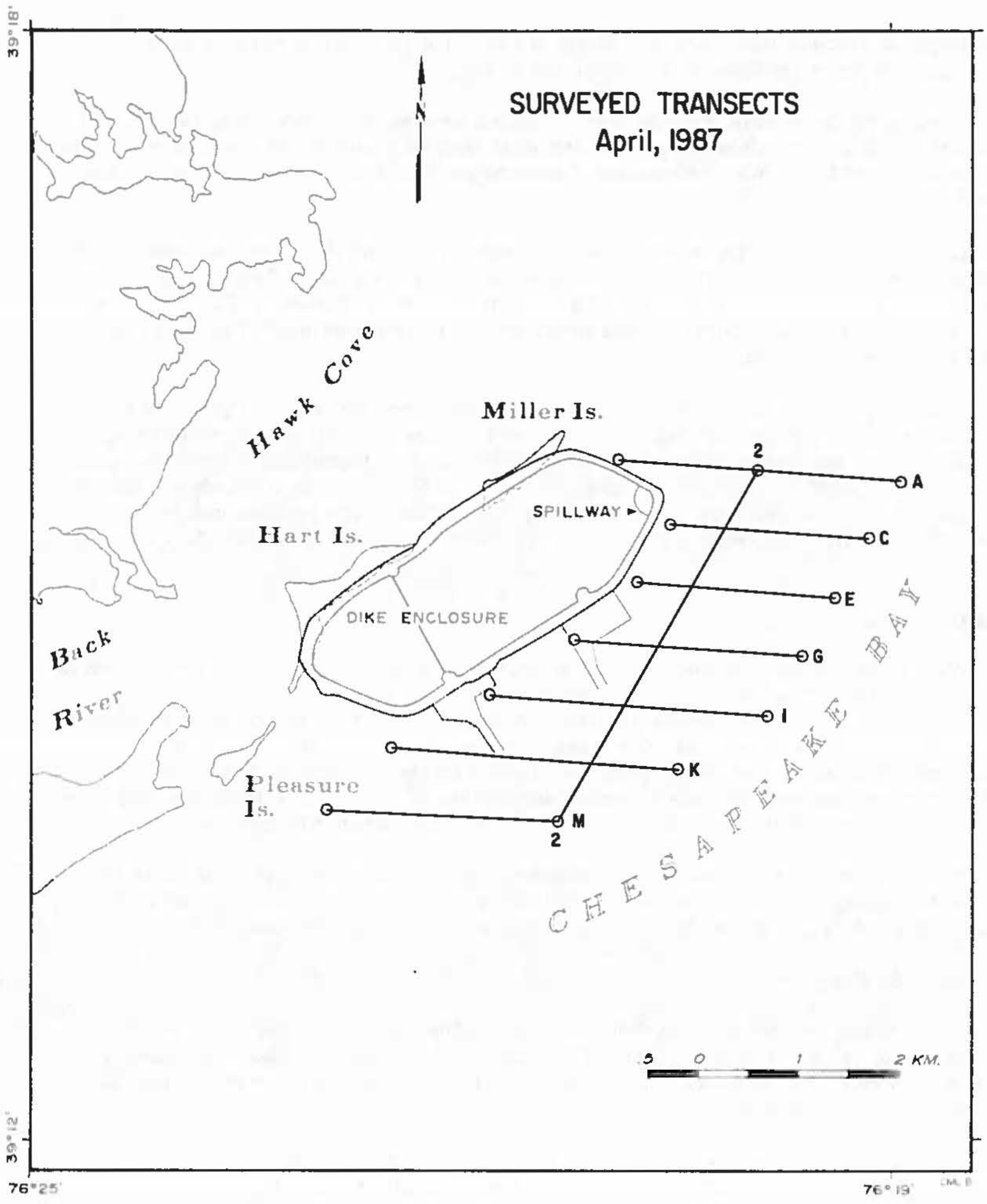


Figure 1-2: Map showing the eight transects surveyed acoustically on April 21, 1987.

The relative proportions of sand, silt, and clay were determined using the sedimentological procedures described in Kerhin et al. (1983). The sediment samples are pre-treated with hydrochloric acid and hydrogen peroxide to remove carbonate and organic matter, respectively. Then the samples are wet sieved through a 62 μm mesh to separate the sand from the mud (silt+clay) fraction. The finer fraction is analyzed using the pipette method to determine the silt and clay components. Each fraction is weighed; percent sand, silt, and clay are determined; and the sediments are categorized according to Shepard's (1954) classification (Fig. 1-3).

Organic and carbonate content is approximated by the percent weight loss due to sample preparation (i.e., pretreatment with acid and peroxide).

Trace Metal Analysis

Sediment solids were analyzed for six trace metals - iron (Fe), manganese (Mn), zinc (Zn), copper (Cu), chromium (Cr), and nickel (Ni) - using a lithium metaborate fusion technique, followed by flame atomic absorption spectrophotometry. This procedure, based on methods developed by Suhr and Ingamells (1966) for whole rock analysis, was refined specifically for the analysis of Chesapeake Bay sediments (Sinex et al. 1980; Sinex and Helz, 1981; Cantillo, 1982).

The MGS laboratory follows the steps below in handling and preparing trace metal samples:

1) Samples are homogenized in the "Whirl-Pak" bags in which they were stored and refrigerated (4°C).

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

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

4) Dried samples are then hand ground with an agate mortar and pestle and stored in "Whirl-Pak" bags.

5) Samples are weighed (0.2±0.0002 g) into a depression formed in $LiB0_2$ (1.00±0.01 g) at the bottom of drill-point graphite crucibles (7.8 cc vol.).

6) The crucibles are placed in a highly regulated muffle furnace at 1050±5°C for 30 min.

7) The molten beads produced are 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 does not occur within 30 minutes, the solution and bead are discarded and the sample is re-fused.

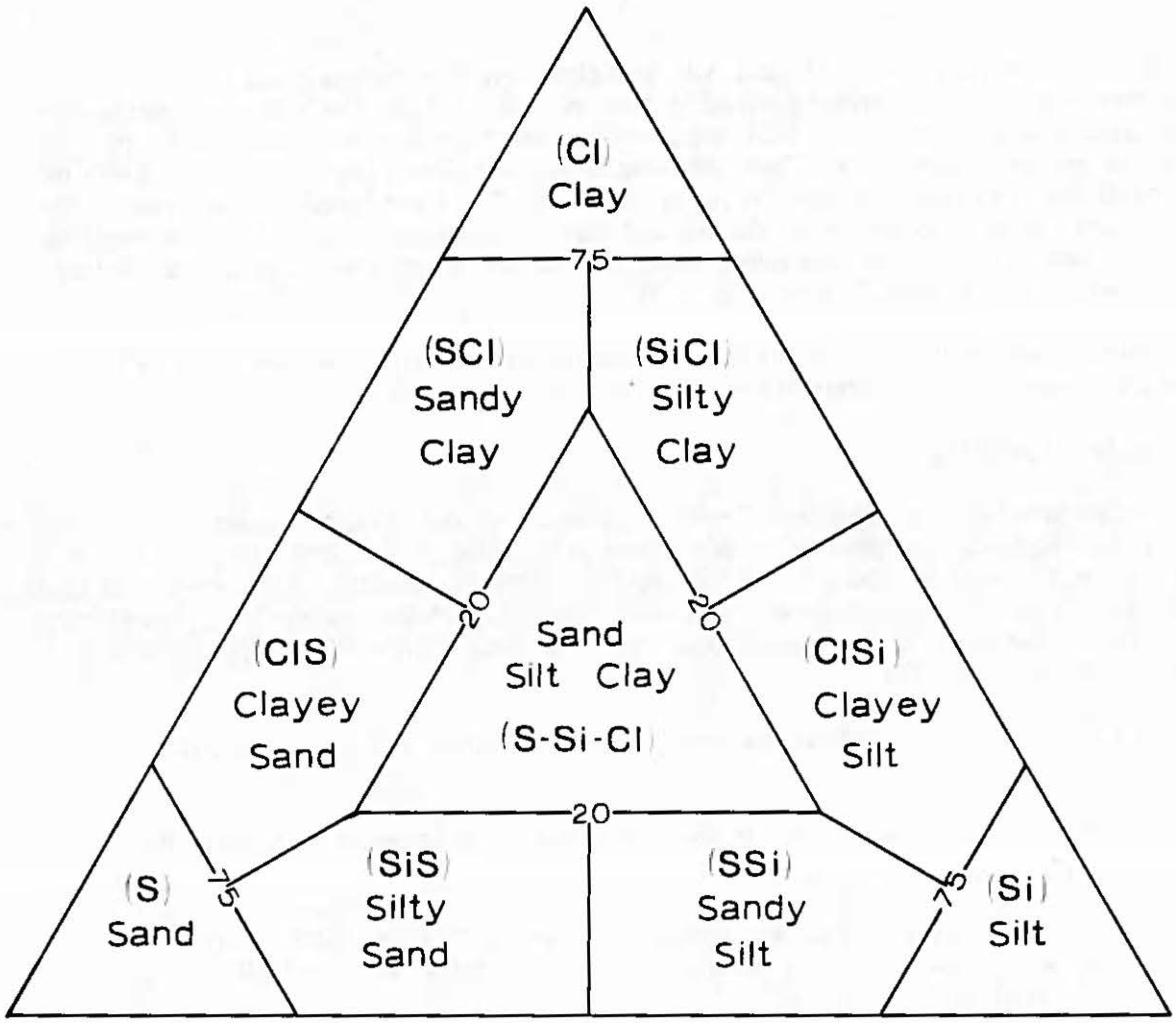


Figure 1-3: Ternary diagram showing Shepard's (1954) classification of sediment type.

8) The dissolved samples are transferred to polyethylene bottles and stored for analysis.

All surfaces that come in contact with the samples are acid washed (3 days 1:1 HNO_3; 3 days 1:1 HCl), rinsed six times in high-purity water (greater than 5 mega-ohms), and stored in high-purity water until use.

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

Results of the analysis of NBS-SRM #1646 are compared to NBS certified values in Table 1-1. There is excellent agreement between the NBS certified concentrations and MGS's analytical results for Cr, Cu, Fe, and Ni; all of these elements fall within the range of the determined standard deviation. Values for Mn (April 1987) and Zn (April 1987) fall well within the range of analytical uncertainty. Zn (November 1986) appears suspect. The discrepancy between the analytical and certified Zn values is thought to be due to loss during the fusion process.

Table 1-1: Results of the MGS analysis of NBS-SRM #1646 compared to the certified values.

Element Analyzed	NBS Certified Concentrations	MGS Results November 1986 Surficials	April 1987 Surficials	April 1987 Cores
Cr	76 ± 3	72 ± 4	76 ± 3	76 ± 3
Cu	18 ± 3	18 ± 6	19 ± 3	19 ± 3
Fe	3.35 ± 0.10%	3.30 ± 0.05%	3.31 ± 0.08%	3.31 ± 0.08%
Mn	375 ± 20	356 ± 6	338 ± 7	339 ± 7
Ni	32 ± 2	32 ± 4	30 ± 2	30 ± 2
Zn	138 ± 6	103 ± 3	120 ± 7	120 ± 7

* concentrations are in μg/g dry weight unless indicated otherwise.

RESULTS AND DISCUSSION

SEDIMENT DISTRIBUTION

Surficial Sediments

November 1986 (Cruise 15)

During the fall sampling cruise, sediment samples were collected at 25 stations. Very little textural change was seen in the sediment. Each of the measured parameters was compared with the range of values obtained for that parameter at that station since the eighth cruise (June, 1983), which immediately followed completion of the dike. At 13 of the stations (3, 6, 7, 9, 11, 13, 14, 16, 19, 20, 23, 25, and 26), the values of all of the parameters measured fell within previously established ranges. At the remaining 12 stations, the most common deviation was an increase in sand content and a concomitant decline in silt and/or clay. For the most part, the new maximum or minimum differed only slightly from its predecessor. However, at three stations - 8A, 12, and 22 - the maximum percentage of sand increased by more than five percentage points.

Station 8A is included among the three anomalous stations largely because of the arbitrary five-percentage-point cut-off. Here the maximum percentage of sand rose from a previous high of 69.1% to 74.2%, an increase of just slightly more than five percentage points. The relative proportions of sand, silt, and clay at this station have fluctuated widely, though apparently cyclically, with a sand maximum occurring every two years (Fig. 1-4 a). The November 1986 maximum is consistent with that pattern.

The marked increase in sand content at station 12 (from 49.1% to 79.3%) is more problematic. Although the relative proportions of sand, silt, and clay have varied considerably since completion of the dike, the bottom sediments here have never approached this composition (Fig. 1-4 b). (however, a sample collected at this location prior to the onset of construction was classified as a sand). Whatever its cause, the phenomenon was short-lived. By the April 1987 cruise, the grain size distribution had reverted to a more typical sand/silt/clay.

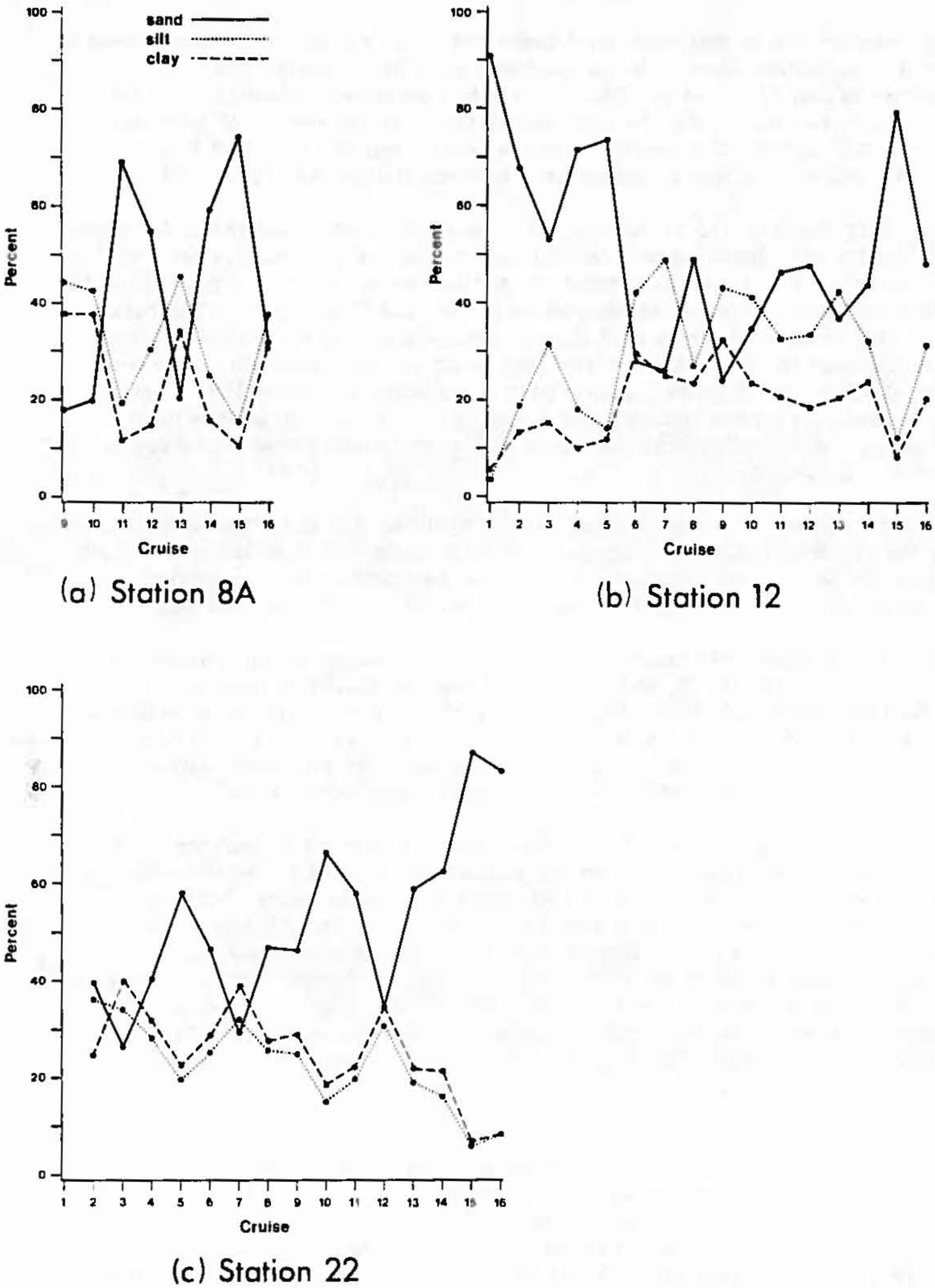


Figure 1-4: Relative proportions of sand, silt, and clay, over time, at the three stations with anomalously high sand contents in November 1986 (Cruise 15)

The 20.6 percent rise in maximum sand content at reference station 22 also appears to be consistent with cyclical changes in the sand:mud ratio there, though this is the largest increase to date (Fig. 1-4 c). Sand content had decreased only slightly by the April 1987 cruise, but that is also characteristic of the emerging pattern of sediment distribution at this station. It is unlikely that the facility can be implicated in any changes at this locality, because of the distance between stations 8A, 12, and 22.

A ternary diagram (Fig. 1-5 c) showing the types of sediments collected in November 1986 resembles the plot depicting samples collected during the preceding (April 1986) cruise. It does not differ appreciably from the distribution of sediment types collected in June 1983, immediately following completion of the dike (Fig. 1-5 b). The basic trend of the sediments passes from sand through sand/silt/clay to the silty clay-clayey silt boundary, except for three samples (two silty sands and one sandy silt). The three samples that deviate from the trend were triplicates collected at Station 21B. Great variability in sediment type is common at this site. Prior to the sixth monitoring year, samples composed of both silty sand and sandy silt were collected here in the course of a single cruise (April 1985).

The areal distribution of sediment types (Fig. 1-6) shows that the siltier sediments were collected at stations located within the zone of fluid mud accumulation. Generally, coarser sediments were found at stations adjacent to the southern and northeastern perimeter of the dike, and finer-grained sediments occurred to the east and west.

Compared to the April 1986 cruise, the classification of sediment type changed at seven stations (3, 4, 5, 12, 16, 20, and 22). The changes at station 16 (silty clay to sand/silt/clay) and station 20 (sand/silt/clay to silty clay) represent returns to sediment types more typical of those sites. Alternation between the observed sediment types is characteristic of stations 3, 4, and 5. As discussed earlier, only the sandy samples collected at stations 12 and 22 had not been previously classified as sands.

Field descriptions of sediments indicate little change in physical appearance since April 1986. The three obvious exceptions are stations 8A, 12, and 22, where sediments were described as being sandier than they had been the previous spring. Material introduced into the surrounding area during dike construction was still evident at stations 4, 5, 6, 8A, 26, and BC-3. Sediments at these stations were described as "smooth (creamy), light gray, white, or pink (fluid) mud". The same description was also applied to sediments at stations 19 and 20. At many of the stations, surface assemblages of articulated shells were found. These sediments had a higher percent weight loss upon digestion (cleaning), indicating high organic and/or carbonate content.

April 1987 (Cruise 16)

In April 1987, sediments were collected at 28 locations - the 25 stations occupied during the fall cruise plus three stations that had been eliminated after the June 1983 cruise. Again, at 13 of the 25 reoccupied stations (2, 3, 4, 5, 8A, 9, 12, 14, 16, 22, 26, BC-3, and BC-6), the values of all the parameters measured fell within previously established ranges. At the remaining 12 stations, none of the new maxima or minima differed from previous limits by more than three percentage points. Parameter values for the three reestablished stations (15, 17, and 18) were compared with their June 1983 counterparts. At station 15, all parameters except percent weight loss were within two percentage points of each other; the sediment remained a silty clay. At stations 17 and

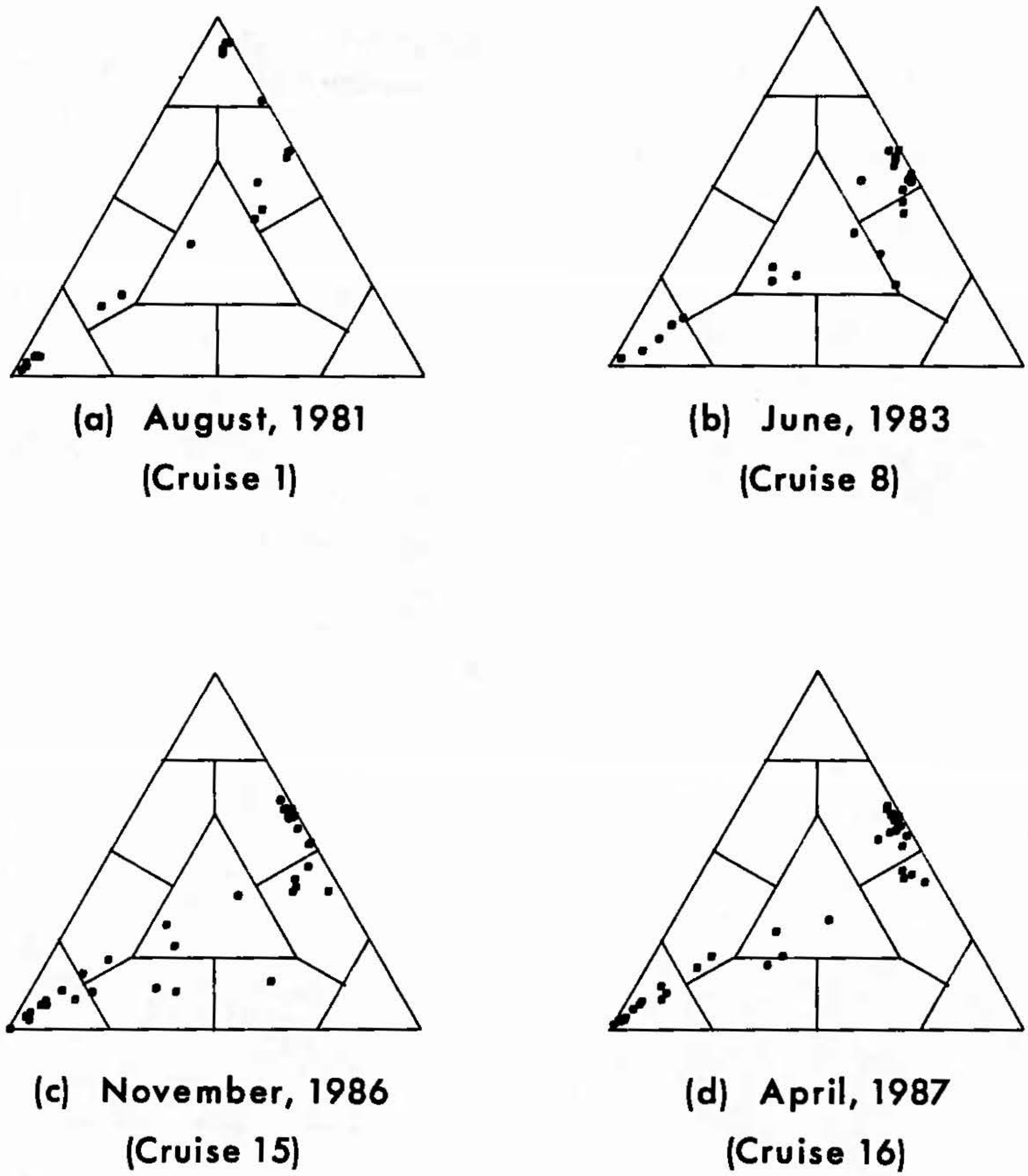


Figure 1-5: Ternary diagrams showing sediment type of samples collected in (a) August 1981 - Cruise 1, prior to the onset of dike constructions (b) June 1983 - Cruise 8, (c) November 1986, (d) April 1987.

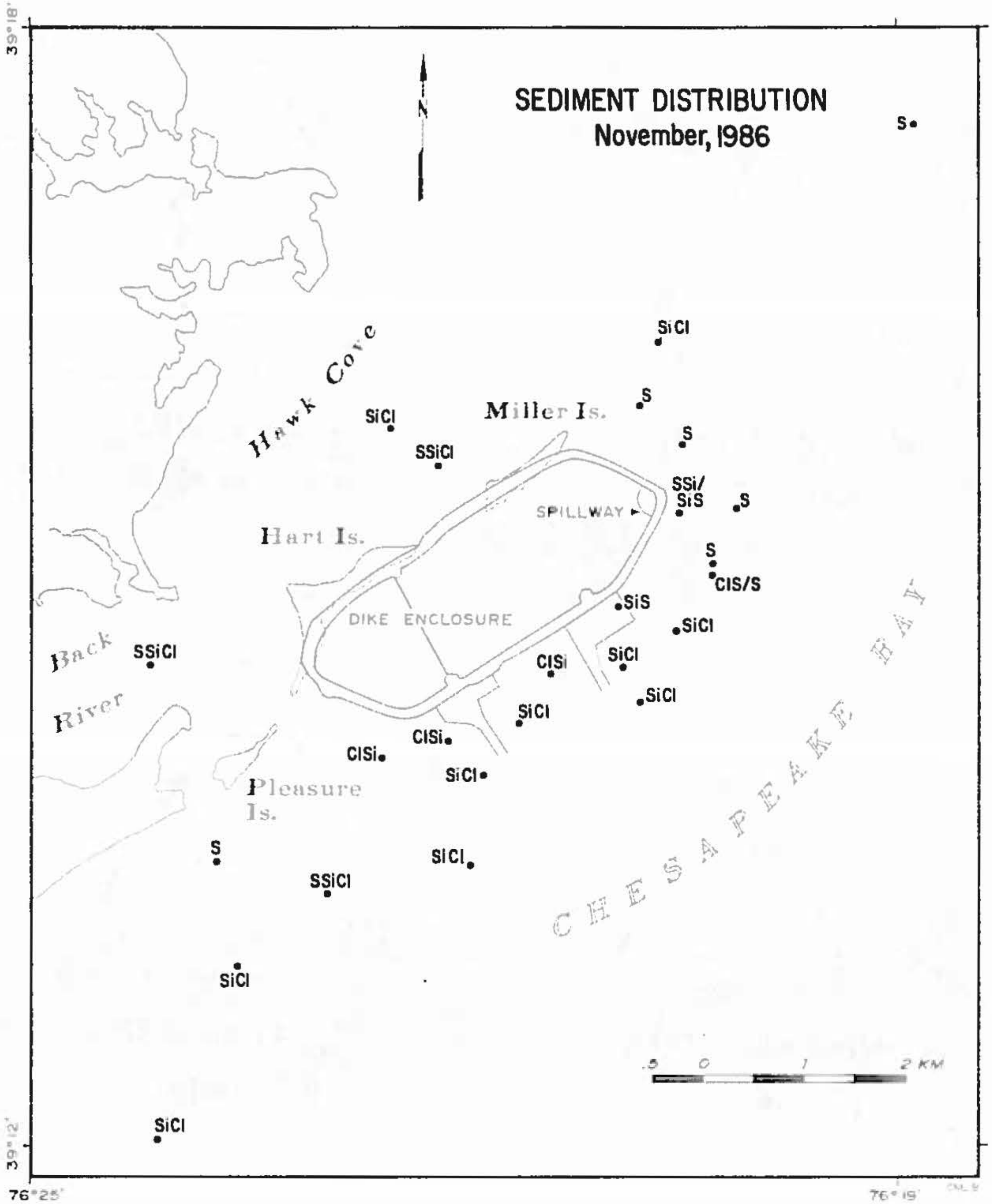


Figure 1-6: Map showing the distribution of sediment types of surficial samples collected on November 20, 1986.

18, the relative proportions of silt and clay were reversed during the time that elapsed between sampling; sediment composition changed from clayey silt to silty clay.

Figure 1-5(d) depicts sediment types collected during the spring cruise. It resembles the ternary diagram for the June 1983 cruise (Fig. 1-5(b)) even more strongly than does the November 1986 plot. The reason for this greater similarity is due primarily to the fact that the triplicates collected at Station 21B in April 1987 - all classified as sands - were no longer scattered between the silty sand and sandy silt fields of Shepard's diagram.

Compared to the preceding cruise, the classification of sediment type changed at six stations (3, 5, 8A, 12, 21B, and 23). At all of these sites except station 23, the observed sediment type had previously occurred. Although the sediments at station 23 are typically classified as sand/silt/clay, with percent clay just slightly greater than 20%, in April, percent clay fell slightly below Shepard's arbitrary 20% cut-off (to 18.0%), forcing the sediment into a new (silty sand) category. This change is considered insignificant. (Dredging of the northern access channel in March 1987 - one month before the April cruise may have affected grain size distribution at Station 8A. It is unclear, however, whether anthropogenic activity alone produced the change in sediment type from silty sand to sand/silt/clay. Sand/silt/clay has been found there before. Figure 1-7 shows the areal distribution of April 1987 sediment types. The same general patterns described for the fall cruise recur in the spring.

Beginning with this cruise, the subjectivity inherent in describing the color of sediments was reduced by using the GSA rock-color chart based on the Munsell system (Goddard et al., 1984). Aside from color, field descriptions of sediments indicate little change in physical appearance since the fall cruise. Fluid mud was recovered at stations 4, 8A, 26, BC-3, and, possibly, at stations 12 and 19. This was the first time that presumed evidence of fluid mud was found at station 12.

Again, surface assemblages of articulated mollusks, particularly *R. cuneata*, were found at many stations. Although percent weight loss is usually high at such stations, exceptions occur because of the selective removal of shells from samples before cleaning.

Gravity Cores

In April 1987, gravity cores were collected at the seven box core (BC) stations and at station 21B. Based on a comparison of xeroradiographs, the cores were very similar to those collected the previous spring, indicating that no major changes have occurred in the sediment column during the past year. Cores collected at stations BC-2, BC-4, BC-5, and BC-6 consisted of dark grayish silty clays and contained surface shell layers (Figs. A2, A4, A5, and A6). The core collected at station BC-7 consisted of an 18-20 cm thick layer of dark grayish clayey silt overlying silty clay and contained only isolated shells (Fig. A7). Highly reticulated networks of burrows and tubes, indicative of high bioturbation levels, were present in all of these cores.

At stations BC-1 and BC-3, cores penetrated the fluid mud layer. Both cores consisted of an upper layer, approximately 24 cm thick, of finely laminated, brown to gray, smooth mud overlying a firmer, more darkly-colored layer (Figs. A1 and A3). The upper 10-15 cm of the fluid mud layer was disrupted or mixed by biogenic activity, which obscured the laminae. Textural analysis of BC-3 subsamples reveal that the upper layer is siltier than the underlying one.

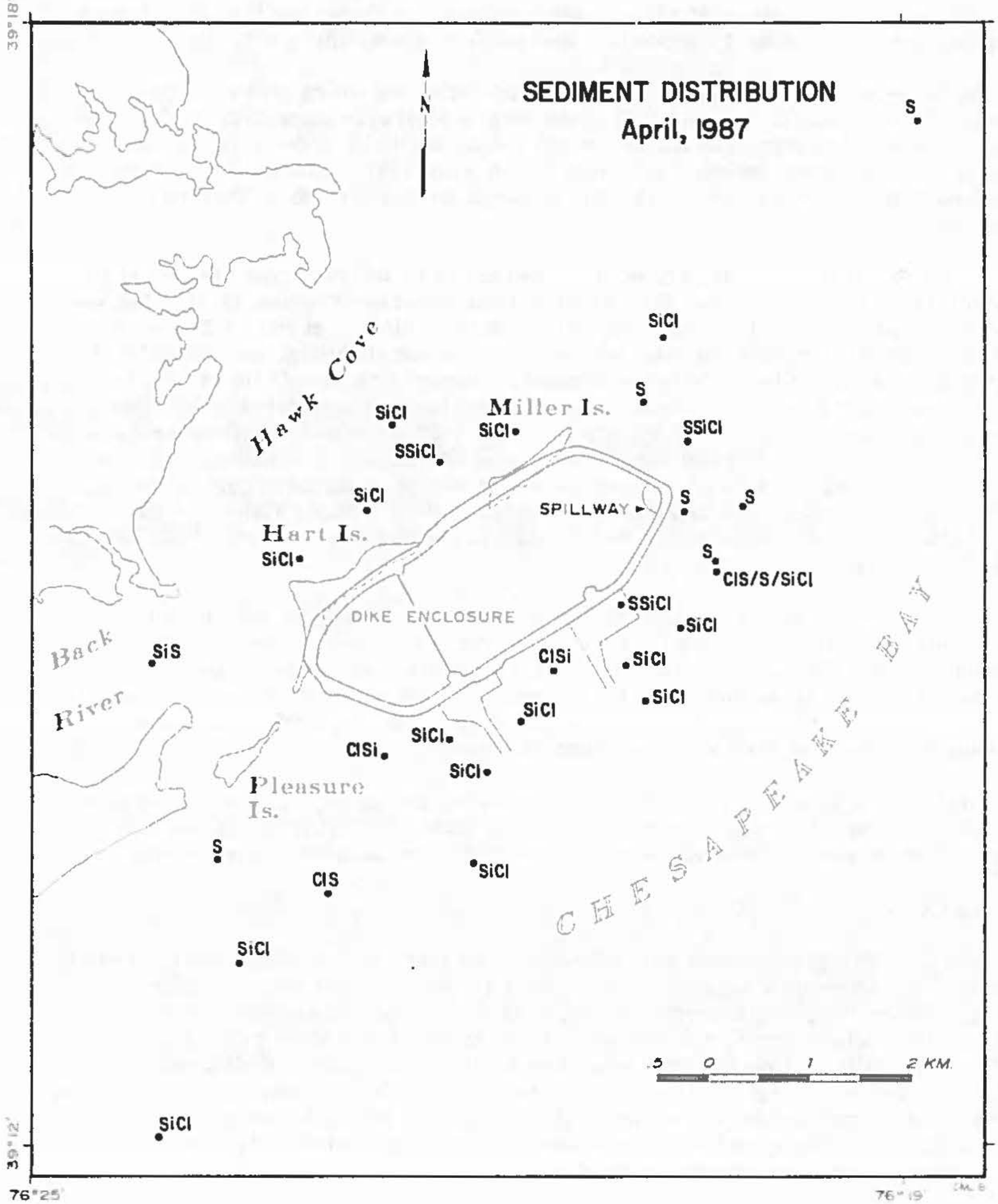


Figure 1-7: Map showing the distribution of sediment types of surficial samples collected on April 22, 198.

An eighth core was collected at Station 21B, adjacent to spillway #1. The hard substrate precluded deep penetration - only 14 cm of sediment were retrieved, consisting of medium to fine sand and containing some *R. cuneata* shells (Fig. A8).

NEAR-SURFACE STRATIGRAPHY

Reduced, two-dimensional cross-sections of the shallow subbottom are presented in Figures 1-8 and 1-9. Two noteworthy features the fluid mud layer and the channels approaching the unloading facilities are evident in the stratigraphic record. The fluid mud layer, acoustically distinct after five years, appears on the record as a thin, light gray surface layer, 30-50 cm thick, along the western ends of transects I, K, and, perhaps, E. The layer, absent at the western end of transect G, was undoubtedly removed during dredging of the northern access channel. That channel, as well as its southern counterpart, are documented on the seismic profiles along transects G and K, respectively.

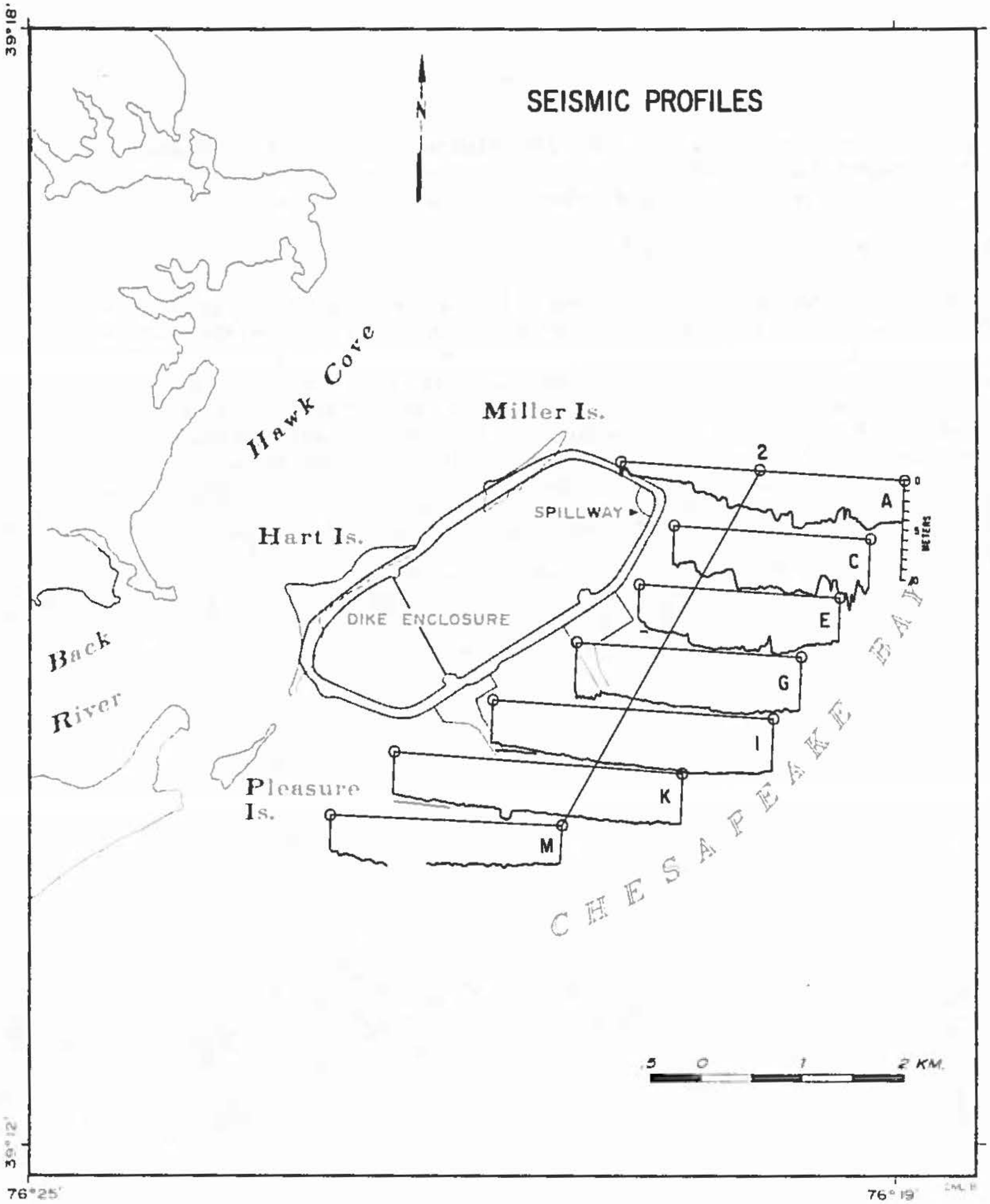


Figure 1-8: Cross-sections of the shallow subbottom obtained along the seven east-west transects shown in Figure 1-2.

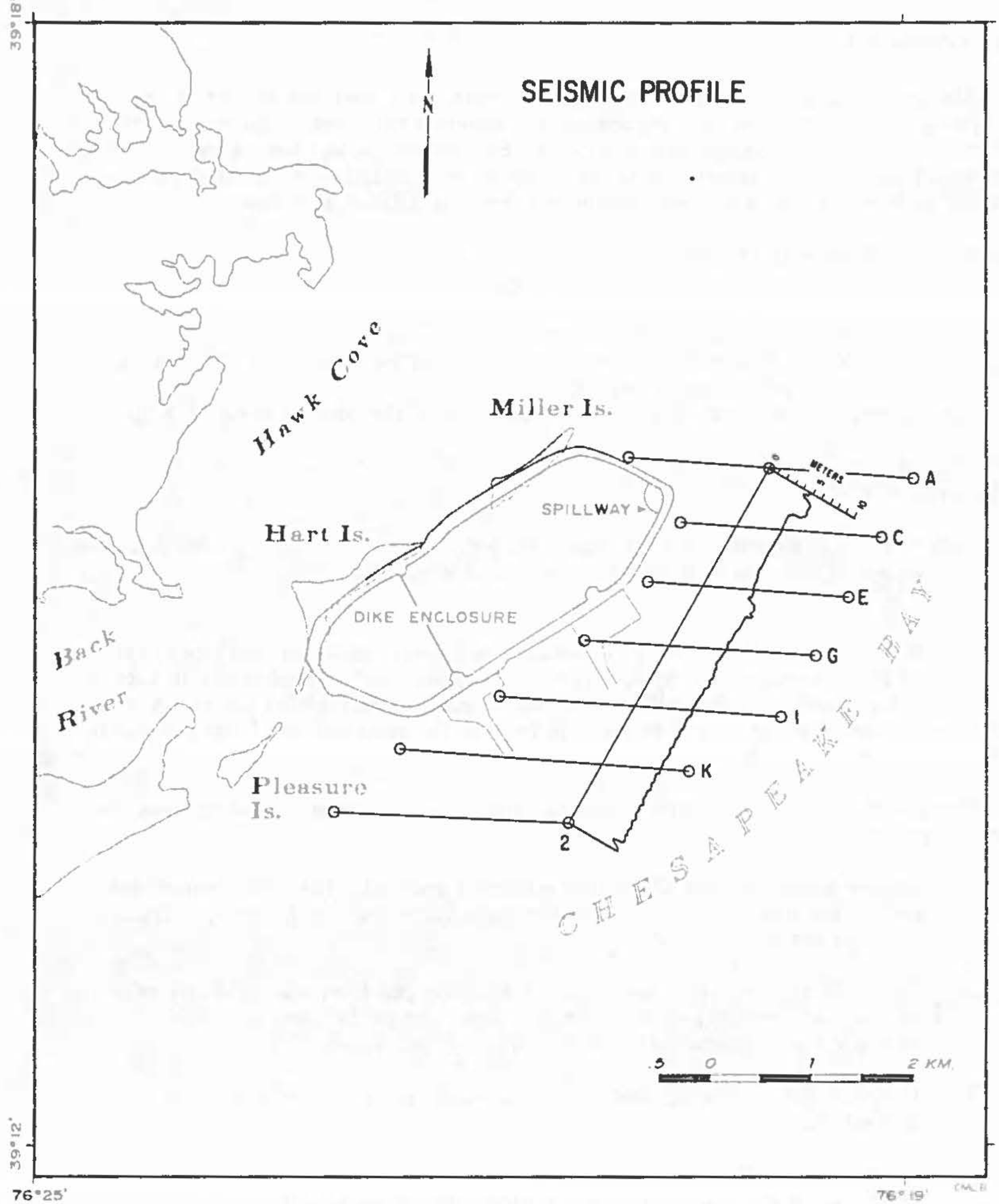


Figure 1-9: Cross-section of the shallow subbottom obtained along the single north-south transect shown in Figure 1-2.

TRACE METALS

Six trace metals, expressed as enrichment factors, were analyzed as part of the ongoing effort to monitor the sedimentary environment surrounding the containment facility and to assess any operational effects. Enrichment factors have been used in lieu of actual elemental concentrations to facilitate the interpretation of changes from one sampling period to the next. An enrichment factor is defined as follows:

(1) $$EF(X)ref = \frac{(X/Y)sample}{(X/Y)ref}$$ where:

X = the element of interest;
Y = an immobile element, such as Al or Fe, that is not affected by anthropogenic inputs;
(X/Y)sample = the analytically determined ratio of the concentration of X to Y in

the sample; and

(X/Y)ref = the ratio of the concentration of X to Y in a reference material, such as an average crustal rock type (Turekian and Wedepohl, 1961).

For the Hart-Miller Island samples, enrichment factors are based on Fe (=Y) and referenced to an average shale composition. Fe was analyzed in studies dating back to 1976 that monitored surficial sediments in the vicinity of Hart-Miller Island. Average shale was selected as the reference material because the composition of Bay sediments closely resembles that of shale.

Using enrichment factors rather than elemental concentrations is advantageous for several reasons:

1. Sample levels are normalized to a reference material. Therefore, enrichment factors are direct comparisons with a known material, in this case, 'pristine' levels in the average shale.

2. The ratio of elemental concentrations acts as a check on the reliability of a set of analytical results and also permits comparison of data sets that were obtained by different analytical techniques (Wells et al., 1986).

3. Differences in elemental concentrations due to grain size variations are minimized.

4. Variations in enrichment factors from the reference material indicate perturbation by natural processes and/or anthropogenic activity.

These characteristics make enrichment factors useful for examining spatial and temporal trends in trace metal levels in sediments.

The enrichment factor for Zn (=X in equation 1) is used in the following discussion as an indicator of change in sediment chemistry. As elaborated in previous reports (Kerhin et al. 1982a; Wells et al., 1984), there are a number of reasons for focusing on Zn:

1. Of the chemical species measured, Zn has been the least influenced by variation in analytical techniques. Since 1976, at least four different laboratories have been involved in monitoring the region around Hart-Miller Island. The most consistent results have been obtained for Zn (and Fe).

2. Variation in the Zn enrichment factor due to differences in reference material, i.e. sandstone versus shale, is small (less than 20%).

3. Zn is one of the few metals in the Bay that has been shown to be affected by anthropogenic input.

4. There is a significant down-Bay gradient in the Zn enrichment factor that can be used to detect the source of imported material.

5. Zn concentrations are highly correlated with other metals of environmental interest.

Figure 1-10 (a-c) shows maps of the Zn enrichment factor for surficial samples collected in November 1986, April 1987, and, for comparison, April 1986. The sedimentary environment has remained stable for the past year. Broad gentle contours, similar to pre-construction conditions, characterize all three sampling periods. There is no evidence of spillage or any other localized event that might have affected the sediment by producing a plume or hot spot.

Trace metal analysis of core subsamples yields information on the long-term net accumulation of sediment in the Hart-Miller Island vicinity, providing an historical record of change. Figure 1-11(a-g), a series of plots of the enrichment factor for Zn versus depth in the core, summarizes data collected during a seven-year period at the seven box core (BC) locations. Based on cores retrieved from the mainstem of the Bay and other unperturbed sedimentary environments, enrichment factors should be highest at the sediment surface and decrease monotonically down-hole to the 'pristine' value of 1, denoted in the diagrams by a dot-dash line. This expected down-hole behavior is exhibited by cores BC-2, BC-4, and BC-6. The scatter in these three plots results from (1) analytical uncertainty (approximately ± 1) due to methodological differences; (2) variability in sampling location; and (3) an imperfect knowledge of sedimentation rates; samples are plotted by depth in the core, not with reference to a distinctive event or time horizon.

Evidence of events that have affected the sedimentary environment around the island complex can be found in the four remaining cores. The most notable event, documented previously (Wells and Kerhin, 1985), was the redeposition of pre-Holocene sediments disturbed during dike construction. This material, referred to as 'fluid mud', is free from the influence of anthropogenic inputs. Its enrichment factor, therefore, is near 1. From xeroradiographs and visual descriptions of the cores, the fluid mud layer is clearly distinguishable in cores BC-1 and BC-3. The depth to which this layer is observed in the April 1987 xeroradiographs is marked on the plots as a dashed horizontal line.

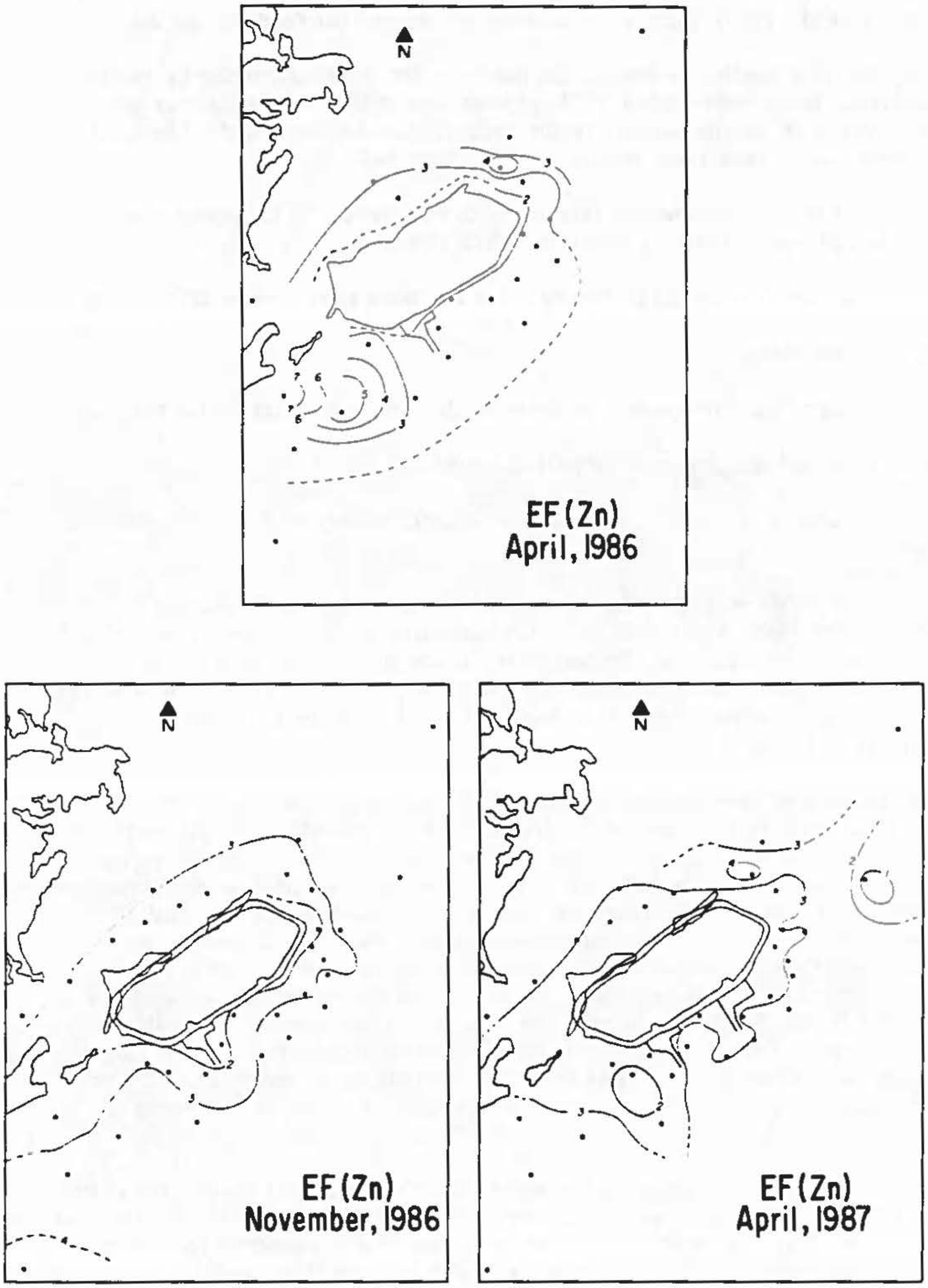


Figure 1-10: Contour maps depicting the spatial distribution of the enrichment factor for zn, based on surficial sediments collected in (a) April 1986, (b) November 1986 and (c) April 1987.

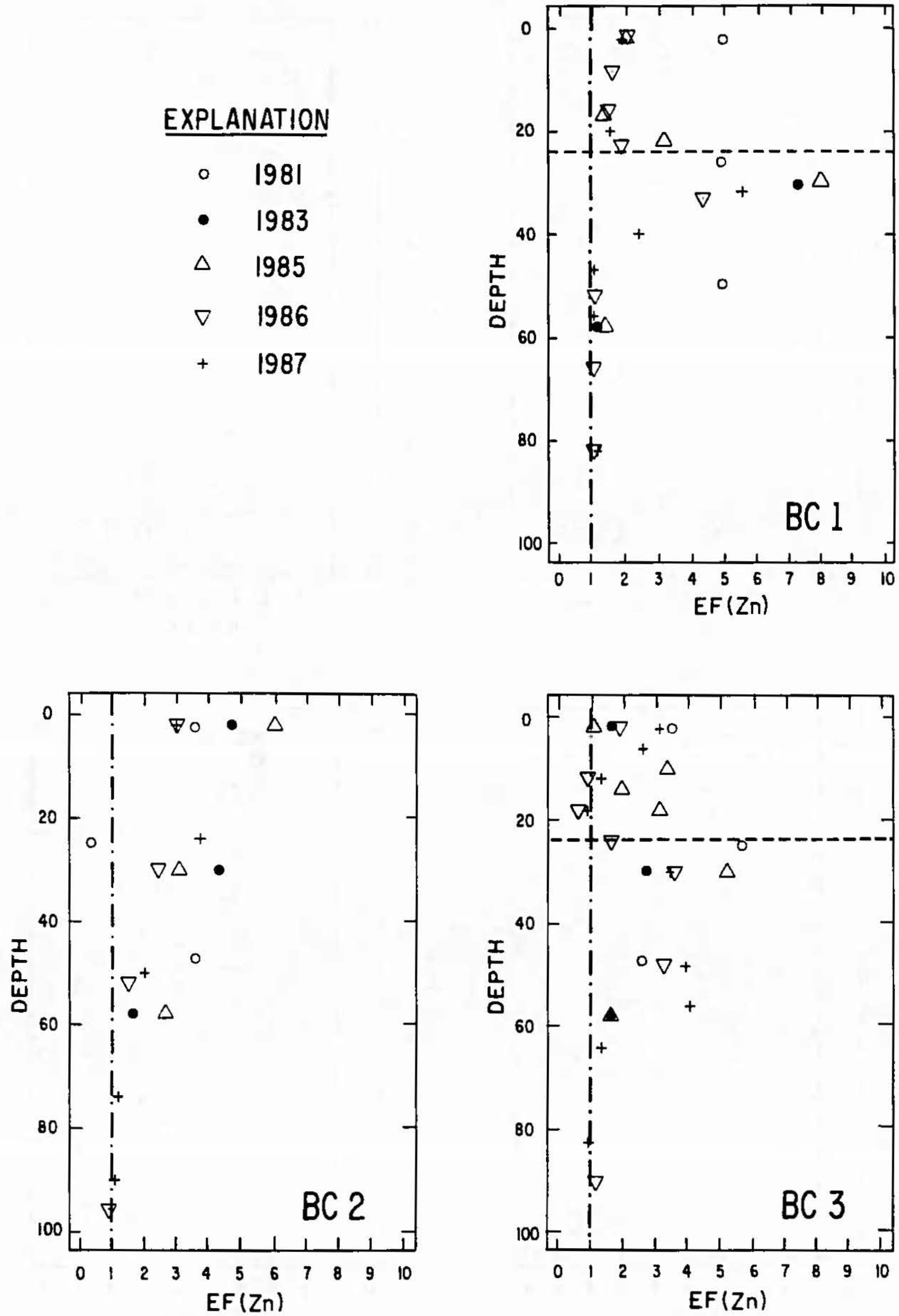


Figure I-11: Down-hole variations in the enrichment factor for zn, overtime, for the seven box cove.

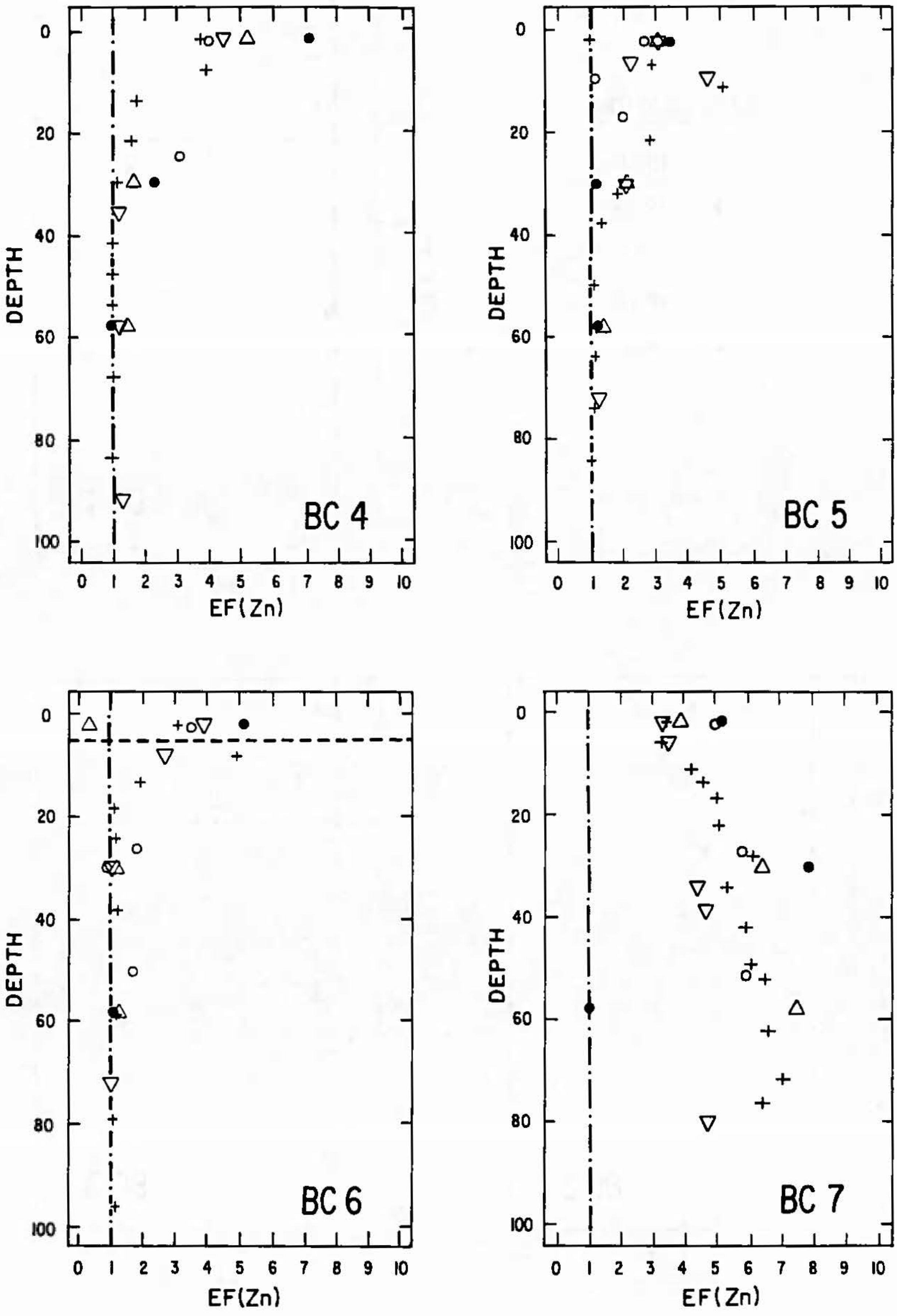


Figure 1-11: (Continued)

Above this horizon, enrichment factors are generally lower than the areal average (3.36) and much closer to 1. Below the layer, enrichment factors decrease monotonically with depth to a value of 1, indicating that the observed horizon is probably the pre-deposition surface in both of these cores.

In BC-5, the horizontal line (at 8 cm) corresponds to the depth of Bay floor scouring apparent in the April 1987 xeroradiographs. The enrichment factors of sediments deposited above the scoured surface are low. On the basis of the expected monotonic down-hole trend, the pre-event surface occurs at about 15 cm. Between this horizon and the depth of scouring, there are two unexpectedly low samples. These points may be indicative of other episodes of scouring/redeposition before cores were collected in April 1986, but neither the xeroradiographs nor the visual descriptions clearly indicate this.

BC-7 profiles are the most anomalous, showing the reverse of the expected trend; enrichment factors at the surface are relatively lower than those found at depth. Nonetheless, the enrichment factor of the surface sediment equals the areal average. The sediments at this site probably reflect input from Back River. Approaching the surface from depth, the decreasing enrichment factors indicate either that the anthropogenic loading of Zn in Back River has declined over time or that the Bay has become increasingly important as a sediment source to the site.

Generally, the spatial distribution of the Zn enrichment factors through time and the down-hole profiles show neither leakage nor spillage of dredged materials. Trace metal behavior indicates that the sedimentary environment around the Facility has been relatively stable since its construction.

CONCLUSIONS

During the sixth monitoring year, no significant changes were observed in the sedimentary environment surrounding the Hart-Miller Island Containment facility.

Generally, the sediments around the Facility remained siltier than pre-construction sediments (Fig. 1-5). The blanket of fluid mud was still very distinct after 5.5 years. Radiographic examination of the fluid mud layer revealed only a slight increase in bioturbation levels compared with the fifth year. Reworking by benthic activity is largely restricted to the upper 10-15 cm.

The distribution and range of the enrichment factor for Zn in the exterior sediments were similar to those found previously. Average enrichment factors for the fluid mud remained lower than pre-construction values. However, slight increases in enrichment factors were observed in the bioturbated zone of the fluid mud layer, indicating that benthic activity contributed to the enrichment of sediments with that metal and, by association, others as well.

RECOMMENDATIONS

Monitoring of the sedimentary environment exterior to the Hart-Miller Island Containment Facility should be continued at its current level through at least 1990, the scheduled completion date of the 50' deepening of Baltimore Harbor and its approach channels. Maximum use of the facility will occur during the 50' Project, which is expected to generate a total of 27+ million cubic yards of dredged material. Settling and de-watering of the emplaced material will result in a large volume of effluent to be discharged from the dike. If operation of the facility produces any impact on the

exterior sedimentary environment, those effects should be evident during the next few years. In addition to the daily operation of the Facility, construction of the proposed inner dike could also produce changes in the surrounding sediments.

ACKNOWLEDGMENTS

We would like to thank our co-workers at MGS their assistance during all phases of the project: Captain Jerry Cox and first mate Rick Younger of the R/V Discovery, for their expert seamanship and spirit of cooperation; Jeff Halka, for his expertise in obtaining and interpreting Datasonics' output; Bob Conkwright and June Park, for braving the elements during sample collection and the lab equipment during sample analysis; Bill Panageotou, for his lucid explanation of seismic run reduction; Tom Sadowski and Greg Kane, for their careful analysis of sediment samples (and their good humor in the face of tedium); Sally Jones for skillfully typing (and retyping) the report; Cindy Lang-Bachur, for drafting many of the figures; and Randy Kerhin, for his interest in the project's progress and his open door. Special thanks are due to Darlene Wells, the project's former principle investigator, for patiently sharing her considerable knowledge of the effects of construction and early operation of the facility on the exterior sedimentary environment. In addition to MGS staff members, we extend our thanks to Gabby Donovan at the Johns Hopkins Hospital, who never hesitated to stay after hours to X-ray sediment cores.

PART 2
BEACH EROSION STUDY

INTRODUCTION

A recreational beach was created between Hart and Miller Islands during the early stages of construction of the containment facility. Approximately 500,000 yd^3 (382,000 m^3) of sediment were pumped from what is now the interior of the dike to a section along the outer dike face. The original plans called for a 250' wide beach sloping gently Bay-ward at a grade of 1:20 (gradient = 2.9°). The beach shoreline, parallel to the outline of the dike, was curvilinear - convex at the northern (Miller Island) end of the beach and concave at the southern (Hart Island) end.

Natural processes began modifying the beach shortly after its completion. Wave-cut escarpments formed, and sheet wash and gully erosion removed material from the dike face. Some of the eroded sediments were deposited along the foreshore at the southern end of the beach. The Maryland Geological Survey (MGS) was enlisted to monitor the beach and document the erosional and depositional changes that were occurring along it.

PREVIOUS WORK

Study of the recreational beach began in May 1984. Results of investigations during the first three years of monitoring are reported in Wells et. al. (1985, 1986, 1987). Based on the results of profile surveys, the beach was divided into three geomorphic regions affected by different natural and anthropogenic processes (Fig. 2-1): (1) the outer dike face, extending from the edge of the dike roadway Bay-ward to the high water mark (wave-cut escarpment); (2) the foreshore, between the high water mark and mean low water (0' MLW); and (3) the nearshore, Bay-ward of mean low water.

The dike face is affected primarily by aeolian (wind-related) and pluvial (rain-related) processes. Annual regrading also contributes to the erosion of this section of the beach. Gullies, excavated by rainfall and runoff, are recurrent erosional features, especially at the northern end of the beach. Smoothing the lower dike face by bulldozing erases these features temporarily. Unfortunately, the slope of the dike face has increased with each successive regrade. Steeper slopes promote gully formation and invite more serious erosion.

The foreshore is being modified by wind-generated wave activity and the resultant longshore transport of sediment from Miller to Hart Island. Wave erosion has simultaneously intensified erosion of the foreshore at the northern end of the beach and produced a shelf-like depositional feature behind Miller Point.

OBJECTIVES

This report is part of an ongoing study of the erosional and depositional patterns on and around the recreational beach between Hart and Miller Islands. Erosional problems identified in past reports are reconsidered in light of this year's findings.

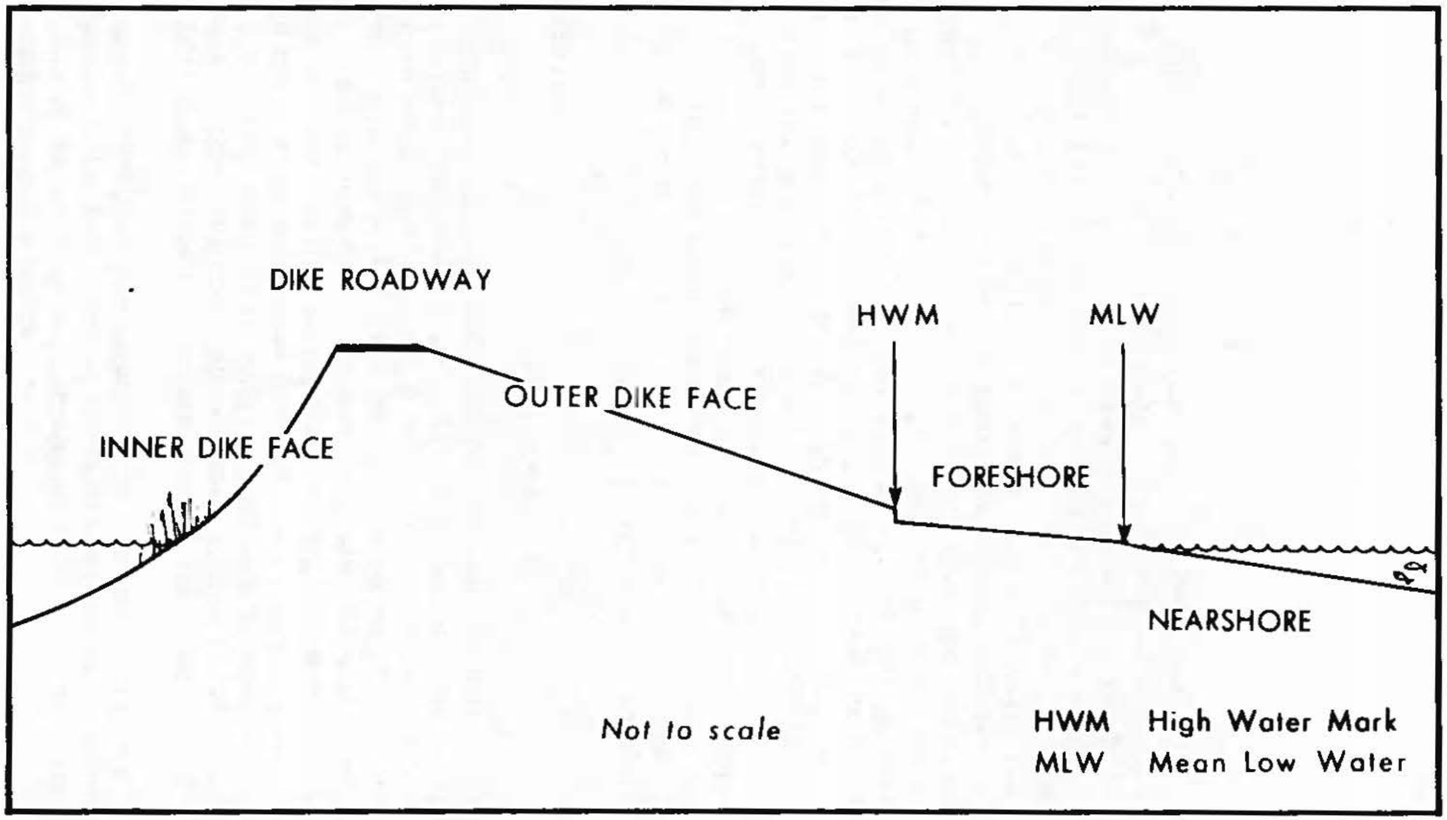


Figure 2-1: Schematic cross-section of the dike illustrating the three geomorphic regions of the beach.

The objectives of this report are to:

1. Analyze the beach configuration;
2. Evaluate the erosional and depositional processes altering the beach; and
3. Determine the time frame of erosional responses and readjustment cycles to known geomorphic and anthropogenic processes in the area.

The report covers the period between May 21, 1986, and May 26, 1987, the time interval between beach regrades. There is some overlap in the period covered by this report and last year's (Wells et al., 1987) because of a decision to change the reporting period. In the past, the monitoring year began and ended in September. Because of the annual May regrade, that time period presented difficulties in distinguishing the effects of natural versus anthropogenic processes. The reporting period was changed so that it begins shortly after the May regrade and ends the following May, just before the next regrade. (The survey schedule itself is unaffected.) As a result, the effects of natural and anthropogenic processes will no longer be confounded, and the time period necessary for the formation of natural geomorphic features will be easier to determine.

METHODOLOGY

FIELD METHODS

Ten profile lines (Fig. 2-2), established by MGS in May, 1984, were surveyed four times during the fourth year of the beach study (Table 2-1). These lines coincide approximately with lines established during a hydrographic survey conducted by the Waterway Improvement Division of the Tidewater Administration during the summer of 1983. All profile elevations were transferred from Maryland Port Administration benchmark number 281614 (elevation = 14.57' MLW), located approximately 22' east of the centerline of the dike roadway at Station 30+00. Initially, each station along the centerline of the roadway was measured off in 100' increments with a steel tape. At each established profile line, a 1' steel spike was driven into the centerline of the roadway, flush with the road surface. The heads of the spikes were painted orange for easy identification. To ensure that the same line down the face of the beach was surveyed on successive occasions, an azimuth was chosen approximately perpendicular to the centerline of the roadway, and the point at which the profile line crossed the chain link fence was marked. The location of each profile station was then referenced to the benchmark. With a theodolite set up over the benchmark, a baseline was established from the benchmark to the Craighill Channel Northern Range light, south of Pleasure Island (Fig. 2-3). The angles between the baseline and the profile stations were recorded. Angles and azimuths are reported in the Sixth Year Data Report.

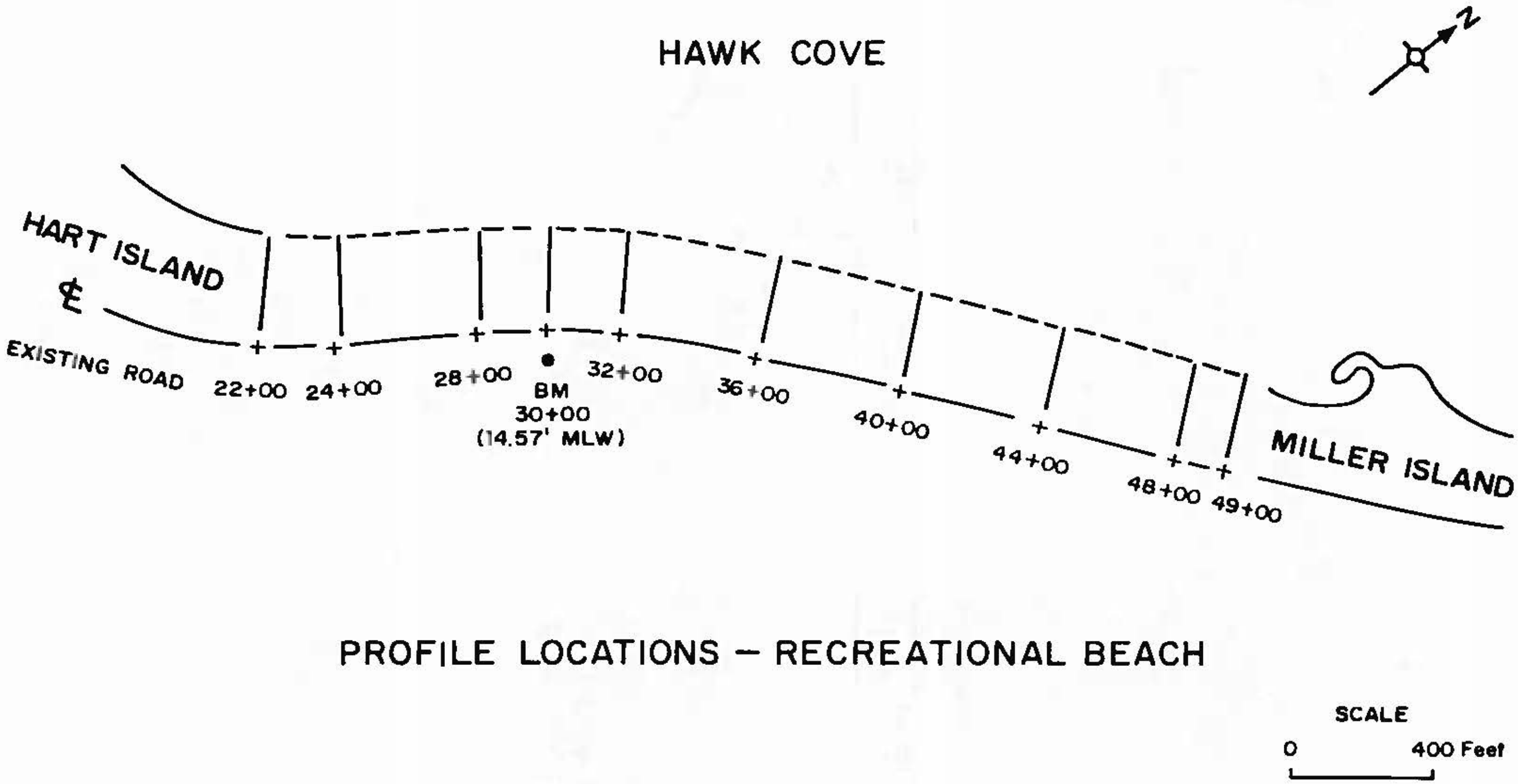


Figure 2-2: Locations of profile lines along the recreational beach between Hart and Miller Islands.

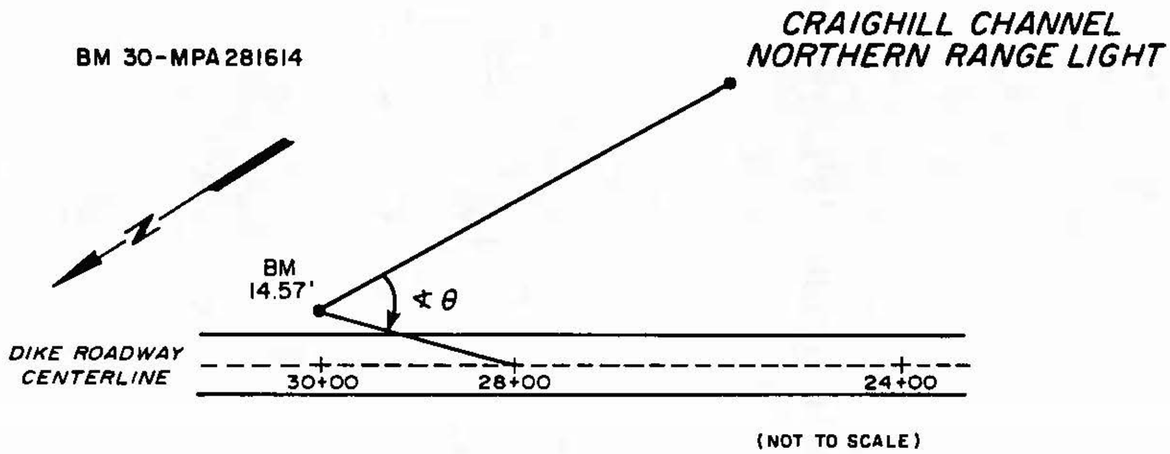


Figure 2-3: Established baseline.

Table 2-1: Beach profile survey dates.

Profile location	1	2	3	4
22+00	6/24/86	9/15/86	12/08/86	3/23/87
24+00	6/24/86	9/15/86	12/08/86	3/23/87
28+00	6/24/86	9/15/86	12/08/86	3/23/87
30+00	6/24/86	9/15/86	12/08/86	3/23/87
32+00	6/24/86	9/15/86	12/08/86	3/23/87
36+00	6/25/86	9/15/86	12/08/86	3/23/87
40+00	6/25/86	9/18/86	12/23/86	3/24/87
44+00	6/25/86	9/18/86	12/23/86	3/24/87
48+00	6/25/86	9/18/86	12/23/86	3/24/87
49+00	6/25/86	9/18/86	12/23/86	3/24/87

Standard surveying techniques, using a self-leveling level, stadia rod, and fiberglass measuring tape, were followed in surveying the profiles. The steel spikes in the dike roadway marked the start of the profiles. Profiles were measured downslope in 50' increments and at abrupt changes in elevation. The water line and a single elevation below mean low water were also recorded. Distance and elevation data from the four surveys are tabulated in the Sixth Year Data Report.

Ground truth photographs were taken to substantiate profile measurements and to document erosional and depositional features present on the beach. Aerial photographs were taken after each profiling period in order to observe overall changes in shoreline configuration, escarpment and gully development, and vegetation patterns.

In order to determine the natural distribution of sediments between beach regrades, sediment samples were collected every 50' downslope from the centerline of the roadway, at changes in slope, and at the water line during the June 1986 and March 1987 surveys.

LABORATORY METHODS

Beach sediment samples were processed using methods similar to those described in Part I of this report (see Laboratory Procedures: Textural Analysis). The Sixth Year Data Report lists the calculated percentages of gravel, sand, and silt/clay. Silt and clay were combined and presented as a single percentage because of their negligible contribution to beach sediment composition.

RESULTS AND DISCUSSION

To document the overall changes in beach configuration and topography, contour maps (Appendix B) and two sets of cross-sectional profiles (Appendix C) were constructed from the accumulated survey data. One set of cross-sectional profiles depicts the beach during the four surveys covered by this report, and the other compares the first beach survey (June 1984) with the most recent one (March 1987).

The shape of the recreational beach, demarcated by the o' contour, was curvilinear throughout the study period, convex near the end of profile 40+00 and concave to either side, at profiles 30+00 and 48+00 (Figs. B-1 through B-4). The points of maximal convexity and concavity migrated laterally during the year. However, except for a slight displacement shoreward, they had shifted back to their original positions by the end of the study period.

Migration of the 0'contour toward or away from shore is useful in inferring erosion or deposition, respectively. Between June and September 1986, the 0' contour south of profile 40+00 shifted slightly away from the beach, due to reworking and deposition of sediments in the nearshore (Figs. B-1 and B-2). For the same time period, the shoreward migration of the 0' contour north of profile 40+00 indicates reworking and erosion of the nearshore and foreshore. Between the September and December 1986 surveys, erosion occurred along the entire length of the beach north of profile 24+00 (Figs. B-2 and B-3). From December 1986 to March 1987, the beach was eroded south of profile 40+00 and remained unchanged to the north (Figs. B-3 and B-4). The cumulative effect over the course of the year was a slight (~8'), shoreward shift of the 0' contour north from profile 30+00, indicating net erosion of the foreshore and nearshore by wave action (Figs. B-1 and B-4). South of profile 30+00, the position of the 0' contour appeared to be stationary.

Cross-sectional profiles for the monitoring period show that erosion and deposition were restricted to the lower dike face and foreshore. Very little if any change was noted on the upper dike face, except for some gully erosion at the northern end of the beach. Sediment accumulation was documented along profiles 22+00 and 24+00 (Figs. C-1 and C-2). The deposited sediments originated on the beach north of profile station 24+00 and were transported to those sites by longshore currents. Northward from profile 40+00 inclusive, erosion occurred along the lower six feet of the dike face, as reflected by the closer spacing of contours on the March 1987 contour map, compared to the June 1986 map (Figs. B-1 and B-4). Sediment loss, attributed to sheet wash and wave erosion, is also apparent on the cross-sectional profiles (Figs. C-7 through C-10). Erosion is indicated by steepened slopes and wave-cut escarpments.

Wave-cut escarpments are erosional features produced when waves generated by high winds assault a beach. Due to the large generating area or fetch, the most damaging waves to the recreational beach occur when winds blow from the north or northeast. These winds are commonly higher in velocity than winds from other directions. To a lesser degree, waves produced by northwesterly and westerly winds may also erode the lower dike face.

There was no evidence of a wave-cut escarpment during the June 1986 survey. A small (<4 inches) escarpment was first observed on profiles 48+00 and 49+00 in September, 1986. By December 1986, the escarpment was continuously defined between profiles 40+00 and 48+00. Between December 1986 and March 1987, a second, very small (2 inches) escarpment was documented photographically from profile 30+00 north.

Wind roses were constructed from data recorded by the Maryland Environmental Service (MES) at a weather station located 1.6 km east of the recreational beach (Fig. 2-4). Summarizing seasonal wind patterns for the time interval between regrades, the diagrams indicate that both the frequency and velocity of northerly and northwesterly winds were greatest during the fall and winter months, the period during which wave-cut escarpments developed.

The formation of gullies was documented photographically as well as notationally during the profile surveys. Gully development along the recreational beach is controlled primarily by rainfall intensity and gradient or slope. Rainfall intensity, the criterion used to define a "storm" (at least half an inch of rain in half an hour (Barnett and Hendrickson (1960)), could not be determined from the weather data collected at the containment facility. Only the amount of rainfall, not its duration, is recorded. Based solely on the amount of precipitation, however, there were 20 storm events during the monitoring year, excluding snow storms (Table 2-2). A total of 27.21 inches of rain was reported. Storms accounted for 20.57 inches of that total, or 76 percent.

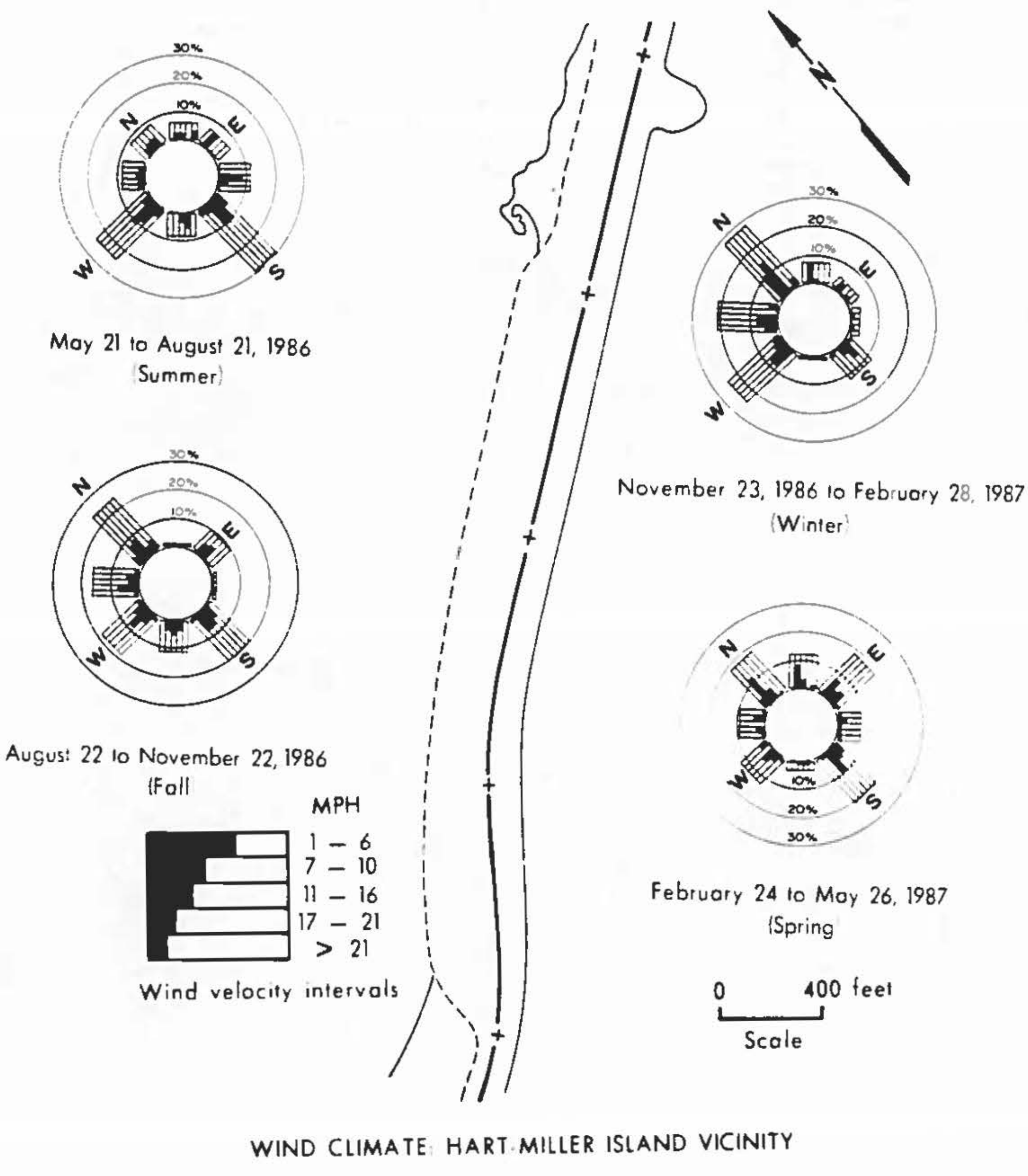


Figure 2-4: Wind roses for the Hart-Miller Island vicinity, based on data collected by MES.

Table II-2: Precipitation data collected by the Maryland Environmental Service (MES) at Hart Miller Island.

Date	Amount of precipitation (inches)	Date	Amount of precipitation (inches)
May, 1986		September, 1986	
21	.40	1	.01
22	.02	2	trace
--------June survey--------		3	.45
July, 1986		5	trace
1	.95	7	trace
9	.05	8	.15
12	.10	18	.05
13	.35	----------September survey----------	
16	.05	19	.05
18	trace	26	.05
20	.70	27	.05
29	.07		
August, 1986		October, 1986	
2	1.25	1	.10
6	.30	4	.10
11	trace	5	.05
17	1.50	13	.60
19	.05	14	.90
20	trace	25	.05
21	2.25	26	.51
28	4.8	27	.40
November, 1986		January, 1987	
1	.52	1	.60
2	.40	2	.35
4	.14	10	.18
5	1.65	15	.03
7	.36	18	.70
9	.26	22	.03
11	.60	26	12 (snow)
18	.52		
20	1.12	February, 1987	
21	.10	12	.05
24	.05		
25	.20	March, 1987	
26	1.30	3	.04
		4	trace
December, 1986		------------March survey-------------	
2	.75		
3	.20		
8	.05		
9	.75		
10	.07		
11	.40		
12	.05		
17	.05		
18	.90		
-------December survey--------			
24	2.50		
27	.05		
30	.20		

In previous monitoring years, it was established that a minimum average slope of 4.1-4.2° is prerequisite to gully formation (Wells et al. 1986, 1987). Throughout this reporting period, average slope equalled or exceeded that critical value along all profiles except 22+00 and 24+00 (Table 2-3). Along the lower dike face, from the break in slope to the water line, slopes were so steep (range = 4.9° to 11.3°) that, given sufficiently intense rainfall, gullying was inevitable.

Table 2-3: Average slope in degrees, of beach profiles, from the roadway to the waterline, by survey date.

	Survey Date					
Profile	6/84	4/86	6/86	9/86	12/86	3/87
22+00	3.1	3.5	3.5	3.6	3.4	3.2
24+00	3.3	3.7	3.7	3.6	3.8	3.5
28+00	3.7	4.4	4.2	4.3	4.3	4.4
30+00	4.2	4.7	4.6	4.7	4.8	4.8
32+00	3.4	4.6	4.7	4.6	4.9	5.0
36+00	3.0	4.1	4.2	4.2	4.2	4.2
40+00	3.2	4.0	4.1	4.1	4.1	4.3
44+00	3.3	4.6	4.7	4.4	4.7	4.8
48+00	4.2	5.4	5.7	5.4	5.3	5.8
49+00	3.7	4.8	4.9	4.9	4.9	5.0

During the study period, gullies were first observed in June 1986, in the vicinity of profiles 48+00 and 49+00. They were very shallow (less than 2 inches deep). Between the beach regrade in May 1986, and the first survey a month later, no storms were reported at the Facility. A total of 0.42 inches of rain fell, most of it (0.40 inches) during a single day. Gully erosion was negligible during this period. Thus, discounting duration, a rainfall of less than 0.4 inches contributes minimally or not all to gully development.

The period between the first and second surveys marked the beginning of incised gullies on all profiles north of 30+00 inclusive. Between surveys, slopes remained the same or decreased along all of the affected profiles except 30+00. None, however, fell below the critical minimum slope of 4.1%. The five storms reported during the period produced a total rainfall of 6.65 inches. The maximum amount of precipitation associated with a single storm, i.e. falling in a single day, was 2.25 inches.

By the December 1986 survey, gullies had become deeply incised (up to 2.5' deep). The maximum headward extent of some of the gullies near profiles 44+00, 48+00, and 49+00 reached the 11' contour. Deeply incised gullies appeared for the first time along profile 32+00. The average slopes of the beach and lower dike face remained the same or increased along all of the profiles except 22+00 and 48+00. By now, vegetation was either dead or dying and no longer acted to deter sheet wash. Consequently, the slopes of almost all of the profiles increased, leading to the potential acceleration of gully erosion with each successive storm. The frequency of storms and, not surprisingly, the total rainfall (10.12 inches) were greater during these three months than during either the preceding or succeding three-month periods. However, none of the storms reached the magnitude (maximum rainfall = 1.65 inches) of earlier or later storms.

During the period between the December 1986 and the March 1987 surveys, the number and size of gullies increased on all profiles except 22+00 and 24+00. From an aerial photograph, even profile 22+00 showed some evidence of an incipient gully. There were three storm events during the period (total rainfall = 3.8 inches), among them the storm on December 24, 1986, which brought the year's highest rainfall (2.50 inches). North of profile 28+00, inclusive, the average slope of the beach increased only slightly. However, in response to sheet wash, which was largely unchecked by the sparse, dead vegetation, the slope of the lower dike face increased dramatically. Profile 32+00 exhibited the greatest increase in slope, from 7.9° to 11.3°.

In previous monitoring years, gullies were largely confined to the profiles north of 44+00. However, this year, gullies were observed along almost all of the beach - at profiles 28+00, 30+00, 32+00, 40+00, 44+00, 48+00, and 49+00. An incipient gully was also noted on profile 22+00. The headward extend of a few of the gullies reach the 11' contour.

Gully erosion has almost certainly been aggravated by regrading the lower dike face and foreshore. Bulldozers smooth the beach, erasing the erosional gullies. Without replenishing the sand, the slope of the lower dike face increases (compare the April and June 1986 surveys, (Table 2-3)), inviting more serious erosion after the regrade.

BEACH SEDIMENT DISTRIBUTION

To assess the natural distribution of sediments, samples were collected in June 1986, after regrading, and in late March 1987, before regrading. Summarizing the results of grain-size analysis of the samples, Figures 2-7 through 2-10 depict the distribution patters of silt/clay and gravel. In order to understand the effects of beach regrading on sediment distribution, similar figures for the April 1986 sampling period are also included (Figs. 2-5 and 2-6).

The effects of beach regrading can be seen by comparing sediment distribution patterns in April 1986, and June 1986. Regrading resulted in a general decrease in the percentage of silt/clay over the entire beach, from an overall average of 6.0% to 4.1% (Figs. 2-5 and 2-7). Changes in silt/clay distribution were most pronounced along the upper dike face. The percentage of gravel also changed, decreasing along profiles south of 32+00 and increasing north of there (Figs. 2-6 and 2-8).

Between June, 1986, and March, 1987, changes in sediment distribution patterns can be attributed solely to natural causes. In June, 1986, most of the higher percentages of silt/clay were found above the 5' contour between profiles 30+00 and 49+00, with an isolated occurrence near the fence along profile 22+00 (Fig. 2-7). By March, 1987, the silt/clay content of the sediments above the 5' contour was as much as seven percentage points higher (Fig. 2-9). This increase was probably due largely to the entrapment of fine, wind-blown sediment by the proliferating vegetation.

The distribution of gravel on the beach is controlled primarily by the use of poorly sorted material in beach construction and secondarily by annual bulldozing. Fluctuations in gravel percentages attributed to natural processes are due, not to the redistribution of

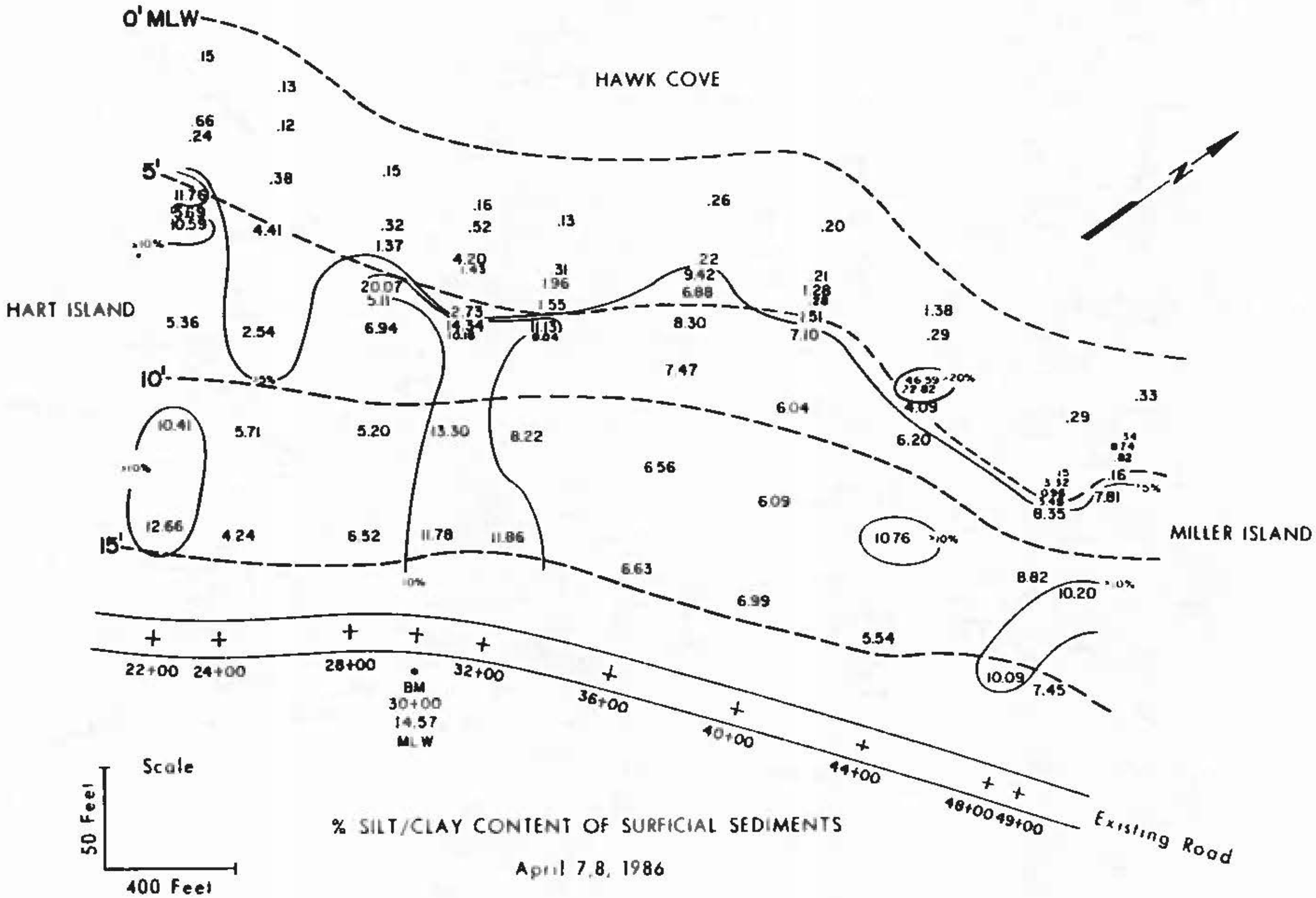


Figure 2-5: Map showing the distribution of silt/clay on the beach in April 1986 (before regrading).

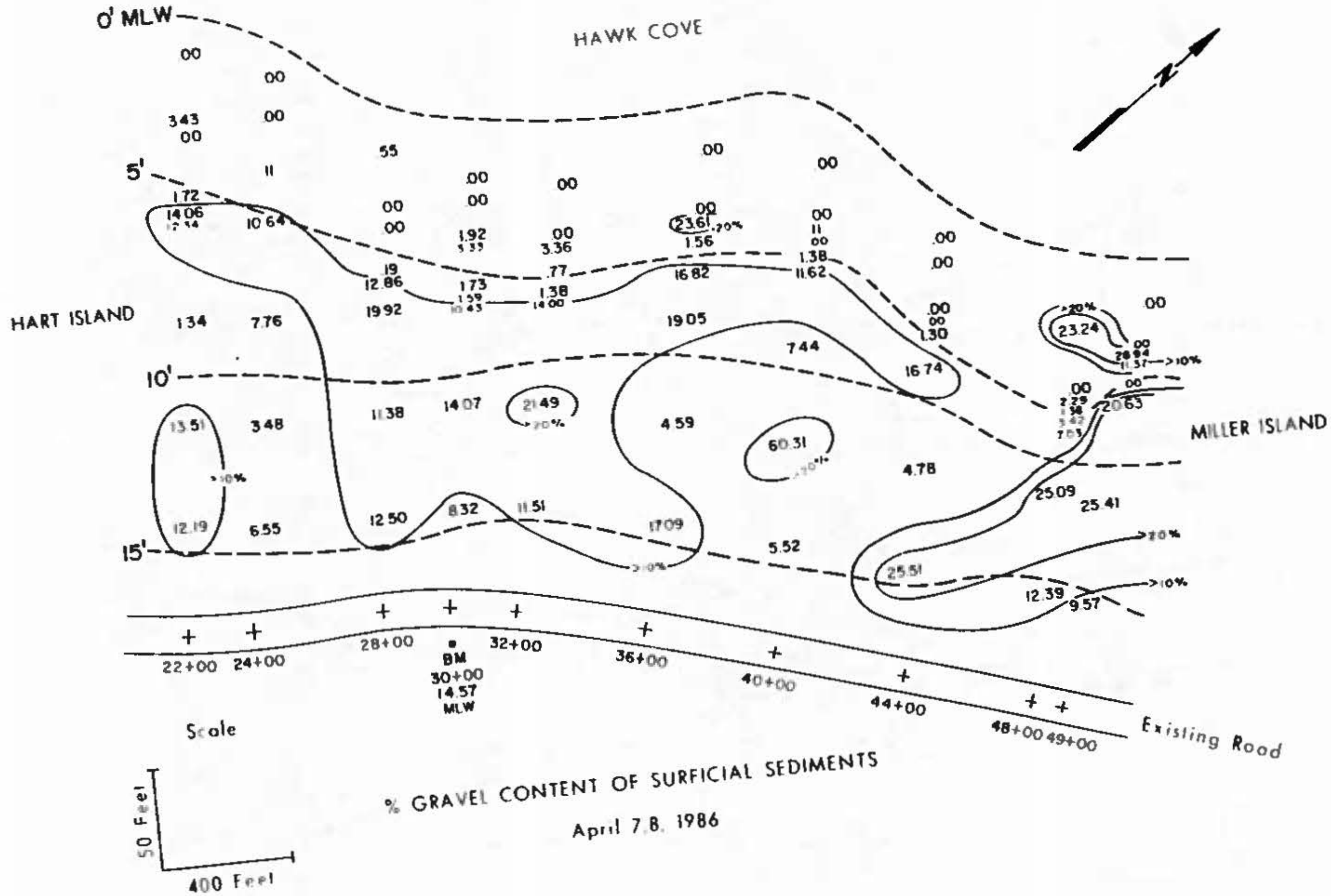


Figure 2-6: Map showing the distribution of gravel on the beach in April 1986 (before regrading).

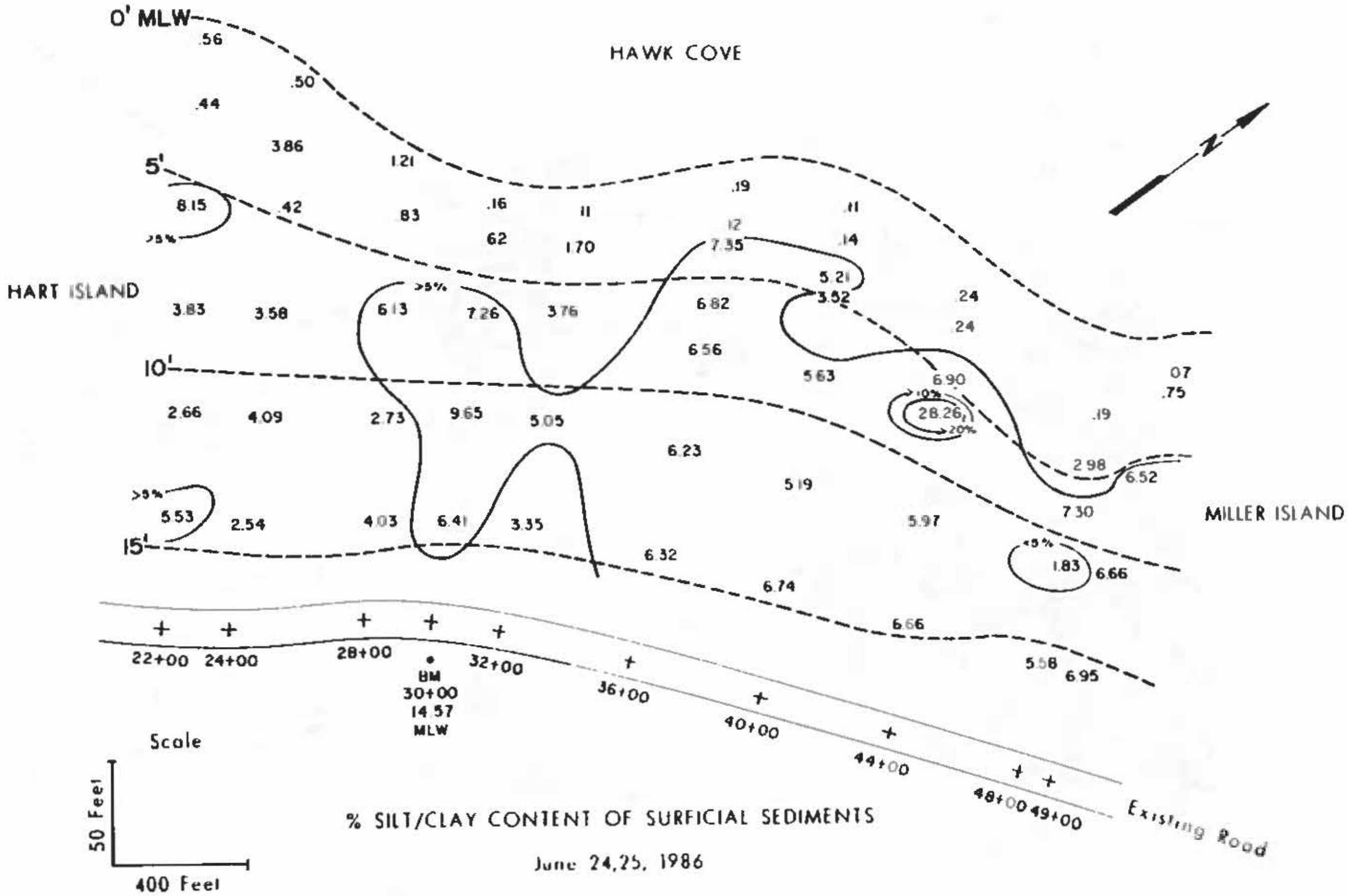


Figure 2-7: Map showing the distribution of silt/clay on the in June 1986 (after regrading).

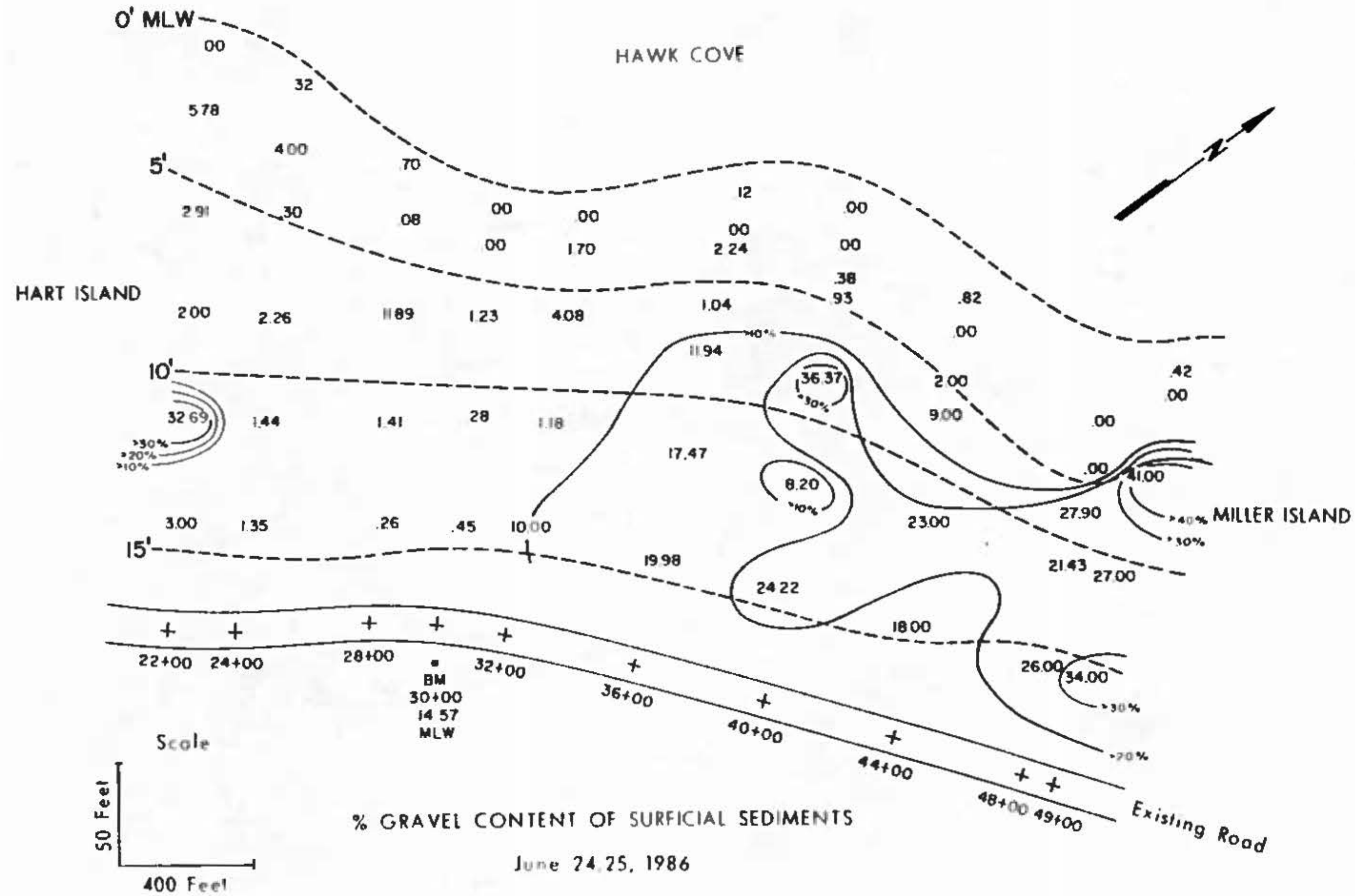


Figure 2-8: Map showing the distribution of gravel on the beach in June 1986 (after regrading).

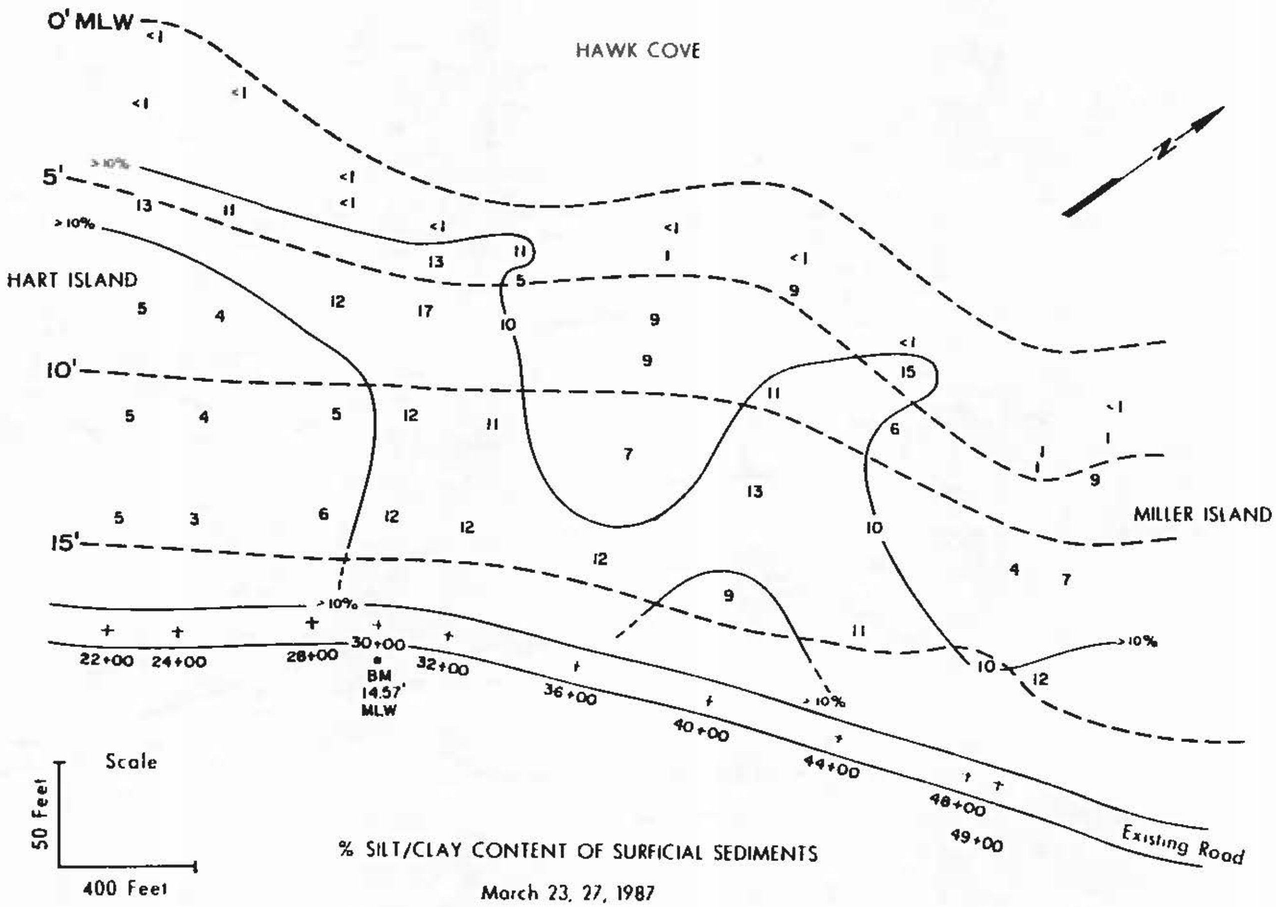


Figure 2-9: Map showing the distribution of silt/clay on the beach in March 1987 (before regrading).

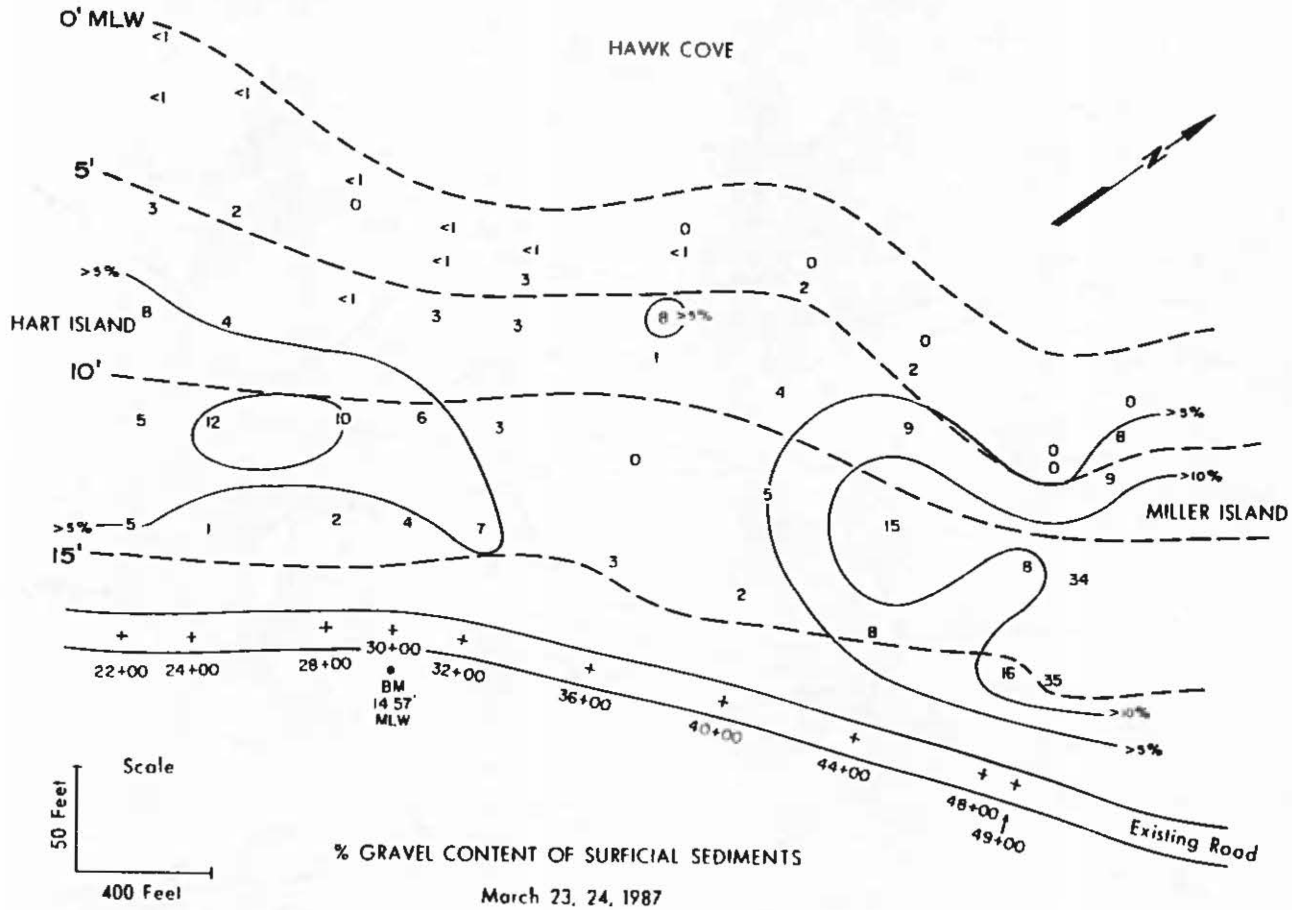


Figure 2-10: Map showing the distribution of gravel on the beach in March 1987 (before regrading).

gravel-sized particles themselves, but to the addition or removal of finer sediments. Throughout the monitoring year, gravel was concentrated north of profile 40+00, although the actual percentages decreased significantly between June 1986, and March 1987 (Figs. 2-8 and 2-10). The accumulation of sand and silt/clay in gullies and the entrapment of fine sediment by vegetation reduced the proportion of gravel relative to these finer sediments.

NET EROSION AND DEPOSITION

This year a different method was used to determine the volumes of sediment eroded or deposited. Rather than planimetrically measuring differences between cross-sectional profiles, a computer program, ISRP (Birkemeier, 1986), calculated sediment gains and losses directly from distance/elevation pairs. Although both methods produced similar results, the computer-generated figures were somewhat lower, precluding direct comparisons with earlier reports.

Net sediment loss was recomputed for the three monitoring periods between regrades (Table 2-4). Erosion has escalated each year since beach surveying began. Compared to the first year of monitoring, almost three times as much sediment - 3472 yd^3 (2655 m^3) - was lost from the beach. The increase in erosion rate is attributed largely to steepening of the lower dike face, particularly by bulldozing. Steeper slopes enable sheet wash to produce deeper gullies with greater headward extent. Also, waves are able to carve off larger sections of the lower dike face by undercutting.

Table 2-4: Volume of sediment eroded between regrades since the inception of the beach study.

Time period	Sediment volume lost (yd^3)	(m^3)
June 1984 - March 1985	1190	910
June 1985 - March 1986	2083	1593
June 1986 - March 1987	3472	2655

*based on ISRP (Birkemeier, 1986)

Since the inception of the beach erosion study (June 1984), approximately 7756 yd^3 (5930 m^3) of sediment have been lost from the recreational beach. This is a conservative estimate it fails to account for gully erosion, which was much more extensive this year than it has been in the past.

CONCLUSIONS

Two geomorphic processes - wave activity and sheet wash - were responsible for the largely erosional features observed on the beach during the study period. Wave action along the foreshore and lower dike face appeared to be the major force responsible for most of the erosion. Sheet wash gave rise to gully erosion, which accelerated during the monitoring year. By steepening the lower dike face, bulldozing greatly amplified the effects of these two natural processes. Selective removal of sand-sized material produced a more gravelly beach surface.

Approximately 7756 yd^3 (5930 m^3) of sediment have been removed from the lower dike face and foreshore, above the 0' contour, since the beach erosion study began in 1984. The erosion rate increased dramatically again this year; almost half (3472 yd^3 or 2655 m^3) of the total sediment lost to date was eroded during the period covered by this report. These are conservative estimates that exclude the amount of sediment lost by gully erosion.

RECOMMENDATIONS

Persistent erosional problems on the recreational beach require attention. Renourishment of the beach with a suitably sized sand (medium-to coarse-grained) would not only reduce erosion by decreasing the slope of the lower dike face and foreshore, but would also increase the attractiveness of the most heavily utilized section of the beach. Sand would probably have to be replenished yearly, depending on the magnitude and frequency of storms in the Hart-Miller Island area.

Additional erosion control measures must be undertaken along the two northernmost profiles (48+00 and 49+00) to reduce the amount of sediment lost by sheet wash and gully erosion. Plans should include vegetating the beach. Diversion of drainage from that area might also be considered.

ACKNOWLEDGMENTS

The following people aided in the collection of survey data: William Panageotou, Darlene Wells, Robert Conkwright, Marguerite Toscano, and Sally Jones. Without their help, there would have been no survey. Thanks also go to the Maryland Environmental Service for providing the climatological data that aided in diagnosing the erosional problems found on the beach.

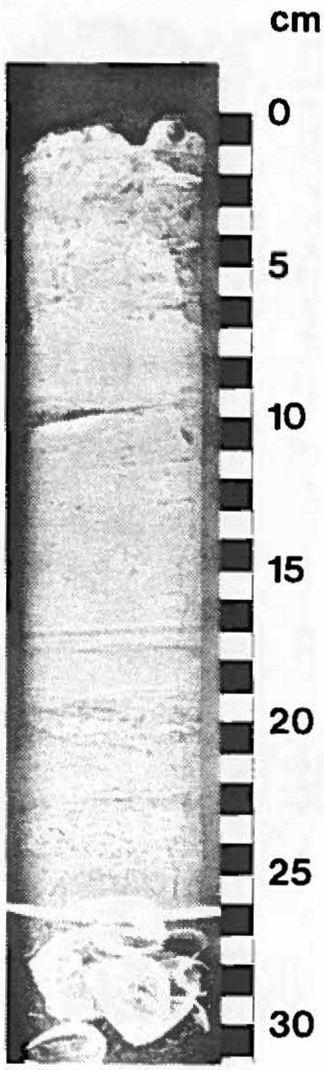
Appendix A

Xeroradiographs of the gravity cores

HART - MILLER ISLAND

Station BC-1

April 21, 1987



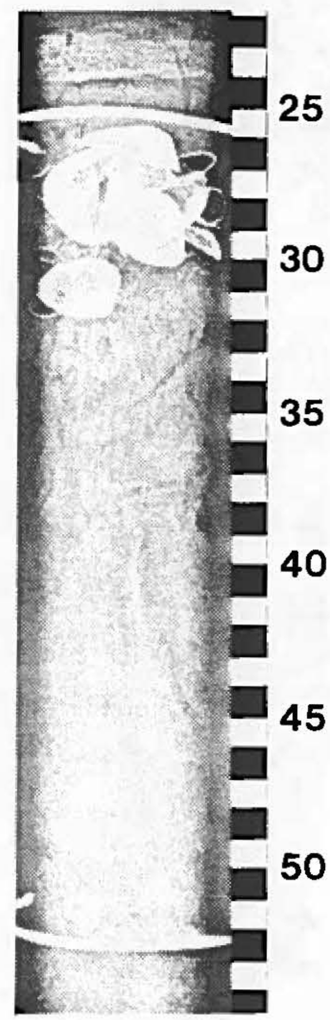


Figure A-1

HART - MILLER ISLAND

Station BC-2

April 21, 1987

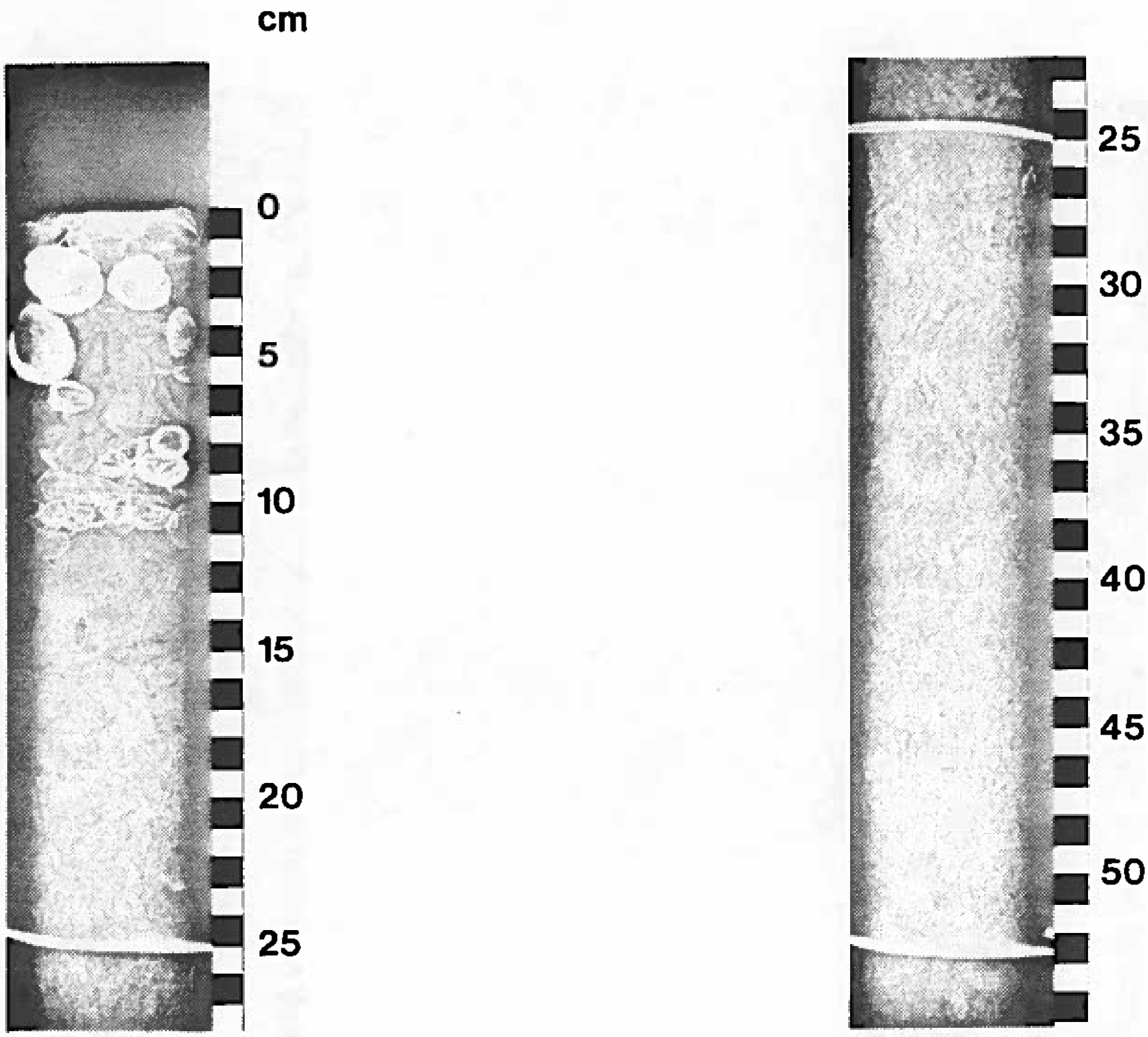
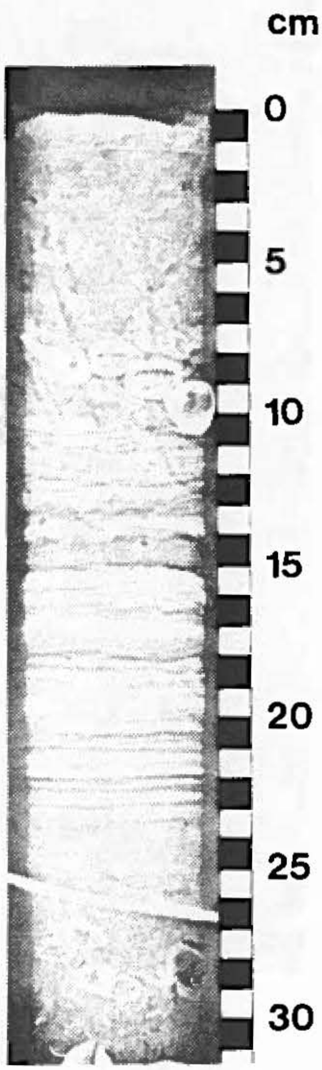


Figure A-2

HART - MILLER ISLAND

Station BC-3

April 21, 1987



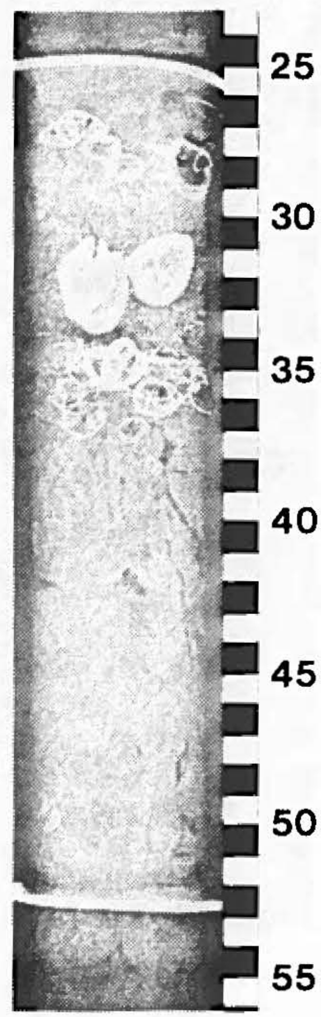


Figure A-3

HART - MILLER ISLAND

Station BC-4

April 21, 1987

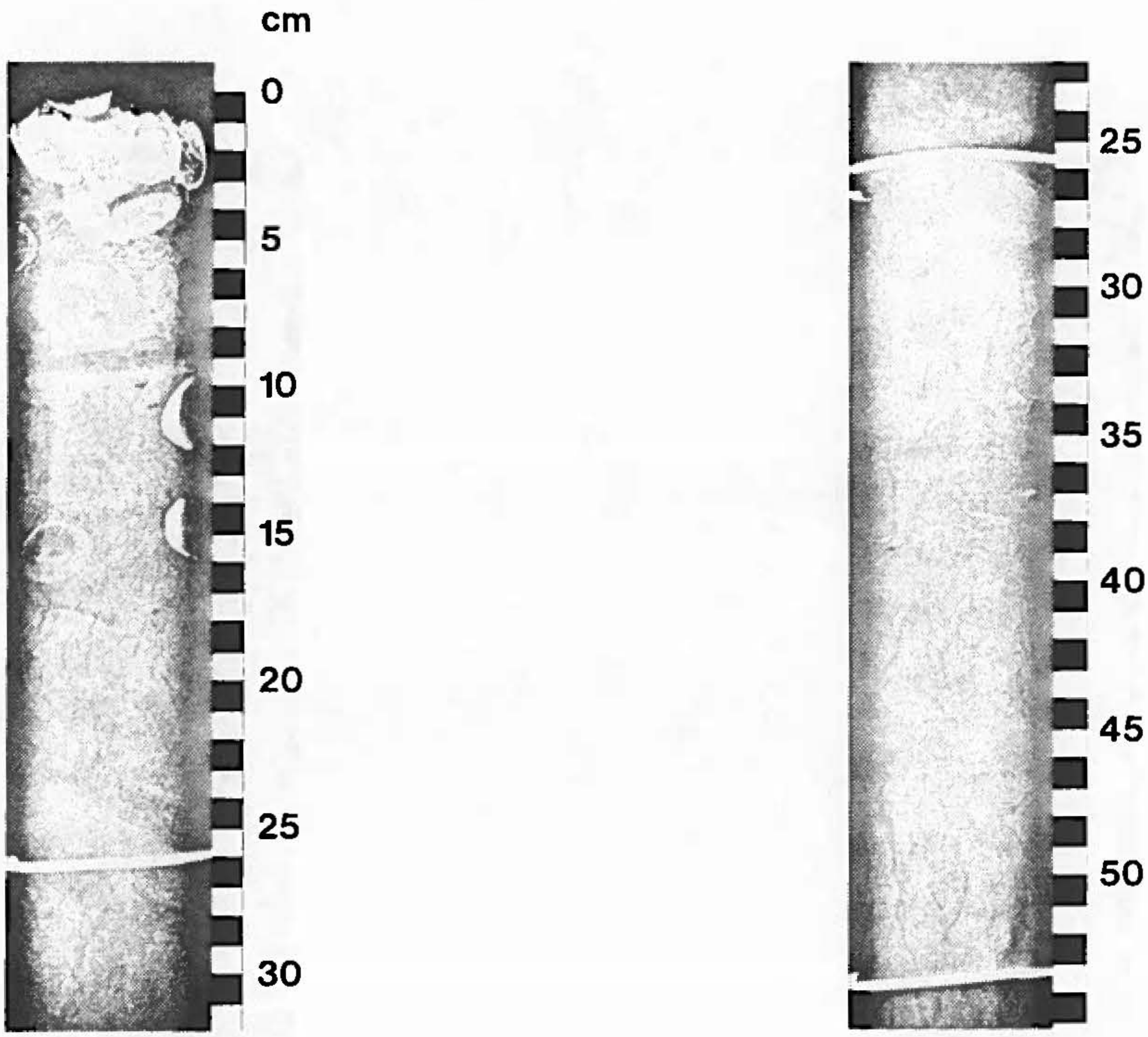


Figure A-4

HART - MILLER ISLAND

Station BC-5

April 21, 1987

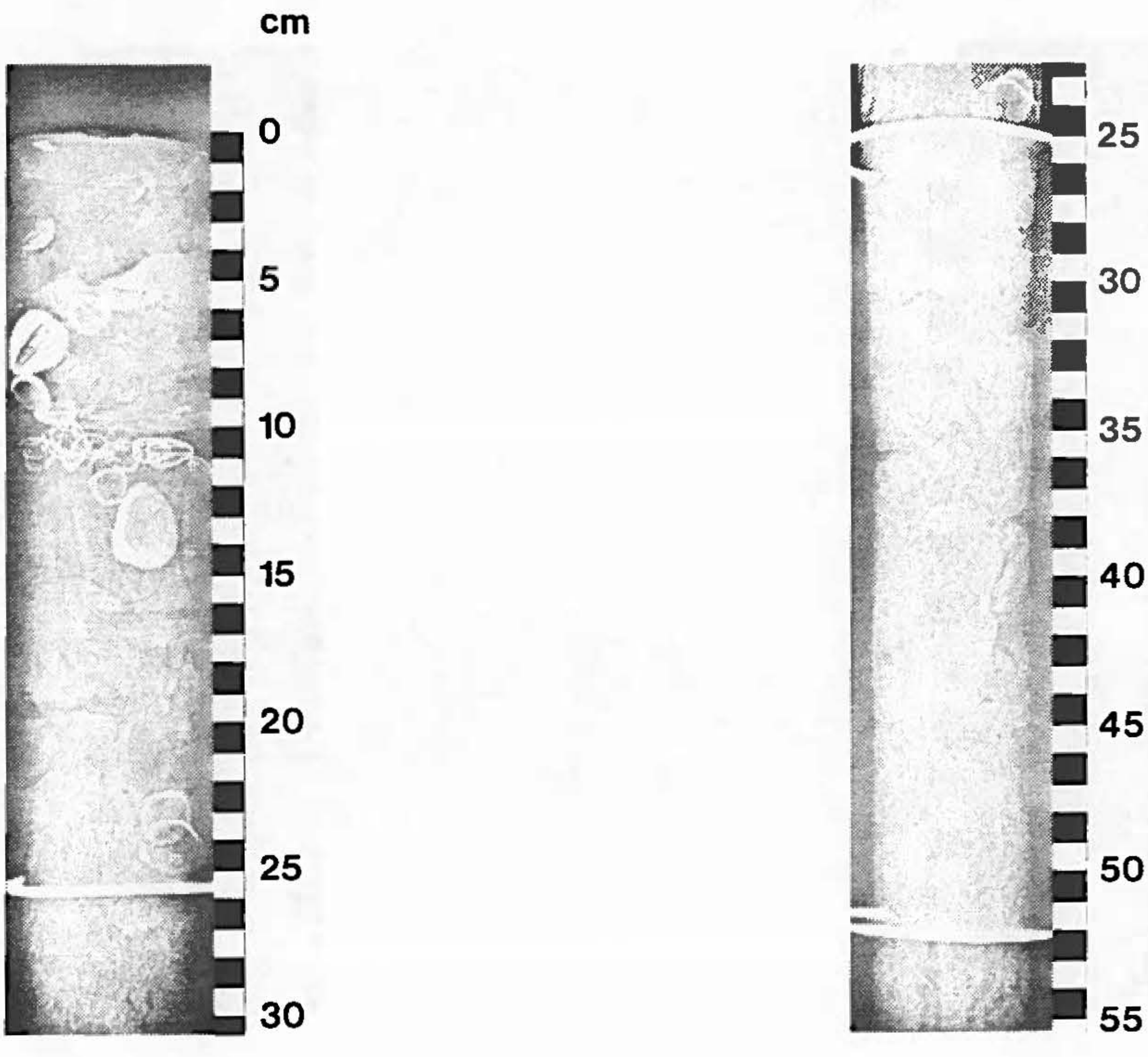
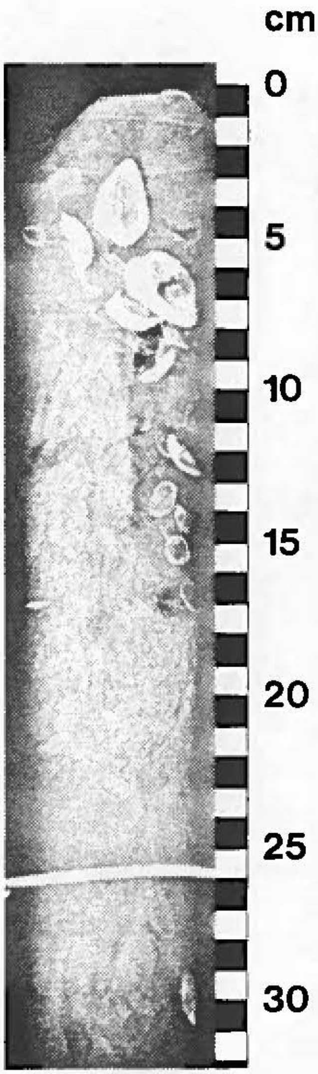


Figure A-5

HART - MILLER ISLAND

Station BC-6

April 21, 1987



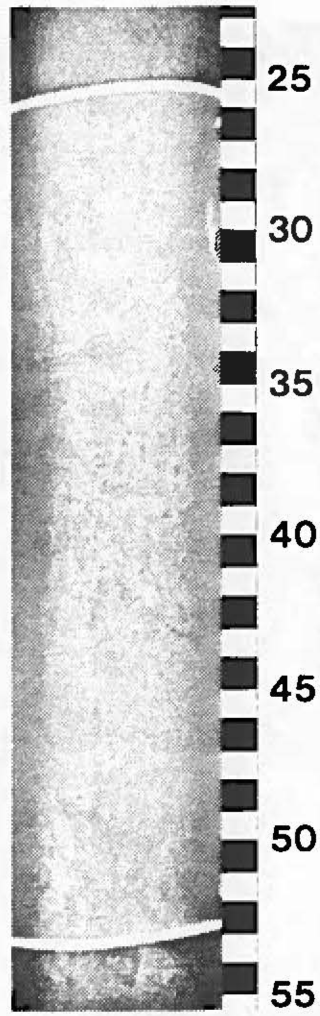


Figure A-6

HART - MILLER ISLAND

Station BC-7

April 21, 1987

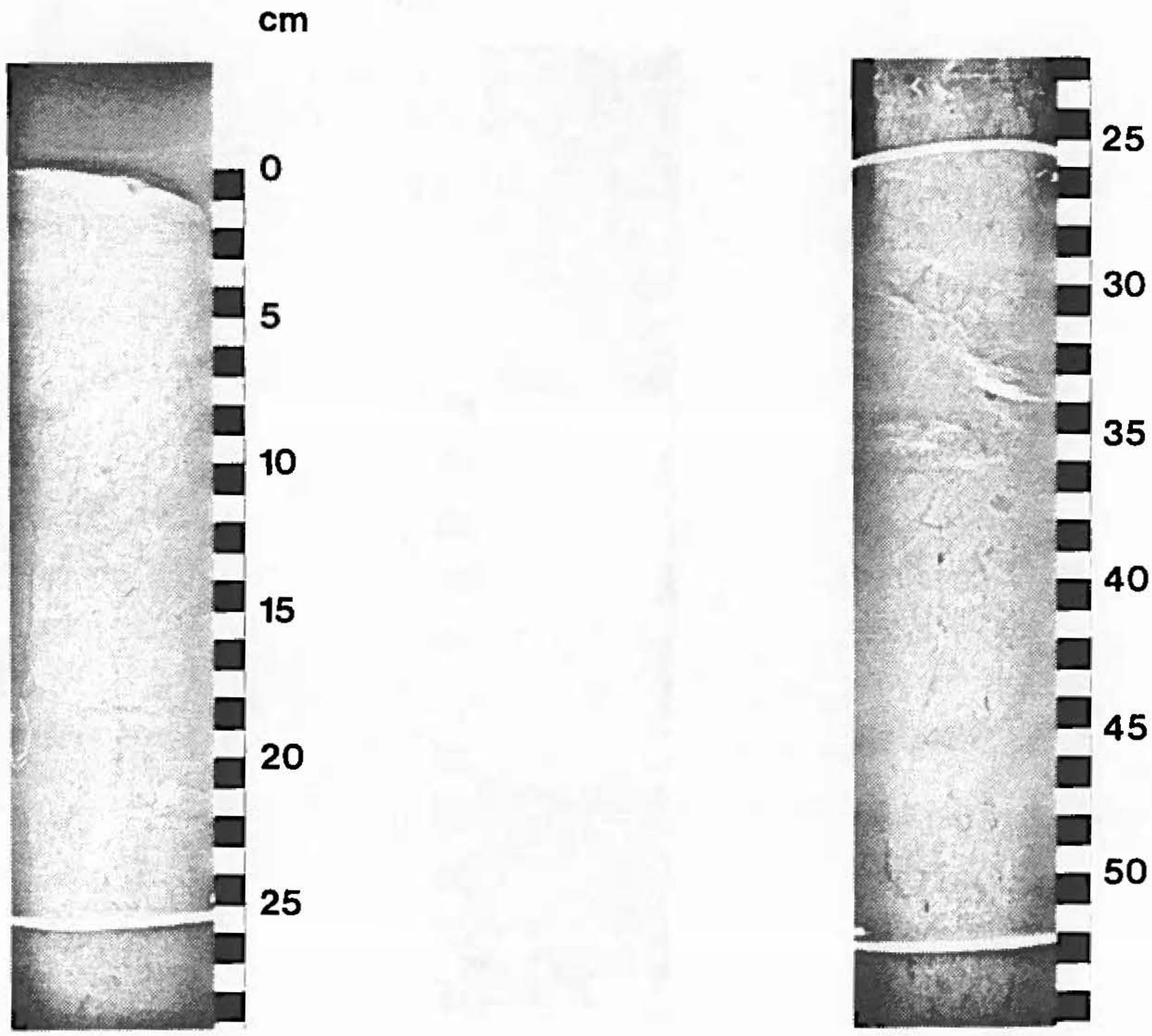


Figure A-7

HART - MILLER ISLAND

Station 21B

April 21, 1987

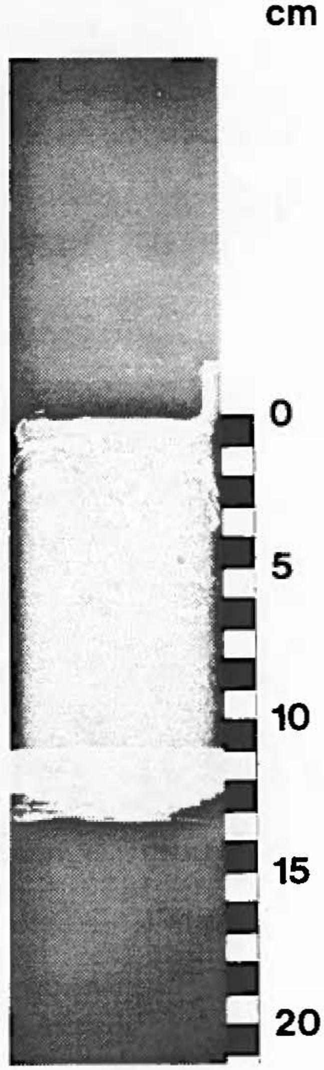
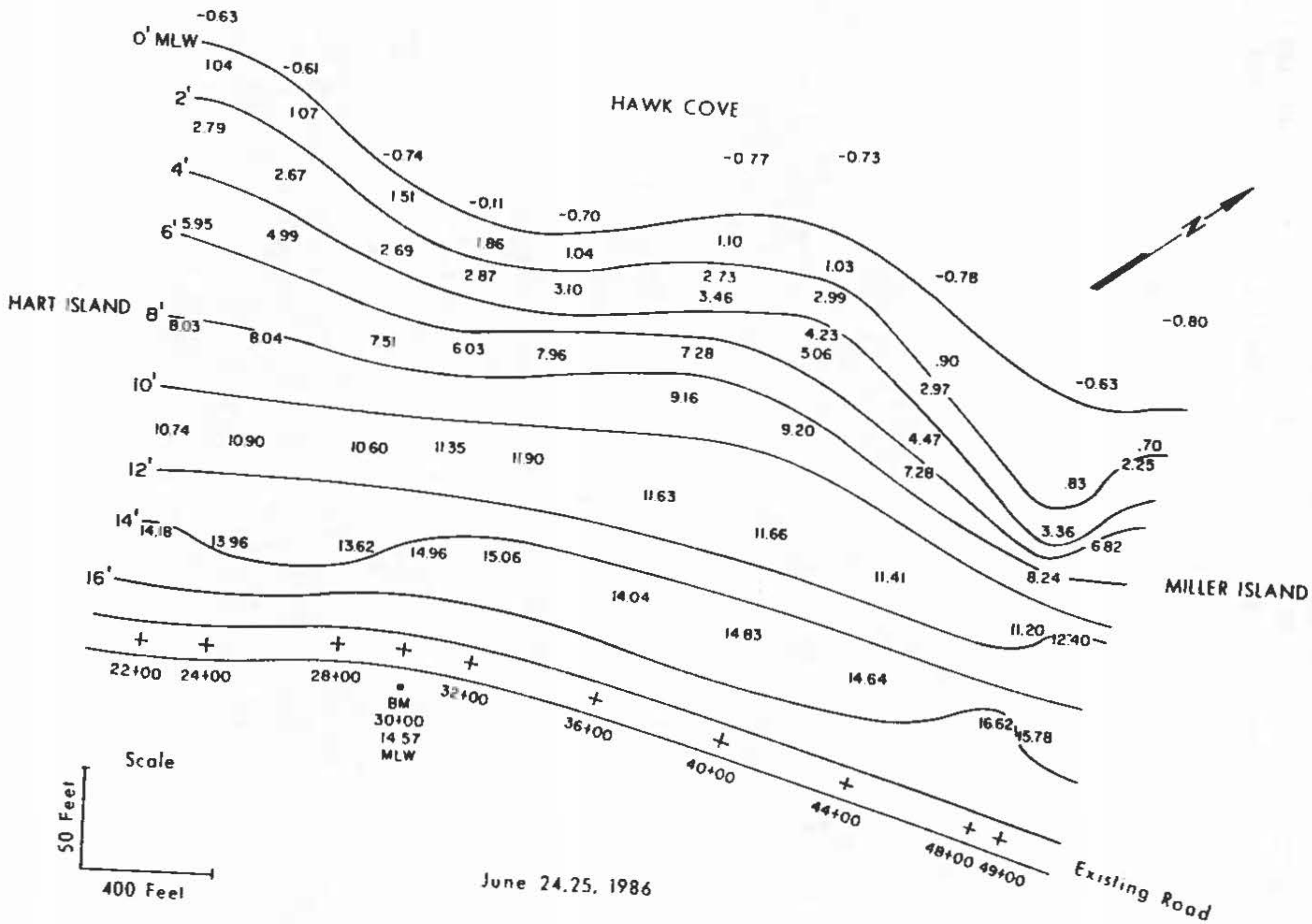


Figure A-8

Appendix B

Figures B-1 through B-4

Contour maps of the recreational beach, based on distance/elevation data collected on June 24 and 25, 1986; September 15 and 18, 1986; December 8 and 23, 1986; and March 23 and 24, 1987.



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
2.87
3.10
2.73
3.46
2.99
8.03
8.04
7.51
6.03
7.96
7.28
4.23
5.06
-0.80
.90
2.97
-0.63
9.16
9.20
4.47
7.28
.70
2.25
.83
10.74
10.90
10.60
11.35
11.90
11.63
11.66
3.36
6.82
8.24
14.18
13.96
13.62
14.96
15.06
14.04
11.41
14.83
11.20
12.40
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-1

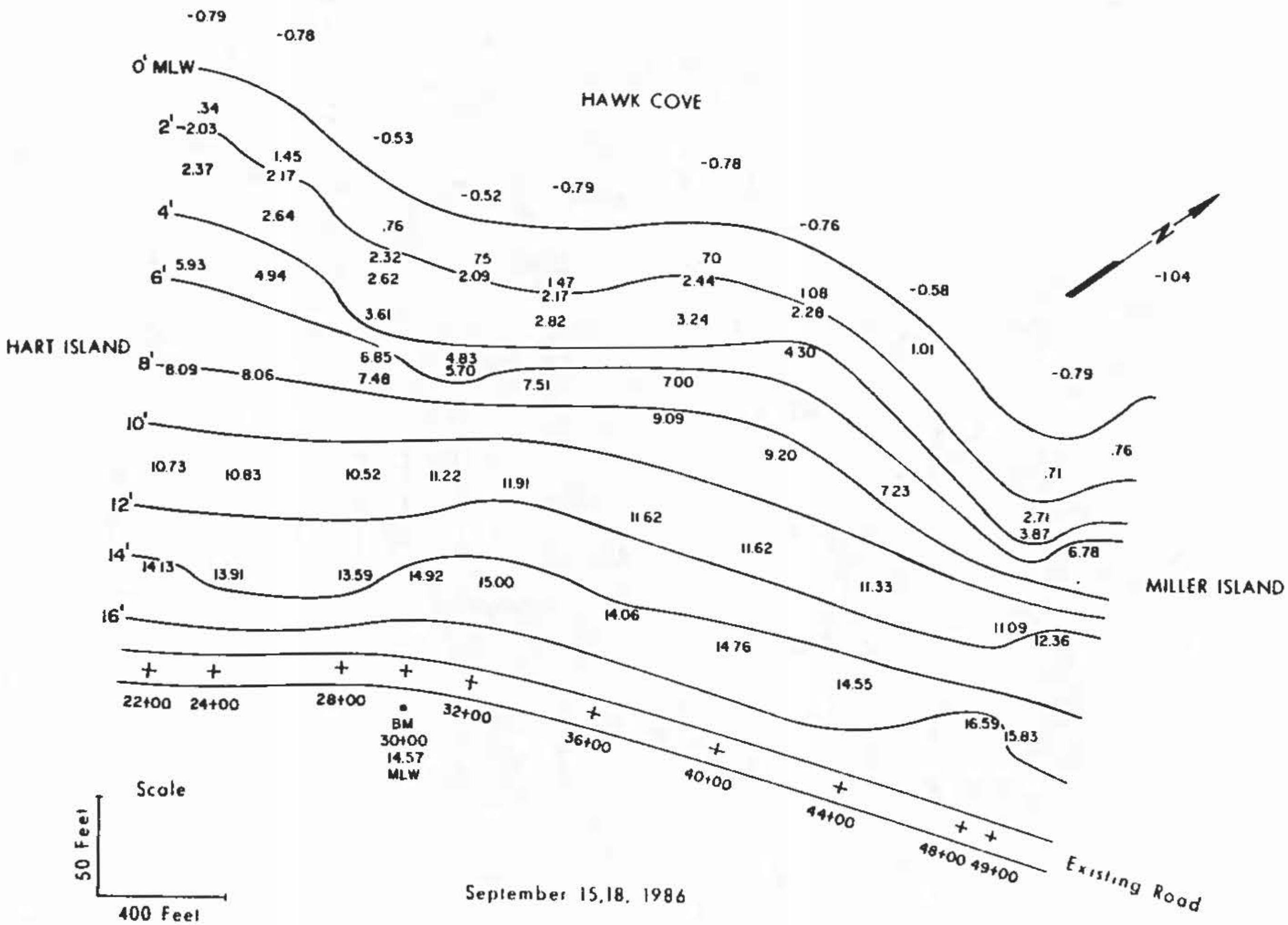

HAWK COVE
HART ISLAND
MILLER ISLAND
0' MLW
2'
4'
6'
8'
10'
12'
14'
16'
-0.79
-0.78
.34
-2.03
1.45
2.17
2.37
2.64
-0.53
-0.52
-0.79
-0.78
-0.76
-0.58
-1.04
-0.79
.76
2.32
2.62
.75
2.09
1.47
2.17
.70
2.44
1.08
2.28
1.01
5.93
4.94
3.61
2.82
3.24
4.30
6.85
4.83
5.70
7.48
7.51
7.00
8.09
8.06
9.09
9.20
7.23
10.73
10.83
10.52
11.22
11.91
11.62
11.62
.71
.76
2.71
3.87
6.78
14.13
13.91
13.59
14.92
15.00
14.06
11.33
11.09
12.36
14.76
14.55
16.59
15.83
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-2

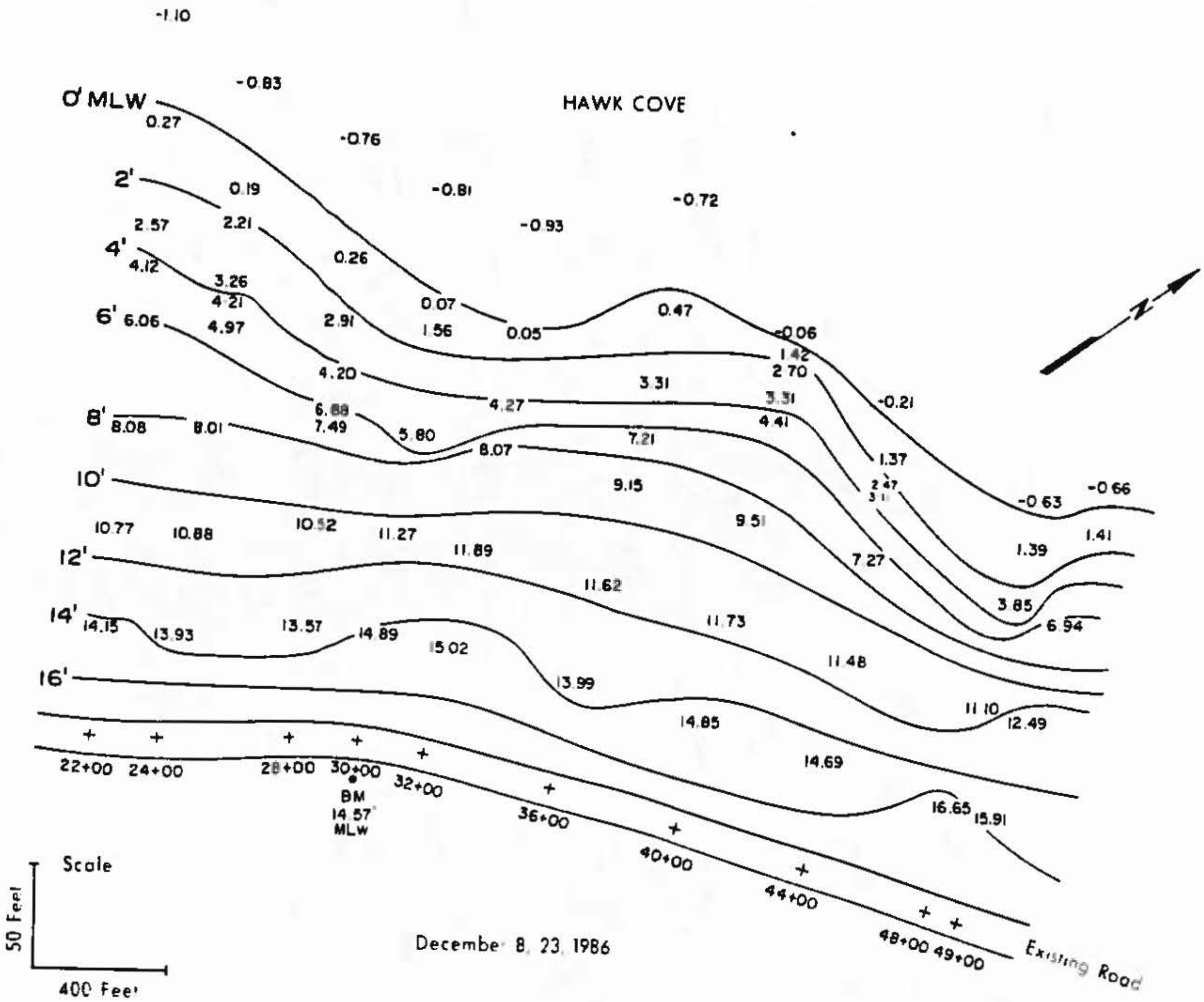

HAWK COVE
N
0' MLW
2'
4'
6'
8'
10'
12'
14'
16'
-1.10
-0.83
0.27
-0.76
0.19
-0.81
-0.72
2.57
2.21
-0.93
4.12
0.26
3.26
4.21
0.07
0.47
6.06
4.97
2.91
1.56
0.05
-0.06
1.42
2.70
4.20
3.31
4.27
3.31
-0.21
6.88
7.49
5.80
4.41
8.08
8.01
8.07
7.21
1.37
9.15
10.77
10.88
10.52
11.27
11.89
9.51
7.27
-0.63
-0.66
1.39
1.41
11.62
3.85
6.94
14.15
13.93
13.57
14.89
15.02
11.73
11.48
13.99
14.85
11.10
12.49
14.69
16.65
15.91
22+00
24+00
28+00
30+00
32+00
36+00
40+00
44+00
48+00
49+00
BM
14.57'
MLW
Existing Road
Scale
50 Feet
400 Feet
December 8, 23, 1986

Figure B-3

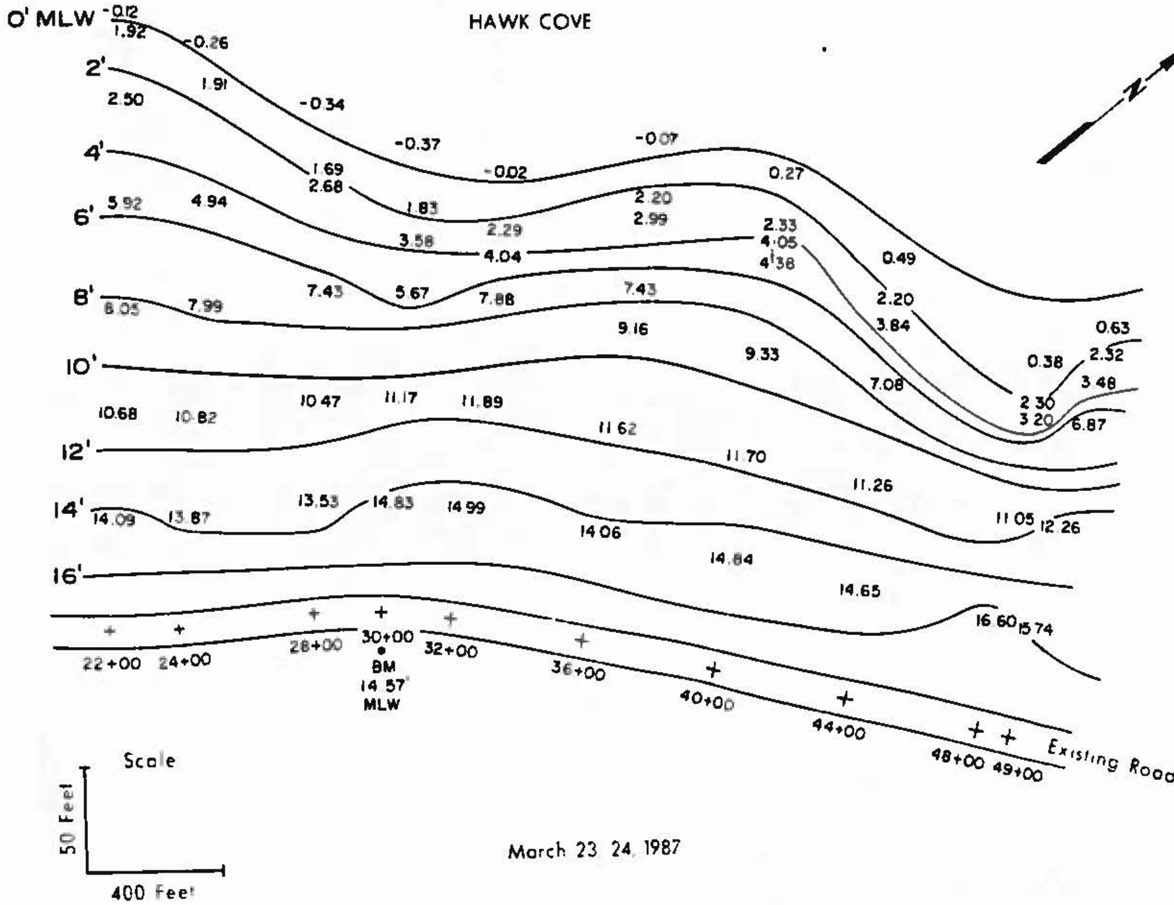

HAWK COVE
O' MLW
2'
4'
6'
8'
10'
12'
14'
16'
22+00
24+00
28+00
30+00
BM
14.57'
MLW
32+00
36+00
40+00
44+00
48+00
49+00
Existing Road
Scale
50 Feet
400 Feet
March 23, 24, 1987

Figure B-4

Appendix C

Figures C-1 through C-10

Cross-sectional profiles for each of the profile stations, based on surveys conducted in June 1986; September 1986; December 1986; and March 1987.

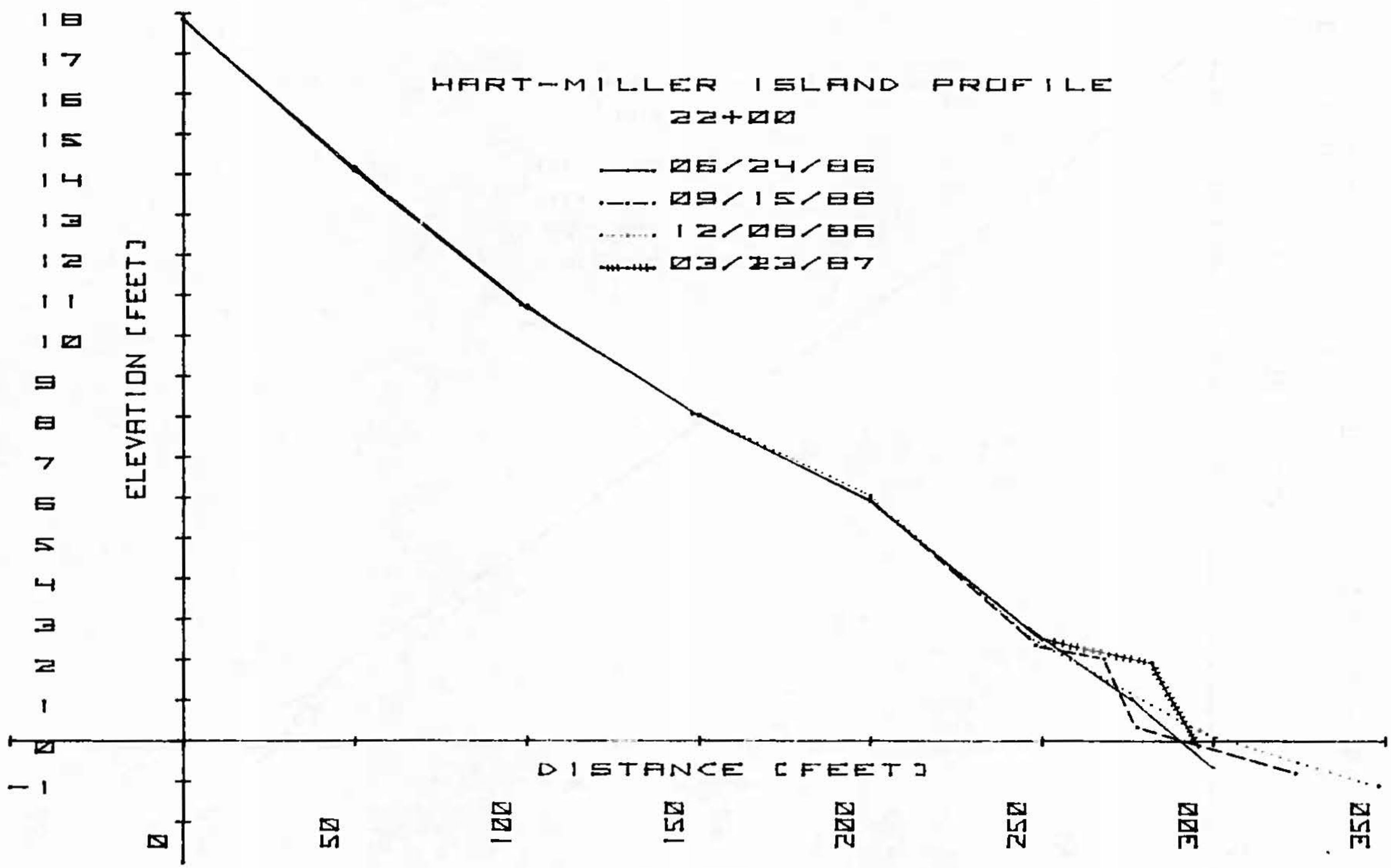

HART-MILLER ISLAND PROFILE
22+00
06/24/86
09/15/86
12/08/86
03/23/87
ELEVATION [FEET]
DISTANCE [FEET]
18
17
16
15
14
13
12
11
10
9
8
7
6
5
4
3
2
1
0
-1
0
50
100
150
200
250
300
350

Figure C-1

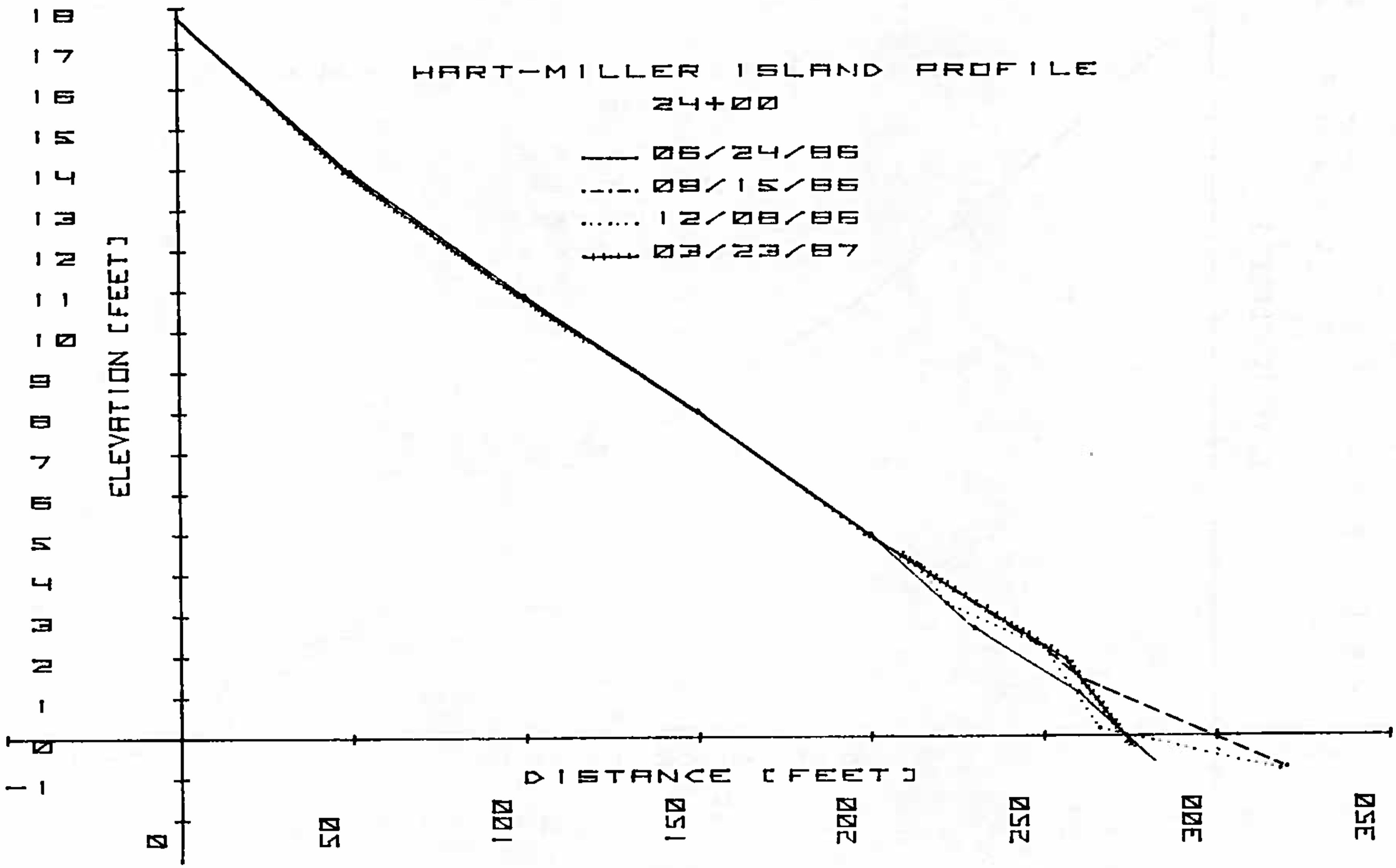

HART-MILLER ISLAND PROFILE
24+00
06/24/86
09/15/86
12/08/86
03/23/87
ELEVATION [FEET]
DISTANCE [FEET]
18
17
16
15
14
13
12
11
10
9
8
7
6
5
4
3
2
1
0
-1
0
50
100
150
200
250
300
350

Figure C-2

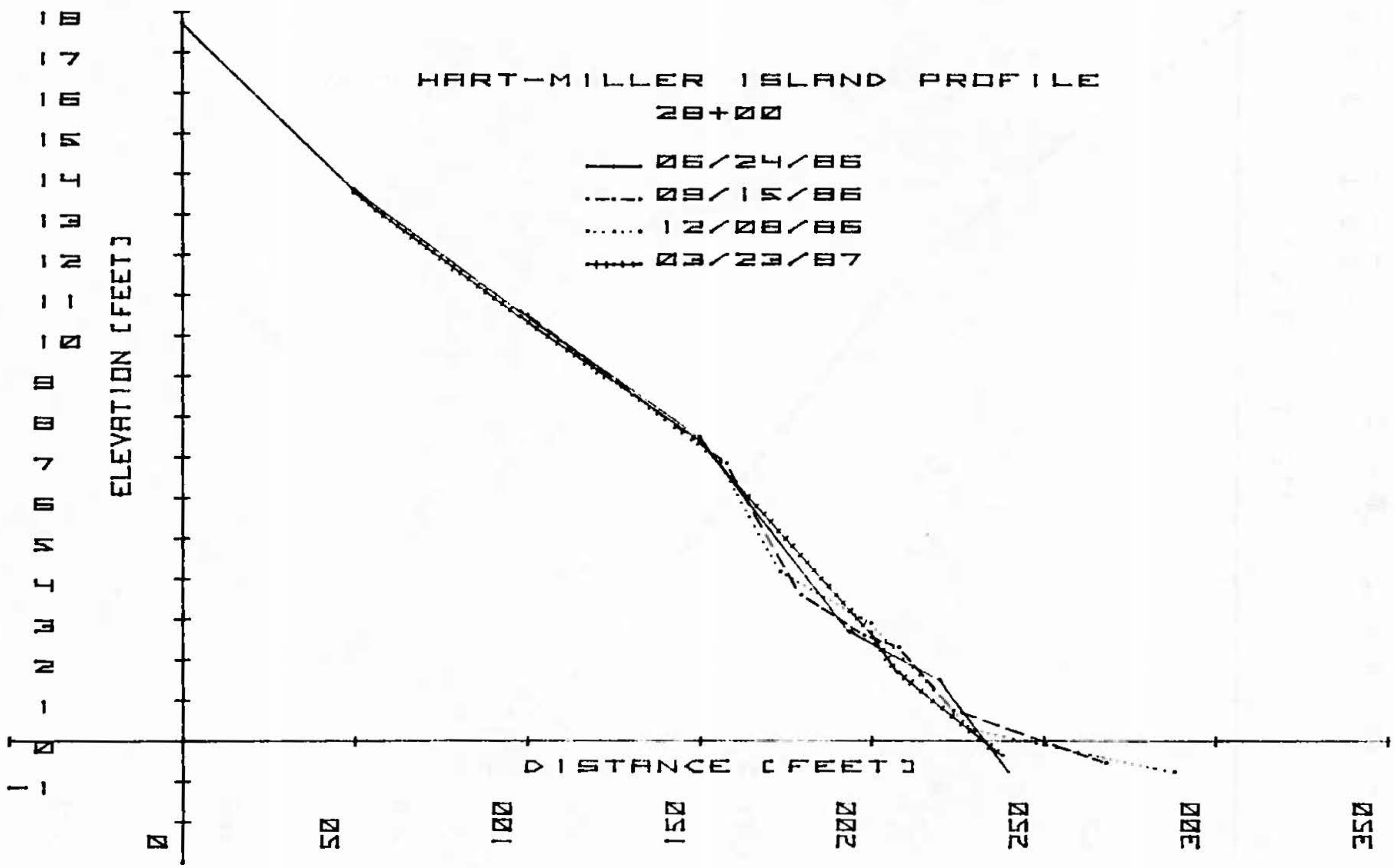

HART-MILLER ISLAND PROFILE
28+00
06/24/86
09/15/86
12/08/86
03/23/87
ELEVATION (FEET)
DISTANCE (FEET)
18
17
16
15
14
13
12
11
10
9
8
7
6
5
4
3
2
1
0
-1
0
50
100
150
200
250
300
350

Figure C-3

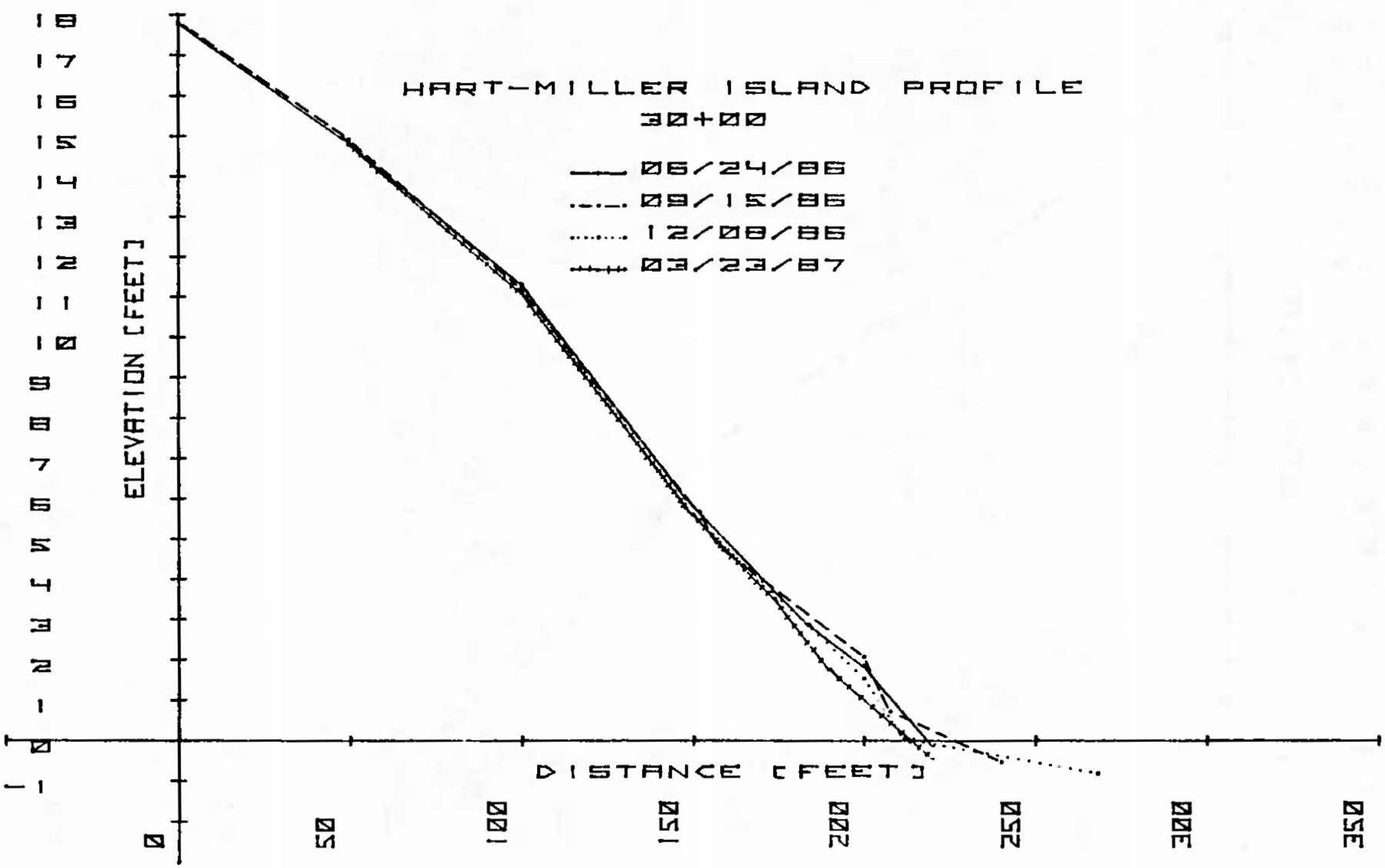

HART-MILLER ISLAND PROFILE
30+00
06/24/86
09/15/86
12/08/86
03/23/87
ELEVATION [FEET]
DISTANCE [FEET]
18
17
16
15
14
13
12
11
10
9
8
7
6
5
4
3
2
1
0
-1
0
50
100
150
200
250
300
350

Figure C-4

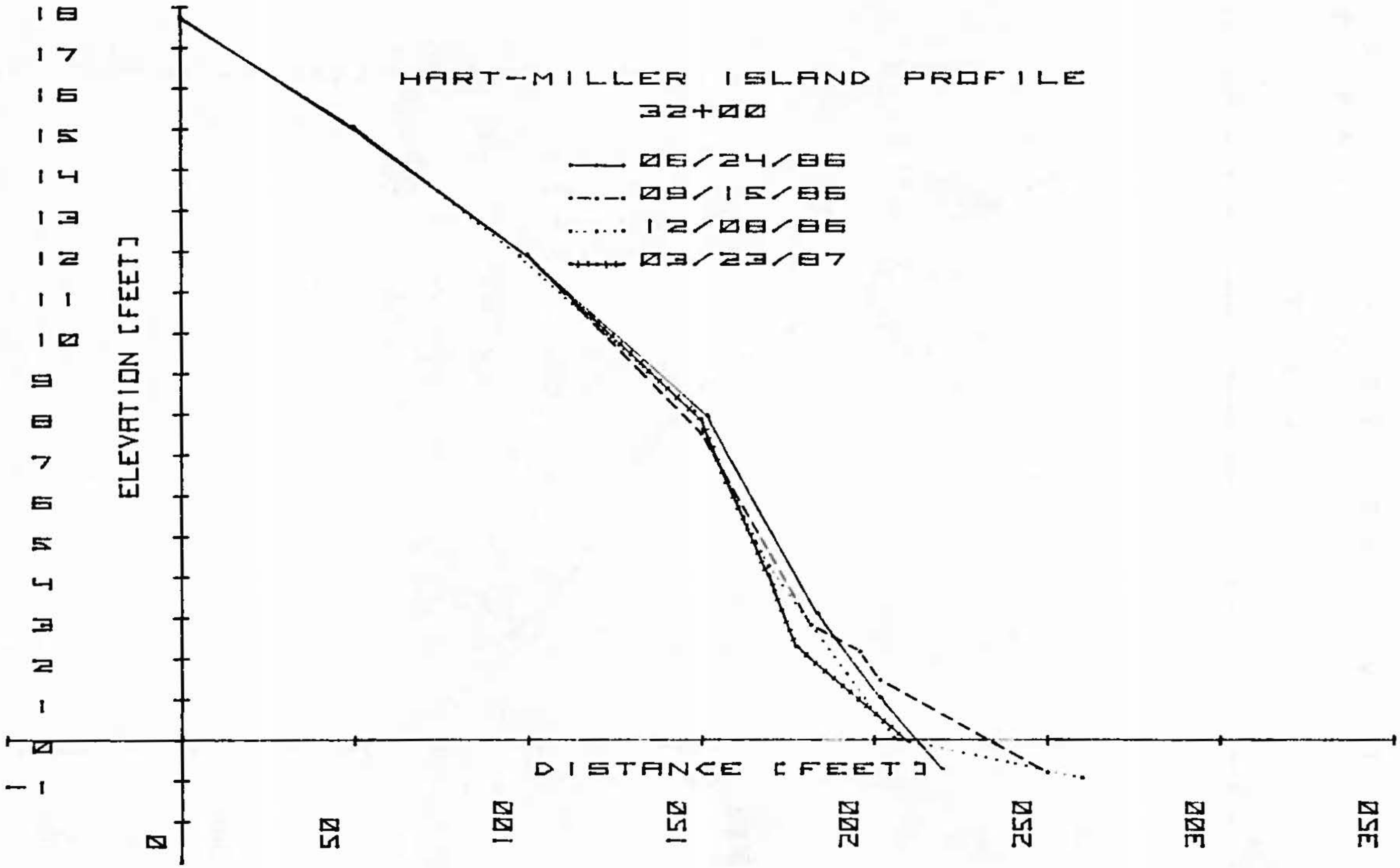
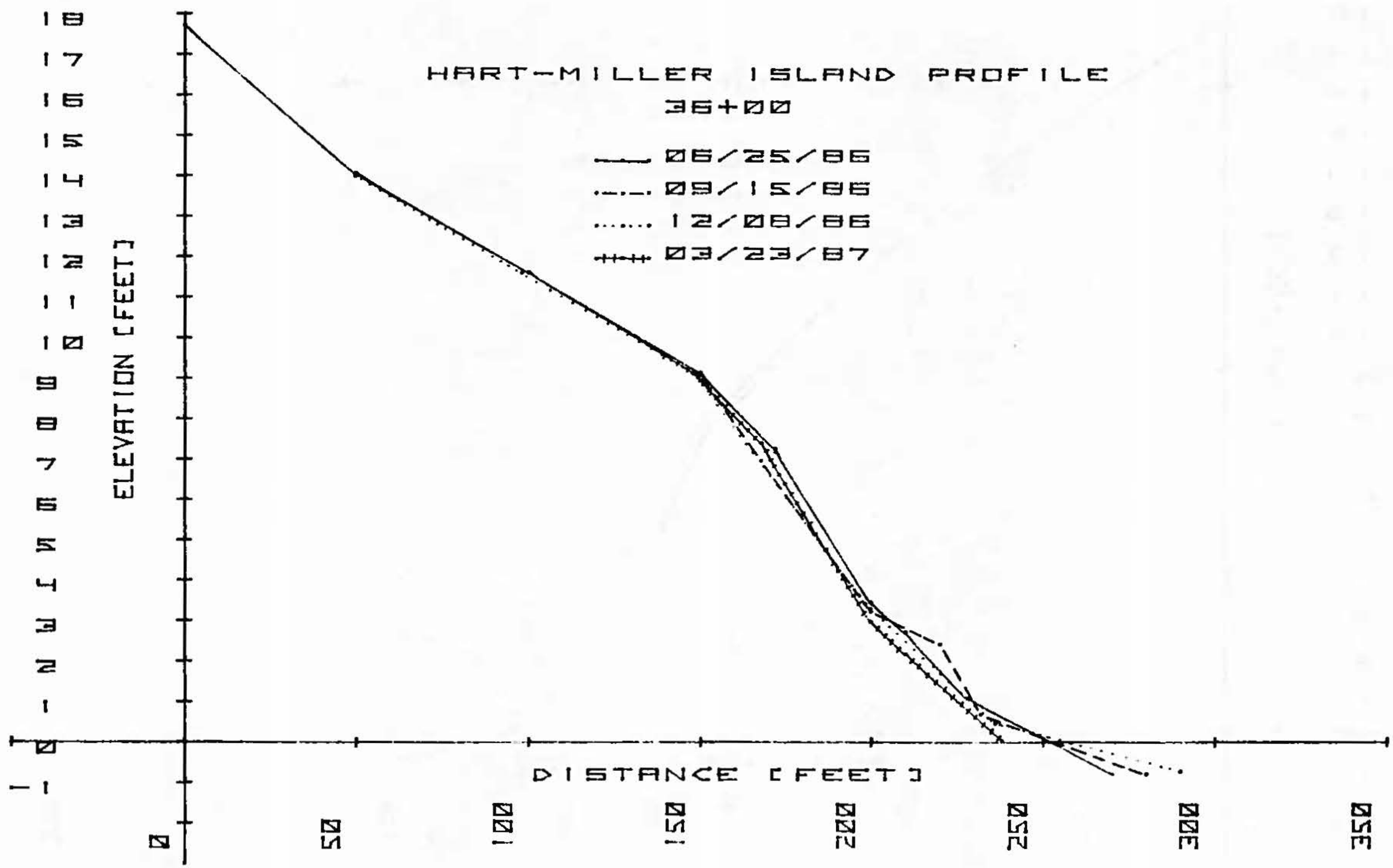

HART-MILLER ISLAND PROFILE
32+00
06/24/86
09/15/86
12/08/86
03/23/87
ELEVATION [FEET]
DISTANCE [FEET]
18
17
16
15
14
13
12
11
10
9
8
7
6
5
4
3
2
1
0
-1
0
50
100
150
200
250
300
350

Figure C-5


HART-MILLER ISLAND PROFILE
36+00
06/25/86
09/15/86
12/08/86
03/23/87
ELEVATION [FEET]
DISTANCE [FEET]
0
50
100
150
200
250
300
350
-1
0
1
2
3
4
5
6
7
8
9
10
11
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13
14
15
16
17
18

Figure C-6

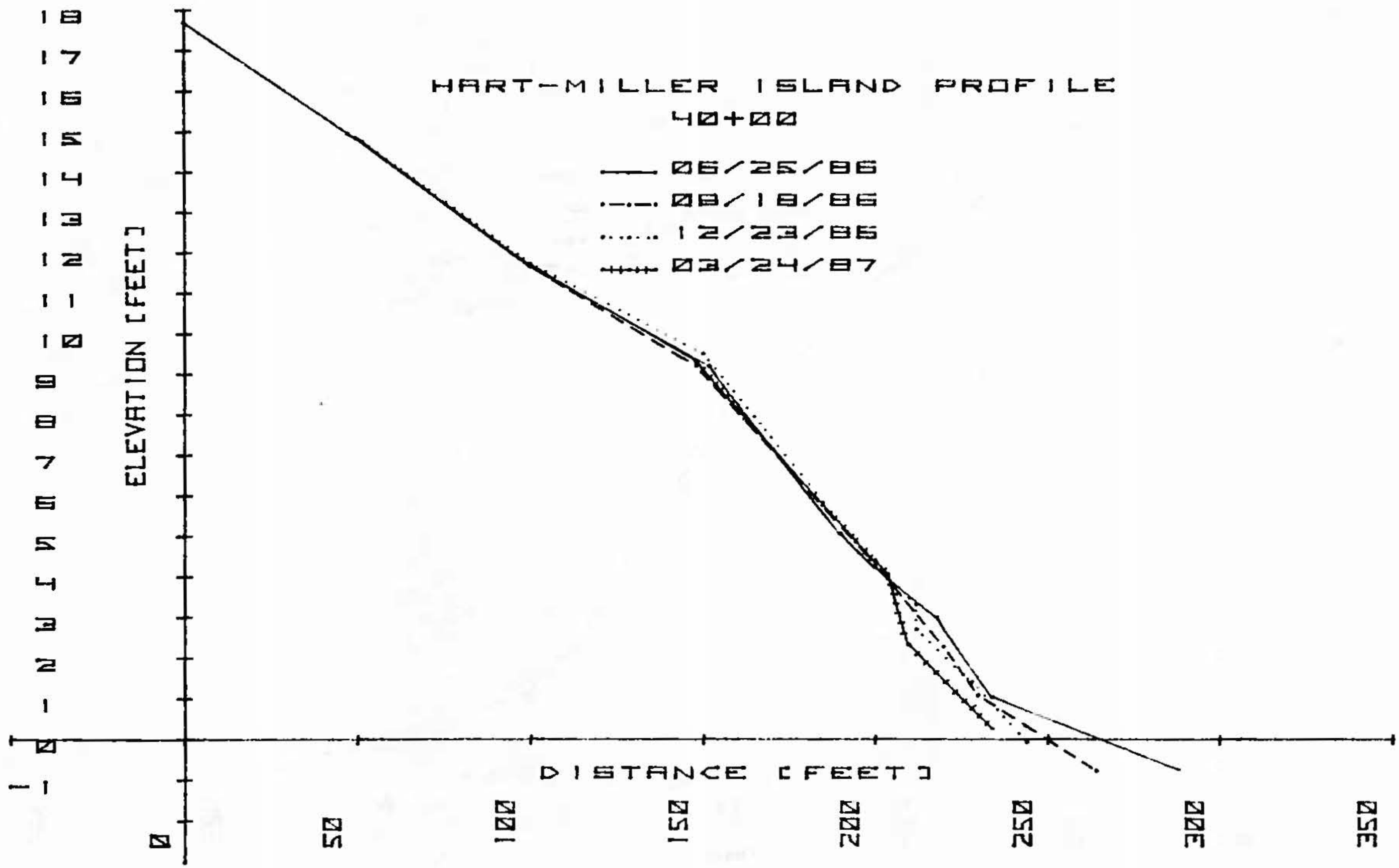

HART-MILLER ISLAND PROFILE
40+00
06/25/86
08/18/86
12/23/86
03/24/87
ELEVATION [FEET]
DISTANCE [FEET]
18
17
16
15
14
13
12
11
10
9
8
7
6
5
4
3
2
1
0
-1
0
50
100
150
200
250
300
350

Figure C-7

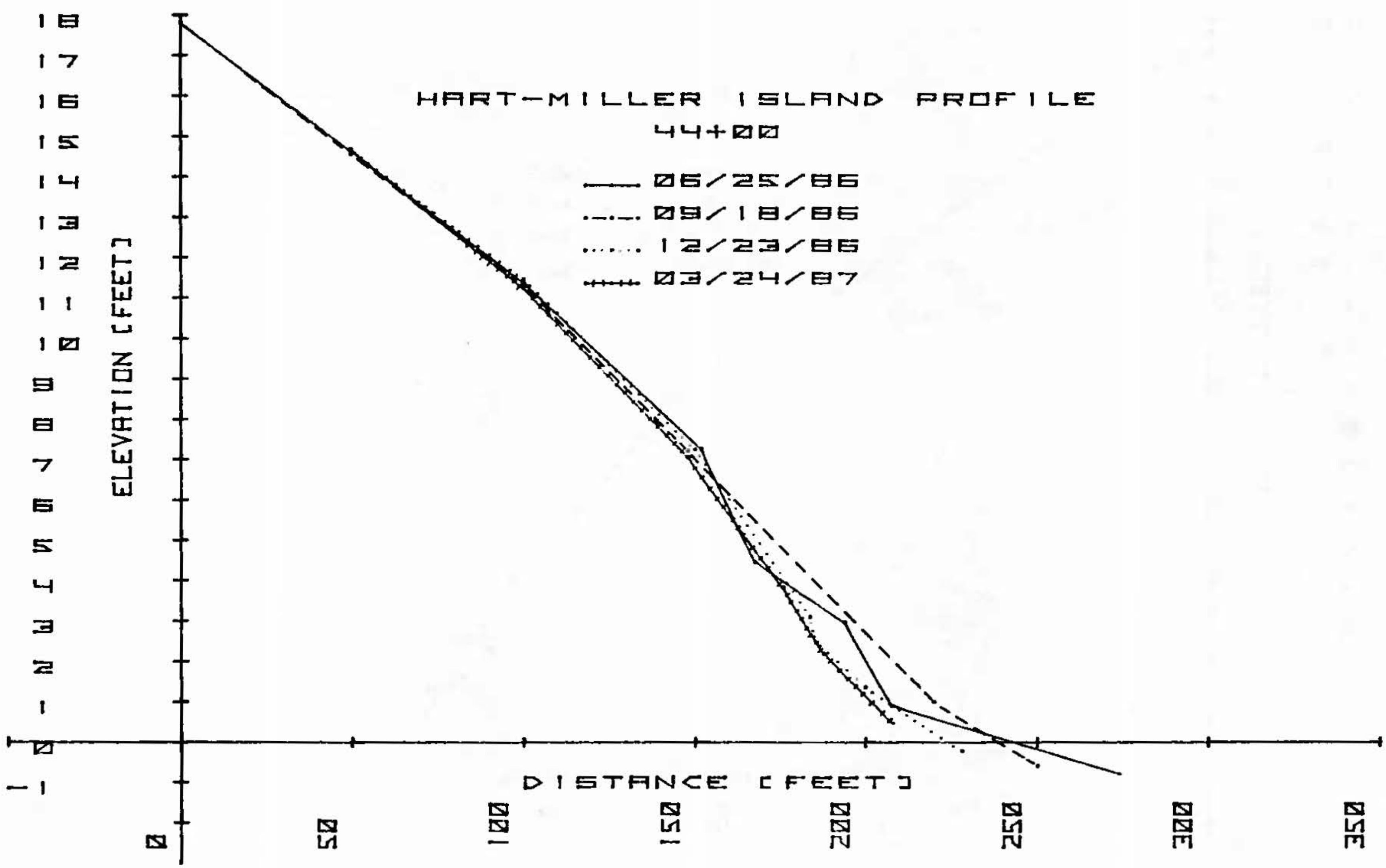

HART-MILLER ISLAND PROFILE
44+00
06/25/86
09/18/86
12/23/86
03/24/87
ELEVATION [FEET]
DISTANCE [FEET]
18
17
16
15
14
13
12
11
10
9
8
7
6
5
4
3
2
1
0
-1
0
50
100
150
200
250
300
350

Figure C-8

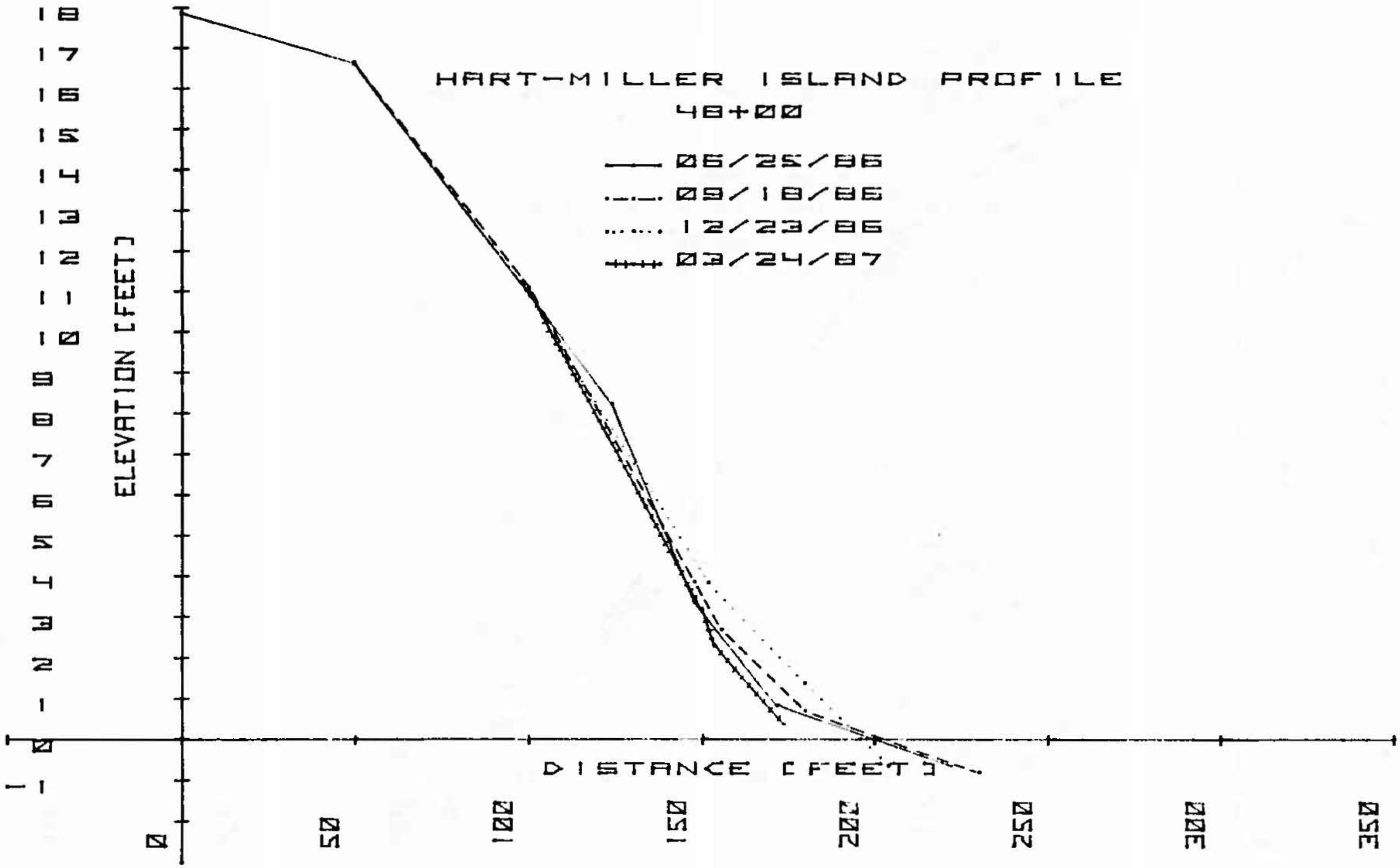

HART-MILLER ISLAND PROFILE
48+00
06/25/86
09/18/86
12/23/86
03/24/87
ELEVATION [FEET]
DISTANCE [FEET]
18
17
16
15
14
13
12
11
10
9
8
7
6
5
4
3
2
1
0
-1
0
50
100
150
200
250
300
350

Figure C-9

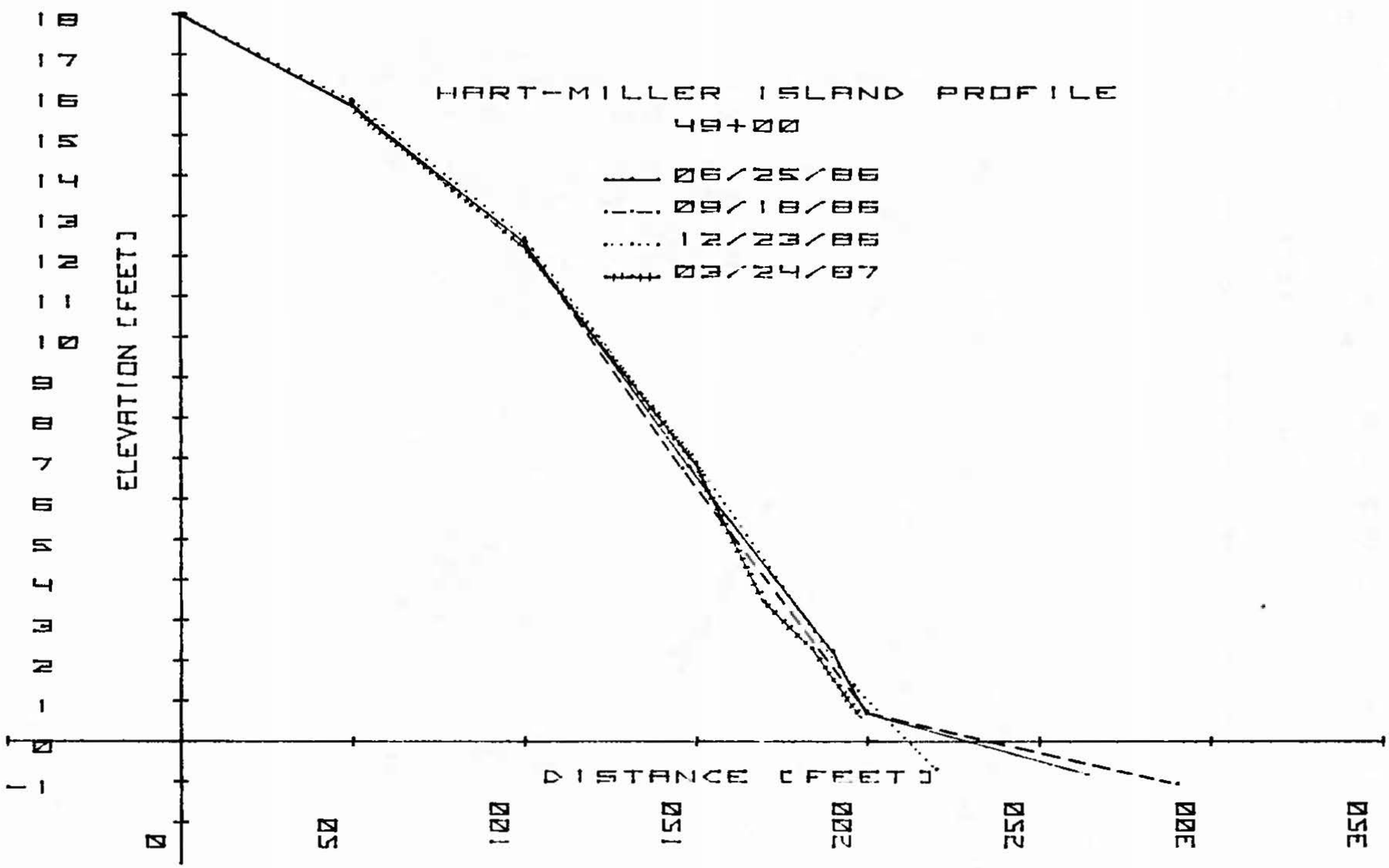

HART-MILLER ISLAND PROFILE
49+00
06/25/86
09/18/86
12/23/86
03/24/87
ELEVATION [FEET]
DISTANCE [FEET]
18
17
16
15
14
13
12
11
10
9
8
7
6
5
4
3
2
1
0
-1
0
50
100
150
200
250
300
350

Figure C-10

Figures C-11 through C-20

Cross-sectional profiles for each of the profile stations, comparing the June 1984 and March 1987 surveys.

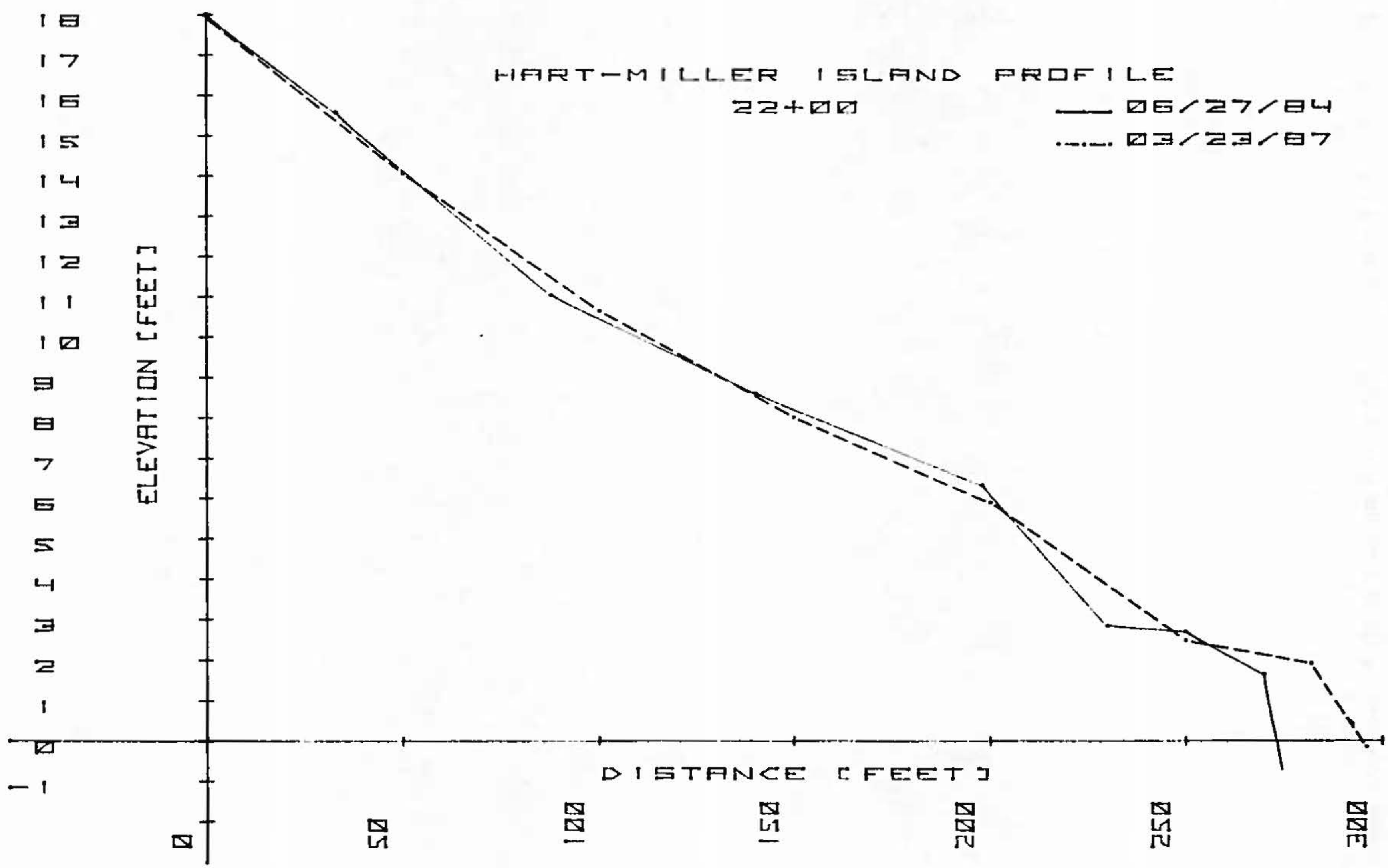

HART-MILLER ISLAND PROFILE
22+00
06/27/84
03/23/87
ELEVATION [FEET]
DISTANCE [FEET]
-1
0
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
0
50
100
150
200
250
300

Figure C-11

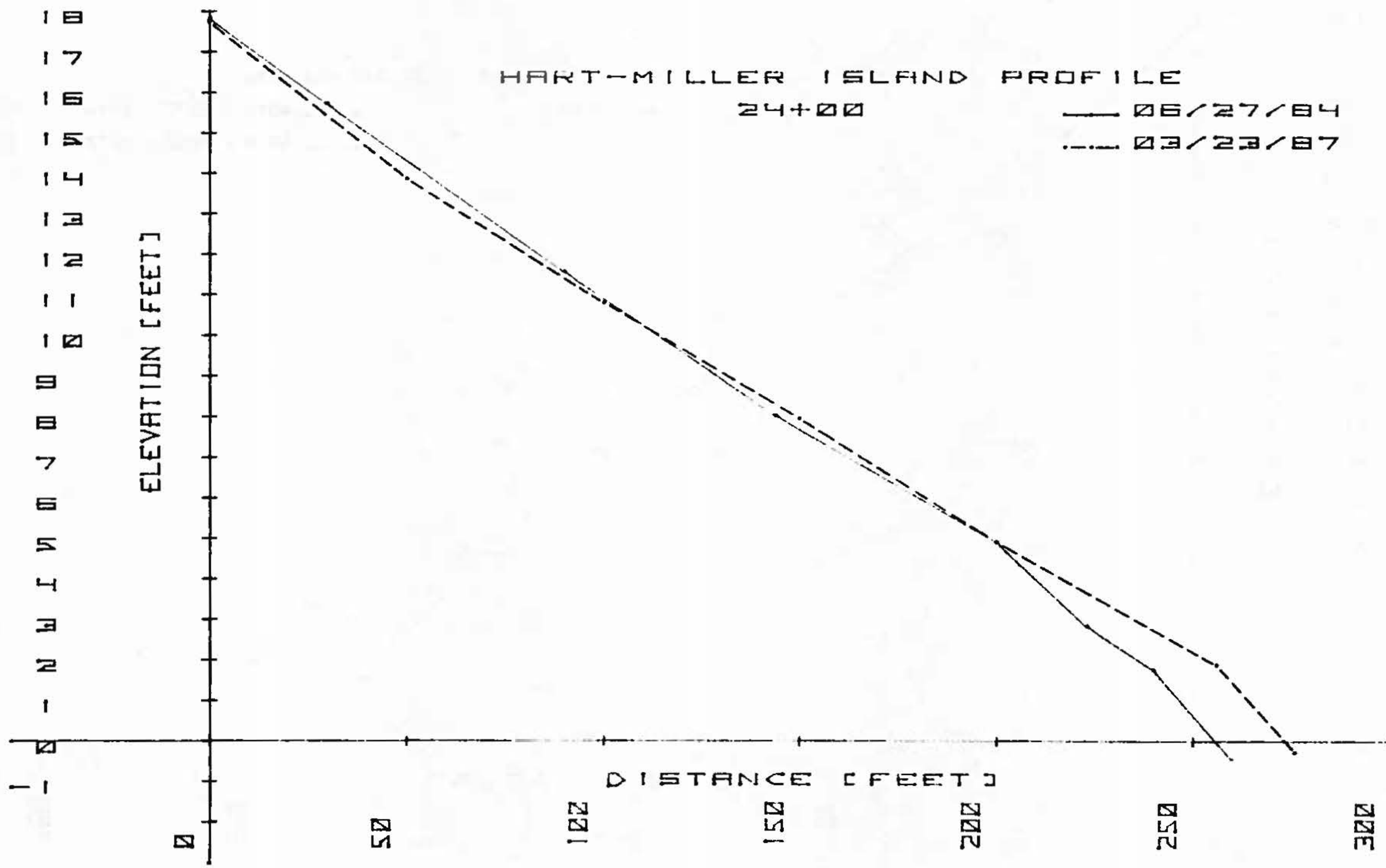

HART-MILLER ISLAND PROFILE
24+00
06/27/84
03/23/87
ELEVATION [FEET]
DISTANCE [FEET]
-1
0
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
0
50
100
150
200
250
300

Figure C-12

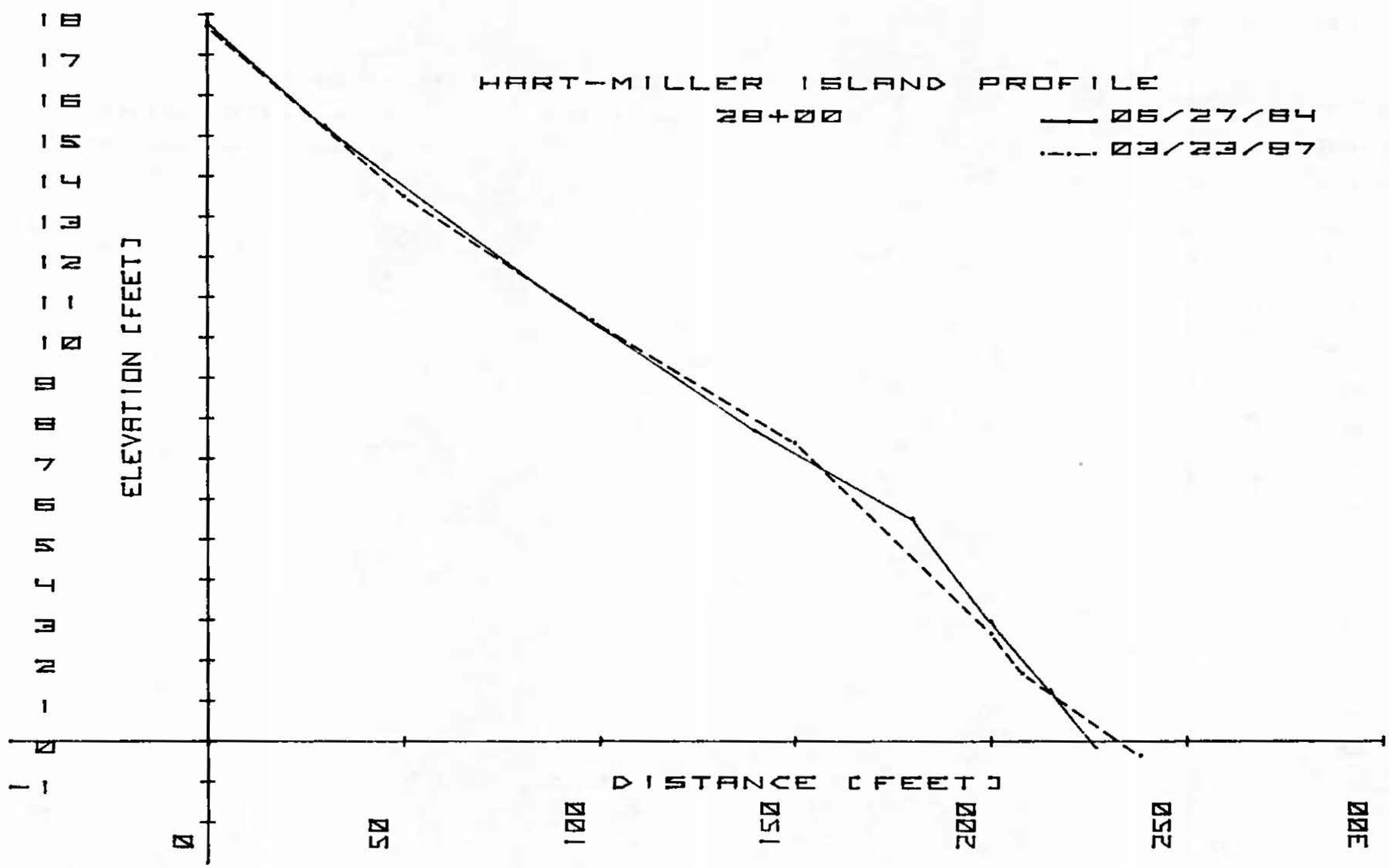

HART-MILLER ISLAND PROFILE
28+00
06/27/84
03/23/87
ELEVATION [FEET]
18
17
16
15
14
13
12
11
10
9
8
7
6
5
4
3
2
1
0
-1
DISTANCE [FEET]
0
50
100
150
200
250
300

Figure C-13

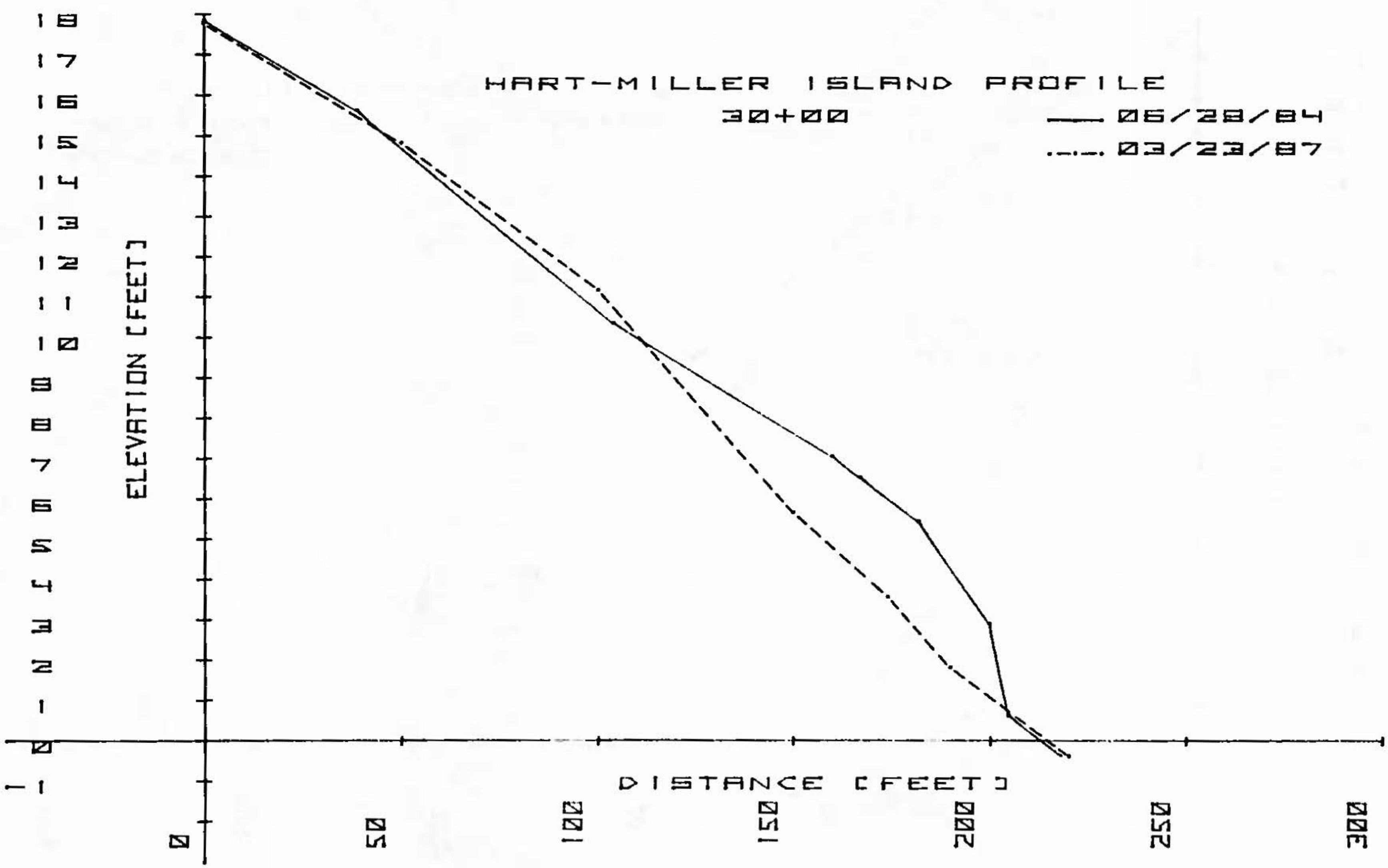
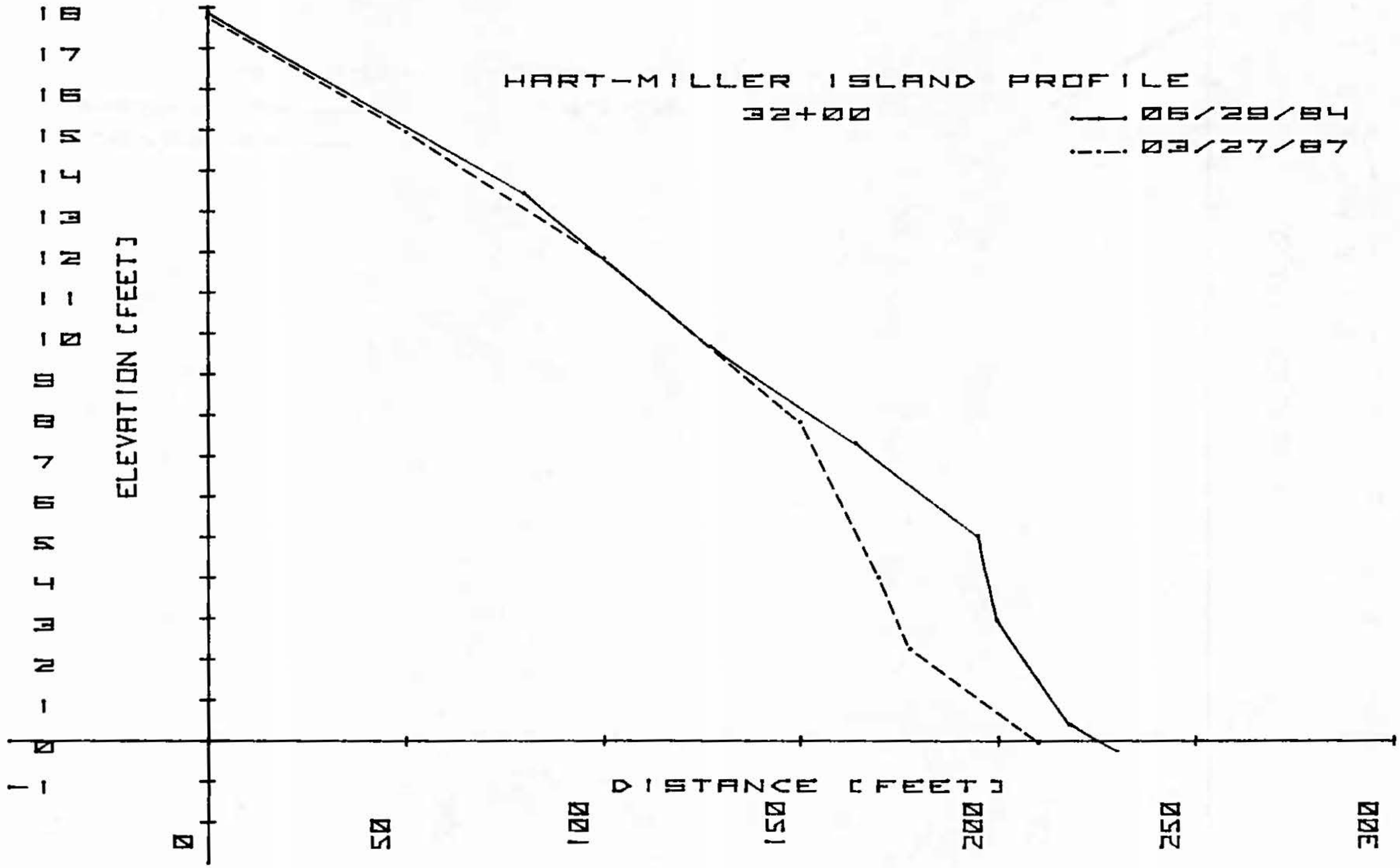

HART-MILLER ISLAND PROFILE
30+00
06/28/84
03/23/87
ELEVATION [FEET]
DISTANCE [FEET]
-1
0
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
0
50
100
150
200
250
300

Figure C-14


HART-MILLER ISLAND PROFILE
32+00
06/28/84
03/27/87
ELEVATION (FEET)
DISTANCE (FEET)
18
17
16
15
14
13
12
11
10
9
8
7
6
5
4
3
2
1
0
-1
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50
100
150
200
250
300

Figure C-15

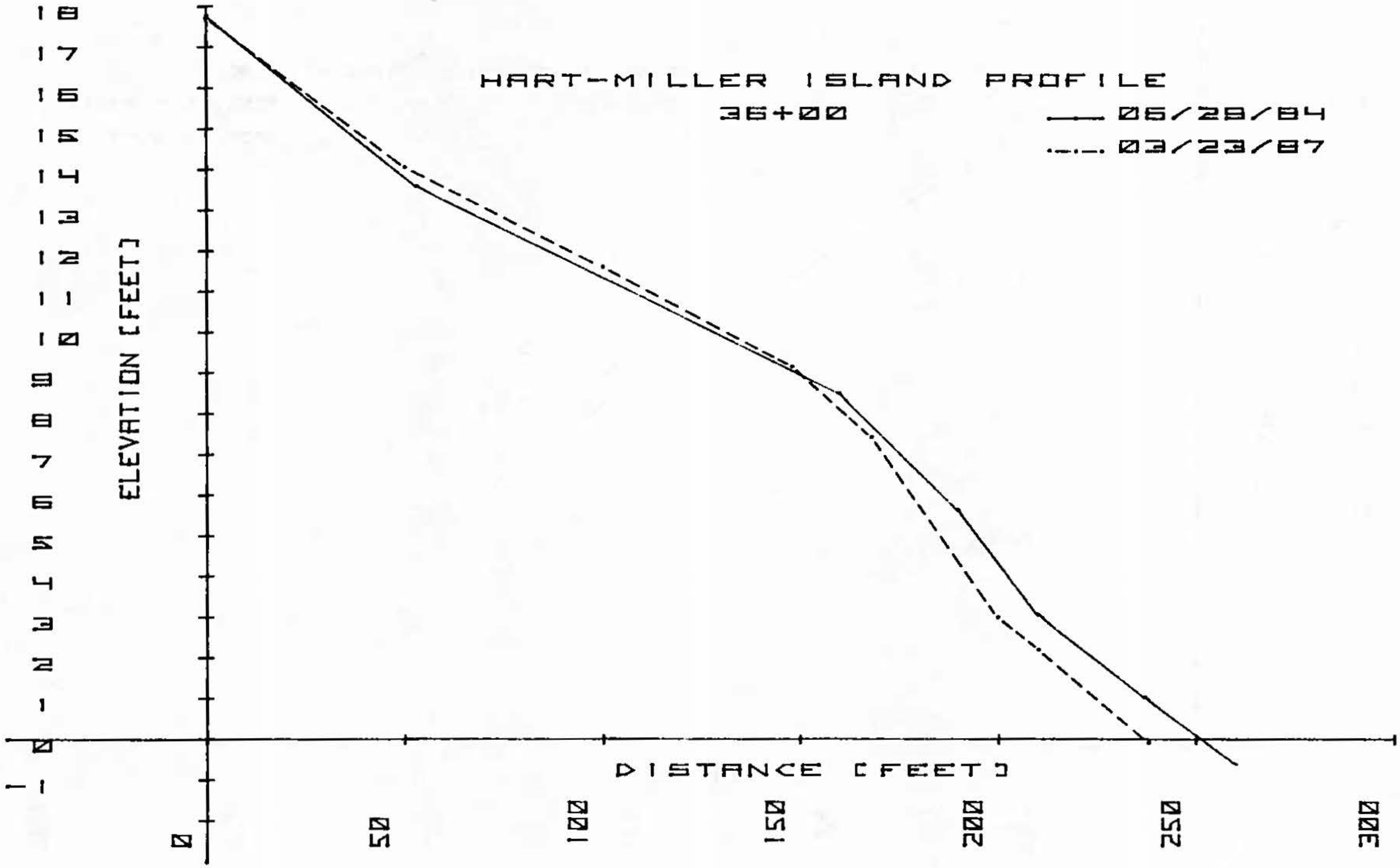
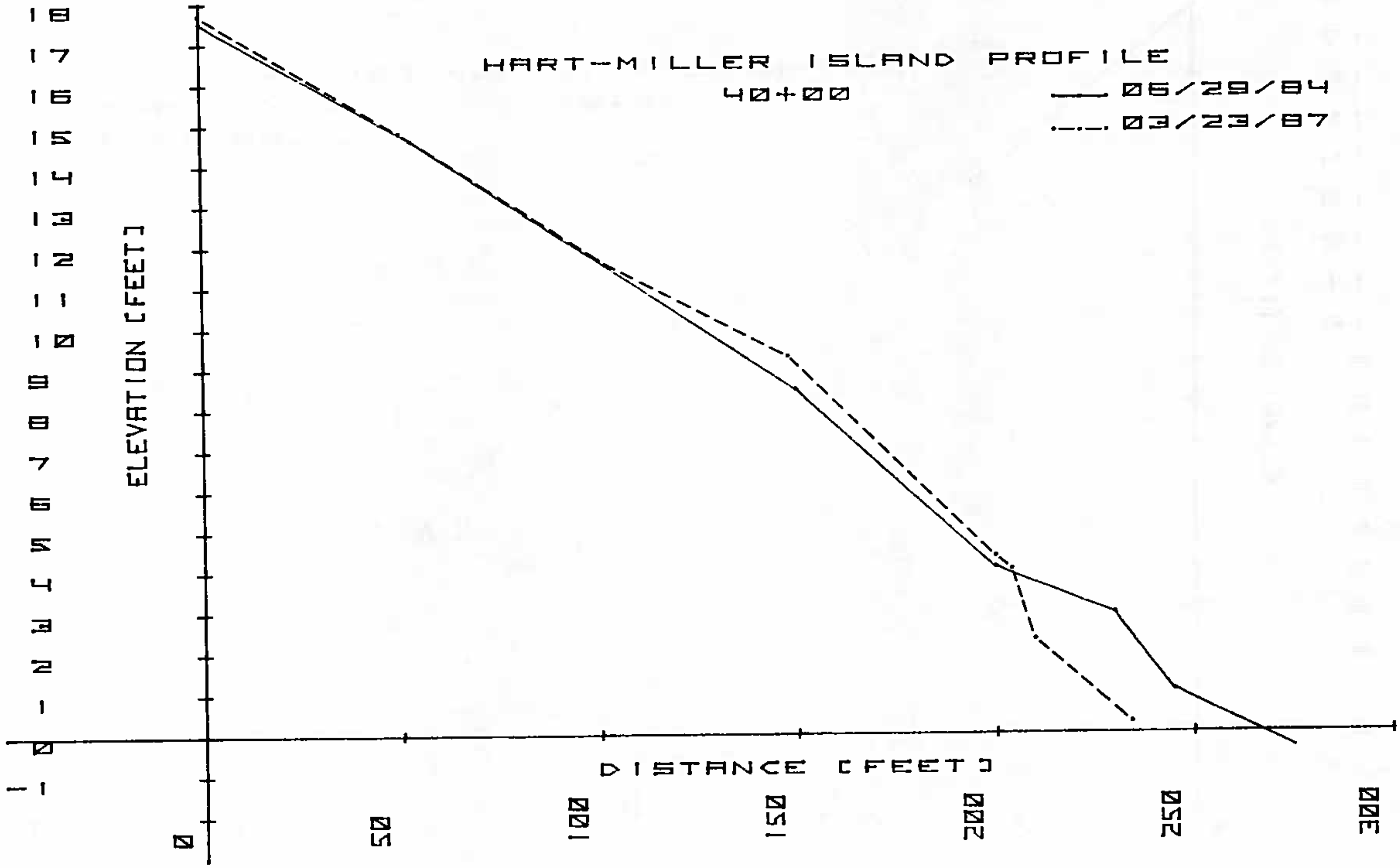

HART-MILLER ISLAND PROFILE
36+00
06/28/84
03/23/87
ELEVATION (FEET)
DISTANCE (FEET)
18
17
16
15
14
13
12
11
10
9
8
7
6
5
4
3
2
1
0
-1
0
50
100
150
200
250
300

Figure C-16


HART-MILLER ISLAND PROFILE
40+00
06/29/84
03/23/87
ELEVATION [FEET]
DISTANCE [FEET]
-1
0
1
2
3
4
5
6
7
8
9
10
11
12
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14
15
16
17
18
0
50
100
150
200
250
300

Figure C-17

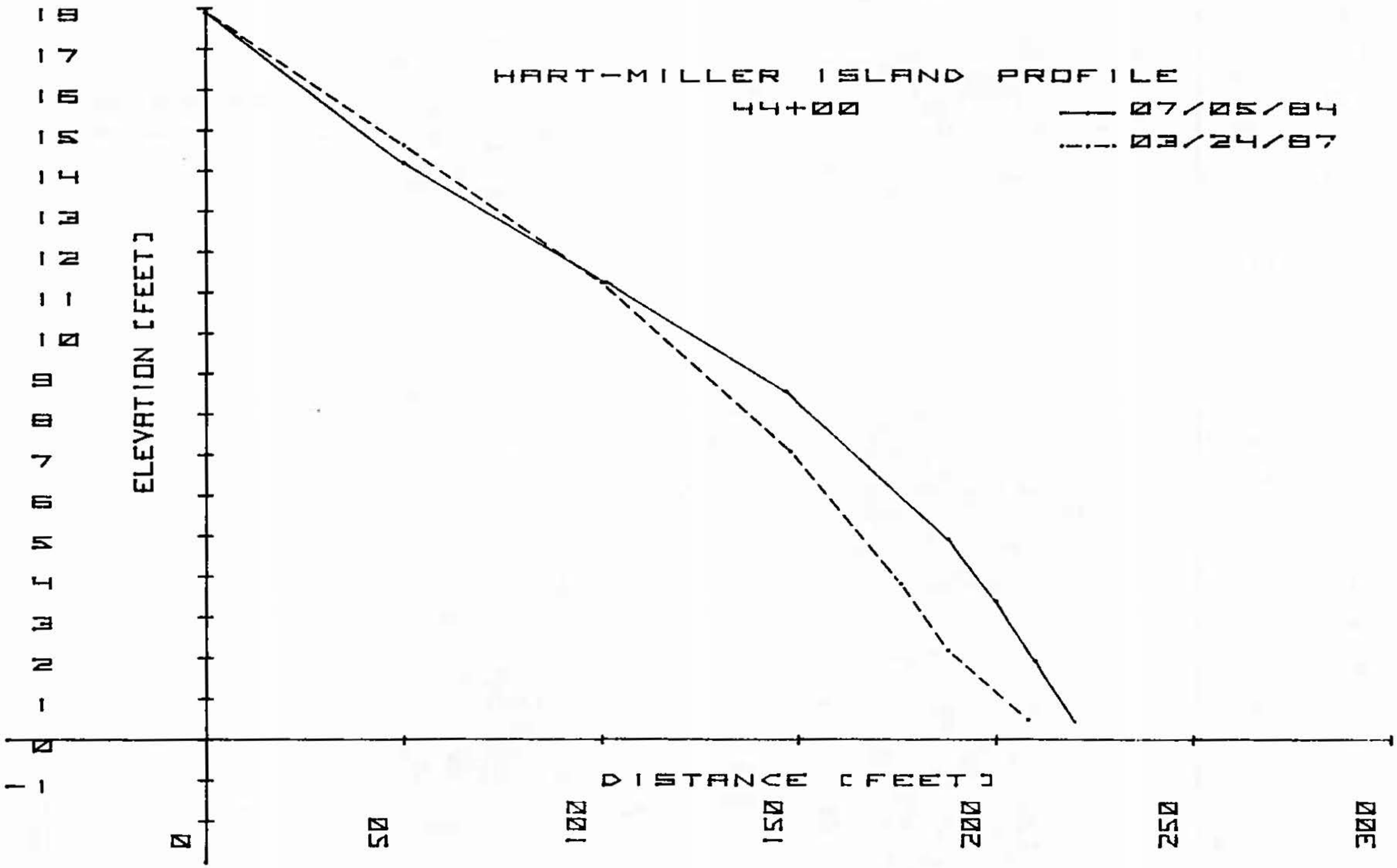
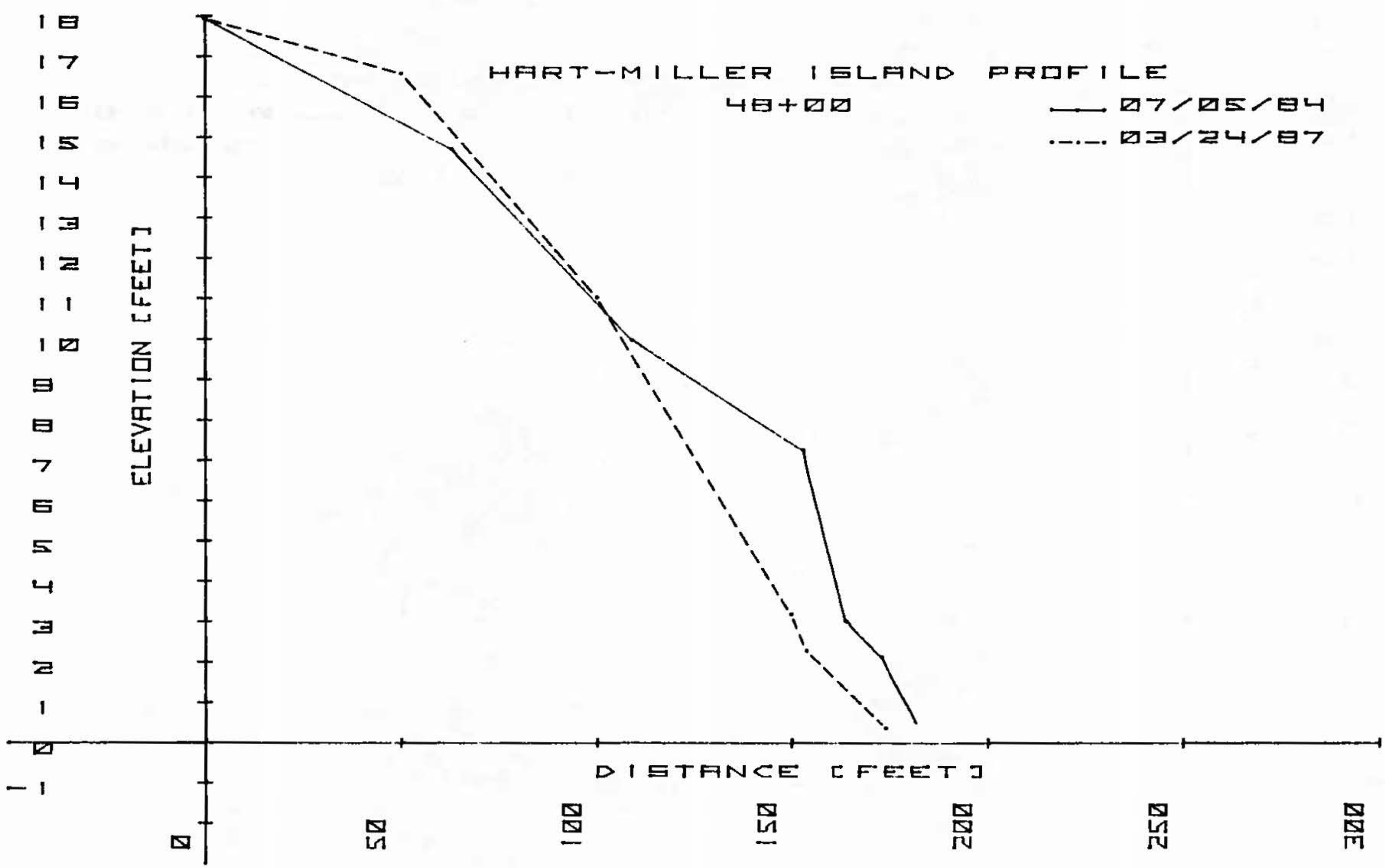

HART-MILLER ISLAND PROFILE
44+00
07/05/84
03/24/87
ELEVATION [FEET]
DISTANCE [FEET]
18
17
16
15
14
13
12
11
10
9
8
7
6
5
4
3
2
1
0
-1
0
50
100
150
200
250
300

Figure C-18


HART-MILLER ISLAND PROFILE
48+00
07/05/84
03/24/87
ELEVATION [FEET]
DISTANCE [FEET]
18
17
16
15
14
13
12
11
10
9
8
7
6
5
4
3
2
1
0
-1
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50
100
150
200
250
300

Figure C-19

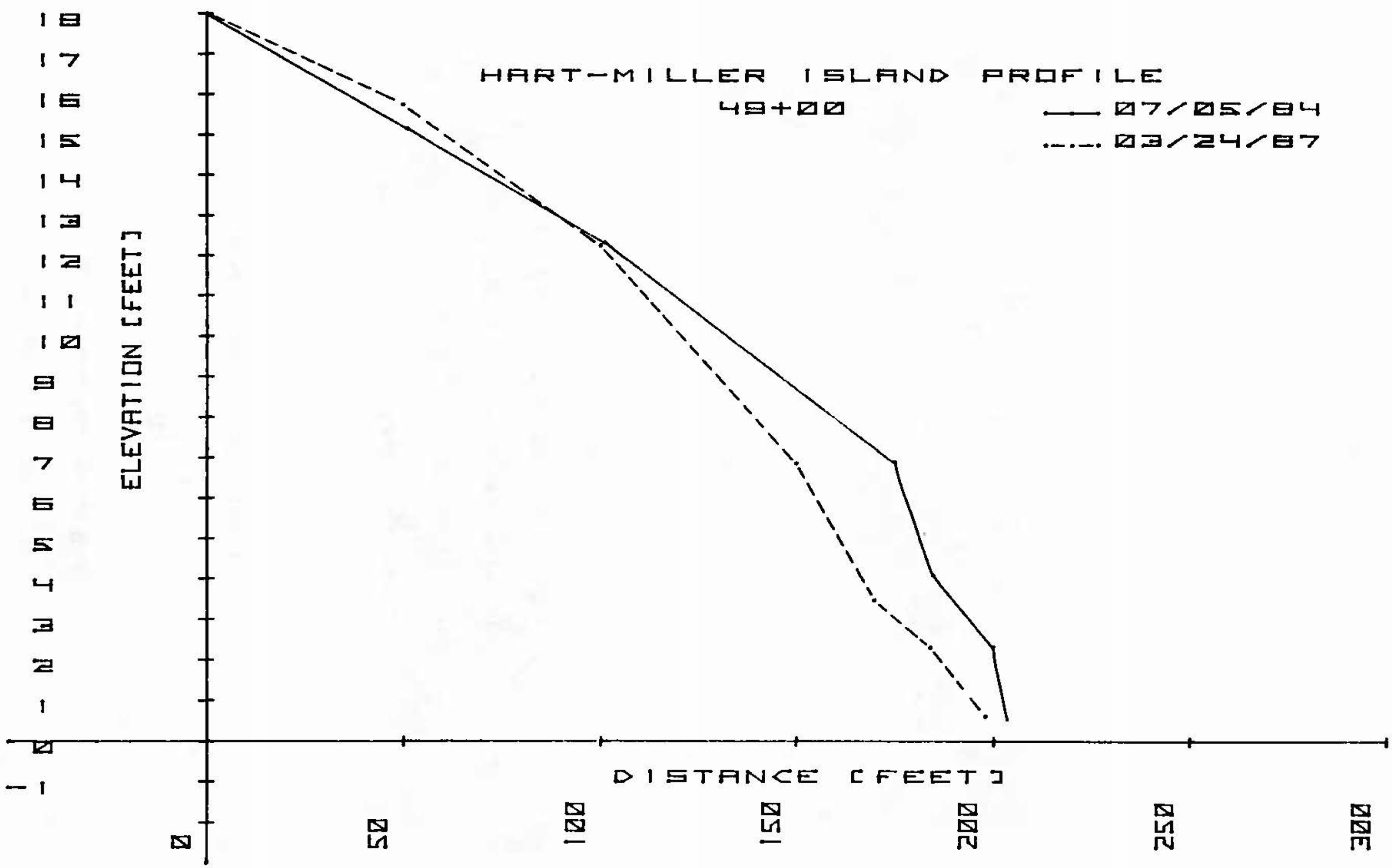
HART-MILLER ISLAND PROFILE
49+00
07/05/84
03/24/87
ELEVATION [FEET]
DISTANCE [FEET]
18
17
16
15
14
13
12
11
10
9
8
7
6
5
4
3
2
1
0
-1
0
50
100
150
200
250
300

Figure C-20

Project III- Benthic Studies

Sixth Annual Interpretive Report

for

Maryland Department of Natural Resources

by

Dr. Linda E. Duguay, Co-Principal Investigator

Dr. Kenneth R. Tenore, Co-Principal Investigator

Mr. Hayes T. Pfitzenmeyer, Consultant

Ref. No. (UMCEES) CBL 88-58

May 1988

ACKNOWLEDGMENTS

We would like to acknowledge our appreciation for assisting in this year's benthic monitoring program to Mr. Timothy Mulligan for helping with the field collections and processing of the preserved samples, to Ms. Kathy Speith for helping with processing the August samples and to Mr. David Jenkins for SCUBA diving to collect the epibenthic samples. We also acknowledge the outstanding assistance of Captain John T. Crane and mates of the R/V ORION.

ABSTRACT

The benthic invertebrate populations at Hart-Miller Island were monitored in order to assess any possible effects on the biota from operation of the Hart-Miller Island Containment Facility. Nearfield infaunal and epifaunal samples were taken along with reference samples in December 1986, and April and August 1987. Infaunal samples were taken by a 0.05 m^2 grab and washed on a 0.5 mm screen. Epibenthic samples were scraped by SCUBA divers from the pilings that support a series of piers which surround the containment facility. A total of 30 species were collected from the 13 sampled statons: nine silt-clay stations, three oyster shell stations and one sand substrate station. The most abundant species were the annelids, *Scolecolepides viridis* and *Heteromastus filiformis*, the crustaceans, *Leptocheirus plumulosus*, *Cyathura polita*, and *Balanus improvisus*, and the clams, *Rangia cuneata* and *Macoma balthica.*

Species diversity (H') values were evaluated at each station. The highest diversity value (3.3702) was obtained for a nearfield oyster shell station (S7) in December. However, the overall highest diversity occurred in August and the lowest overall diversity values occurred in April. The length-frequencies of the clams, *R. cuneata*, *M. balthica*, and *Macoma mitchelli* were examined at the nearfield and reference stations and correspond quite closely for the three sampling dates. Cluster analysis of the stations over the three sampling periods usually associated stations in response to bottom type. Variations in recruitment could explain why some specific stations did not form tight groupings. The clusters were consistent with earlier studies and did not indicate any unusual groupings associated with the containment facility. A one way analysis of variance, using the Student Neuman-Keuls test, of the number of individuals of each species in the samples for each station, indicated that nearfield station, S1 was significantly different in December and August, presumably because of its shallow depth and sandy substrate. Also, during August, rank-analysis of differences in the means of samples taken at stations with silt/clay substrates indicated significant differences for the nearfield stations. This significant difference was attributed to a large recent spat set and growth of the clam *R. cuneata* at station S5. Faunal disruption at this particular station, located close to the rehandling pier, has occurred since 1984, when dredged material began to be unloaded at the facility. The disruption apparently results from tug activity scouring and/or washing away the bottom substrates.

Epifaunal populations were similar to previous years. Samples were collected at depths below the winter ice scour zone and the epifaunal population persisted throughout the year at these deeper locations along the pilings. The nearfield and reference populations were very similar over all three sampling periods and, as previously reported, the amphipod, *Corophium lacustre*, is the most abundant organism present on all pilings at all sampling periods.

The results of the current monitoring effort suggest once again that only localized and temporary effects on the benthos result from the containment facility. These effects are limited primarily to the area where dredged material was transferred from barges into the facility. They are believed to be caused by a washing-away of the bottom by the props of the tug boats. Discharge of effluent from the facility has begun during this sampling year and no adverse effects on the benthic populations have been observed to date. However, it is still early and continued monitoring of the area is necessary during this period of increased activity around the facility.

INTRODUCTION

This report presents the results for the sixth year of consecutive benthic sampling for baseline and monitoring studies at Hart-Miller Island. Estuarine areas such as this, with wide seasonal salinity changes and vast shallow soft-bottom shoals, are important to protect because they serve as breeding and nursery grounds rich in nutrients for many commercial and non-commercial species of invertebrates and migratory fish.

Since Hart-Miller 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) and Holland et al. (1987) completed long term studies of more stable mesohaline areas further down-bay and found most macrobenthic species showed significant year-to-year fluctuations in abundance, primarily as a result of slight salinity changes; and that the spring was a critical period for the establishment of both regional and long-term distribution patterns. Based on those studies, one can expect even greater fluctuations in this highly variable oligohaline portion of the bay.

Activities at Hart-Miller Island 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 has now reached a sufficient level for effluent to be discharged.

METHODS

Sampling was conducted at a network of stations surrounding the disposal area (Figs. 1 & 2, CBL and DNR designations, respectively). Six nearfield stations (S1-S6) were located along the eastern side of the dike, extending within 90 m of the dike from the northern end to the southern end. A station (S7) was also located about 180 m from the effluent pipes and another station (S8) was located about the same distance from the rehandling piers. Four reference stations 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 of that impacted area and its possible influence 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 1-1.3 m below the surface as well as at 2-3 m below the surface. 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 1986, and in April and August 1987. Three replicate grabs were taken with a 0.05 m^2 Ponar grab at each benthic station for each sampling period. The samples were washed separately on a 0.5 mm screen, fixed in 10% formalin and later transferred to 70% ethyl alcohol. In the laboratory each organism was removed, identified, and enumerated. Length-frequency measurements were made on the three most abundant mollusks. A qualitative sample was scraped from the pilings at the epifaunal stations by a SCUBA diver and treated similarly to the infaunal benthic samples. A relative estimate of abundance was made for each species through a set of numerical ratings, which ranged from 1 (very abundant) to 4 (present).

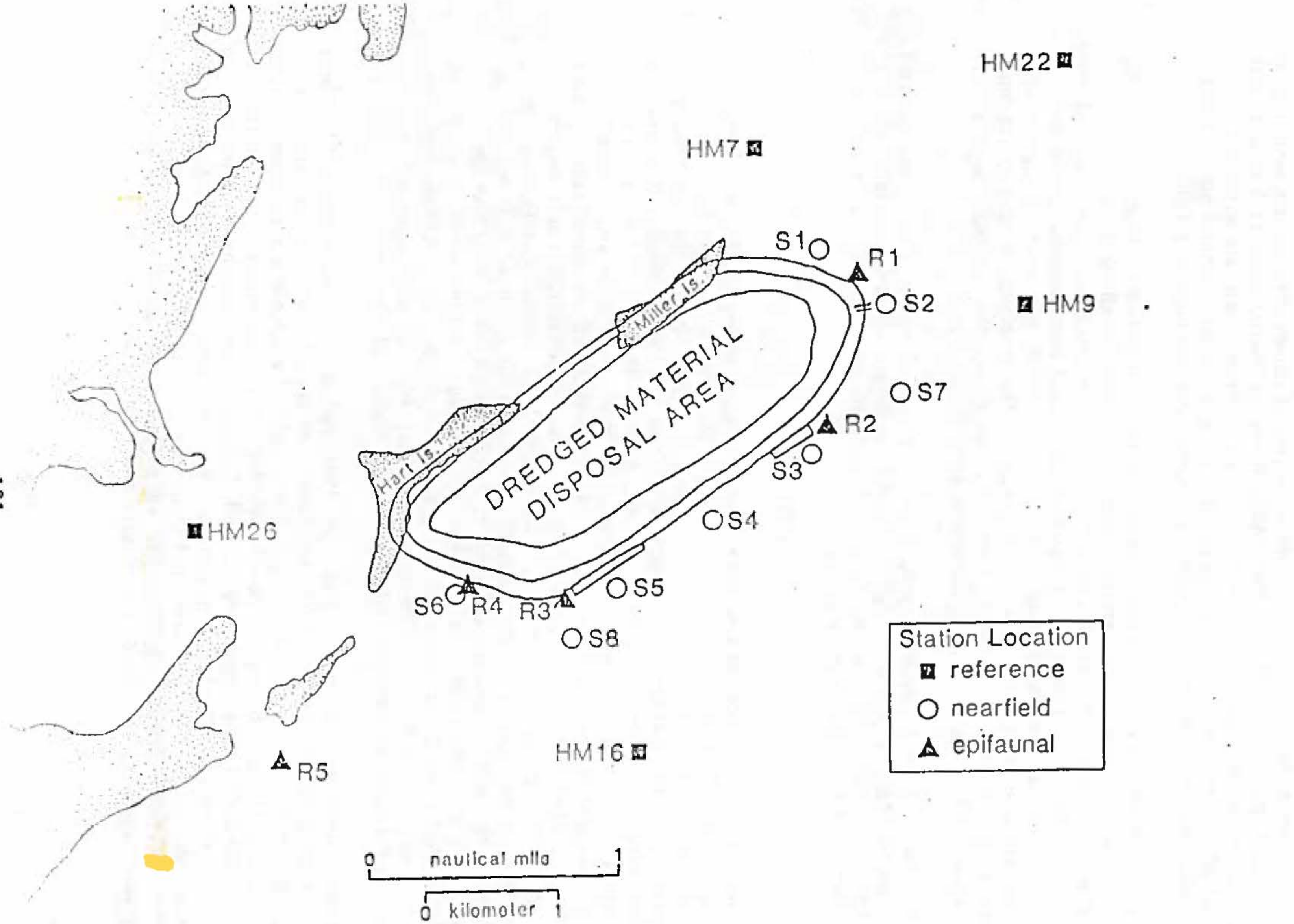

Figure 1: Benthic infaunal and epifaunal sampling station locations at the Hart-Miller Island containment facility. University of Maryland, Chesapeake Biological Lab designations.

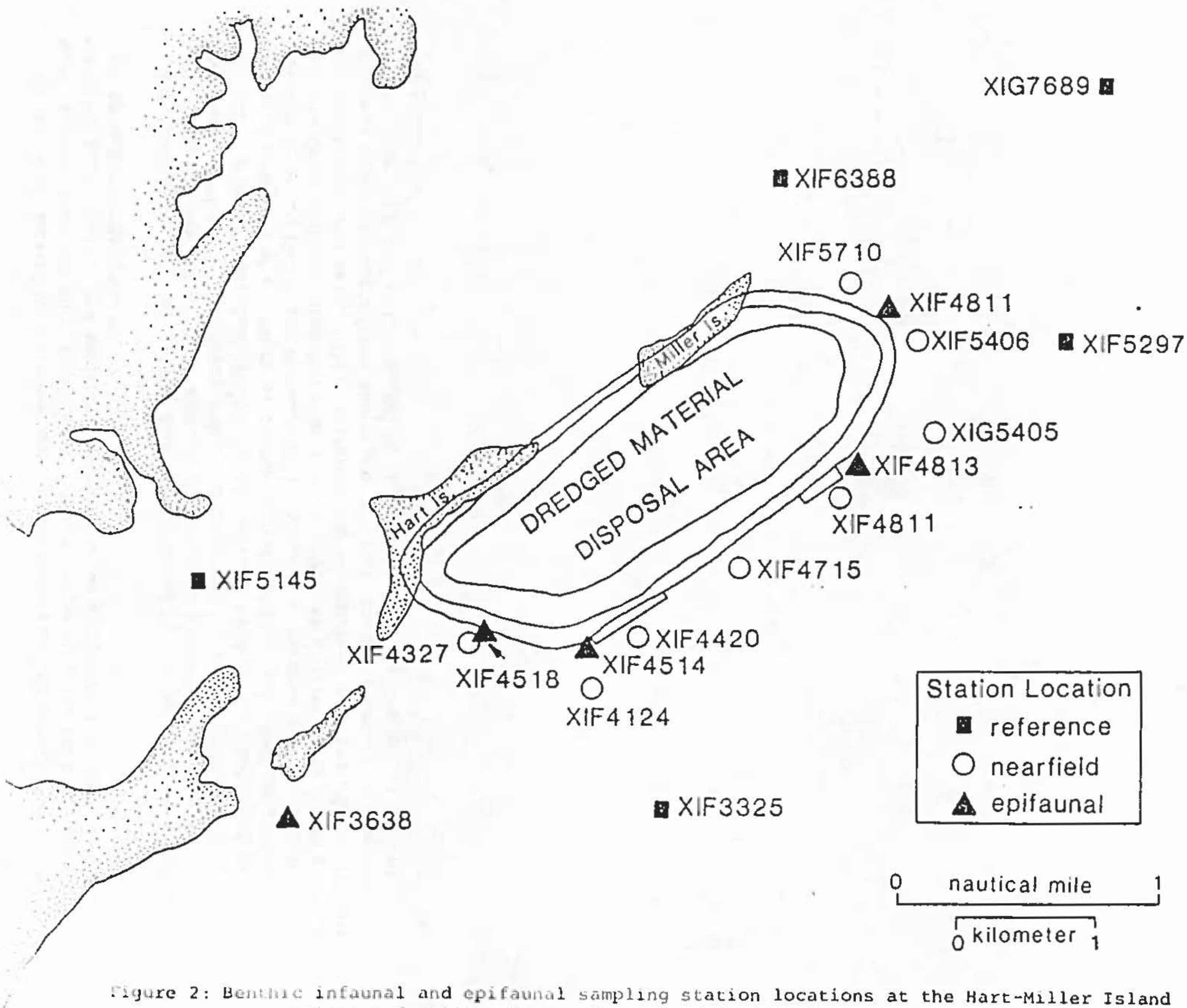

Figure 2: Benthic infaunal and epifaunal sampling station locations at the Hart-Miller Island containment facility. State of Maryland designations.

Stations were located with the research vessel's radar and LORAN C. Station depths were recorded from the ships'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.

The quantitative infaunal sample data were analyzed by a series of statistical tests. 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 rank analysis test (Elliott 1977) was used to compare mean numbers of the most abundant species, between the silt/clay, nearfield, and reference stations separately. Then the two sets of stations were added together and retested.

RESULTS AND DISCUSSION

Since the beginning of the project in 1981, a small number of species has dominated the populations of benthic invertebrates collected at the various nearfield and reference sites in the vicinity of the Hart and Miller Island Containment Facility. The three most abundant species this year were the annelid worm, *Scolecolepides viridis*; the crustacean, *Leptocheirus plumulosus*; and the clam, *Rangia cuneata*. Variations in the range and average number of these three species since the beginning of the project in 1981 are presented in Table 1. The populations, particularly of the first two species, have remained relatively stable over this monitoring period. Variations in dominant or most abundant species occur primarily as a result of the different bottom types (Table 2). The annelid worms, *S. viridis* and *H. filiformis*, the crustaceans, *L. plumulosus* and *C. polita* prefer soft bottoms, while the most common inhabitants of the predominately old oyster shell substrates are the barnacle, *Balanus improvisus*, the worm, *Nereis succinea*, and the crustacean, *Rithropanopeus harrisi*. However, there is occasionally some overlap even between the bottom types as evidenced in August for the reference stations when the three dominant species were exactly the same, *R. cuneata*, *C. polita* and *H. filiformis*. Sudden freshwater inflows during the 1987 spring spawning period have favored the recruitment success of *R. cuneata* in different years, and in this particular monitoring year high influxes into the population were observed at several stations during our August sampling. However, if high salinities (>10 ppt) persist throughout the winter, then large mortalities of this clam can be expected (Cain 1975). The worm, *H. filiformis*, has a preference for the higher mesohaline area of an estuary. It is an opportunist species with the ability to rapidly increase its progeny as favorable saline conditions arrive. It also has been acknowledged as a nitrate enrichment indicator (Dean and Haskin, 1964). Station HM26, at the mouth of the Back River had the most diverse annelid fauna with seven different species present in August. Major population bursts of *Streblospio benedicti* and *Tubificoides sp.* occurred during this time period (Table 3).

The worm, *S. viridis*, and the crustacean, *L. plumulosus*, were numerically the most abundant organisms at most stations, including, on occasion, the hard-bottom stations where shells are interspersed with silt (Tables 3 and 4). Over the course of these monitoring studies, the worm, *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 in late spring play an important role in determining the dominance of these two species. The crustacean, *L. plumulosus*, becomes more abundant during the low salinity years while *S. viridis* prefers slightly higher salinities. This particular year *L. plumulosus* was the numerically more dominant. Occasionally, the isopod crustacean, *C. polita* becomes one of the three dominant species (Tables 3 and 4). This dominance appears to coincide with the abundance of *L. plumulosus*, since it also prefers low salinity and silt-clay substrates. Population density is more stable for *L. plumulosus* than the other dominants at all seasons. This species is tolerant of physical and chemical disturbances and repopulates areas such as dredged material disposal areas more quickly than other species (Pfitzenmeyer, 1985).

Table 1. Abundances of the three major species since the inception of the monitoring project. Based only on the reference station data after February - 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	Dec. 1986 Apr., Aug. 1987
Scolecolepides								
	Range/m^2	0-1825	0-286	0-264		11-153	7-1287	13-447
	Avg./m^2	229	121	69	546	92	398	179
Leptocheirus								
	Range/m^2	0-2960	0-5749	7-6626		20-441	7-1293	7-3312
	Avg./m^2	832	1459	2259	614	272	308	1,111
Rangia								
	Range/m^2	0-46	0-99	0-135		0-75	0-273	13-3007
	Avg./m^2	9	9	22	455	27	102	687

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

	December 1986	April 1987	August 1987
NEARFIELD			
SOFT BOTTOM			
	Leptochierus plumulosus	*Leptochierus plumulosus*	*Scolecolepides viridis*
	Heteromastus filiformis	*Scolecolepides viridis*	*Leptochierus plumulosus*
	Corophium lascustre	*Macoma balthica*	*Heteromastus filiformis*
SHELL BOTTOM			
	Balanus improvisus	*Balanus improvisus*	*Balanus improvisus*
	Nereis succinea	*Nereis succinea*	*Rithropanopeus harrisi*
	Rithropanopeus harrisi	*Scolecolepides viridis*	*Heteromastus filiformis*
REFERENCE			
SOFT BOTTOM			
	Scolecolepides viridis	*Leptochierus plumulosus*	*Rangia cuneata*
	Cyathura polita	*Scolecolepides viridis*	*Cyathura polita*
	Leptochierus plumulosus	*Macoma balthica*	*Heteromastus filiformis*
SHELL BOTTOM			
	Leptochierus plumulosus	*Balanus improvisus*	*Rangia cuneata*
	Scolecolepides viridis	*Scolecolepides viridis*	*Cyathura polita*
	Cassidinidea lunifrons	*Nereis succinea*	*Heteromastus filiformis*
BACK RIVER REFERENCE			
SOFT BOTTOM			
	Leptochierus plumulosus	*Leptochierus plumulosus*	*Streblospio benedicti*
	Macoma balthica	*Tubificoides sp.*	*Tubificoides sp.*
	Eteone heteropoda	*Macoma balthica*	*Leptochierus plumulosus*

Table 3: Abundance (numbers/m^2) of all benthic invertebrates at 5 reference stations for the 6th monitoring year of studies at the Hart-Miller Island containment facility. Stations sampled on December 1986, and April and August 1987.

HMI #/m2 for 6th year 1986-1987

SPECIES NAME	HM7 X1F6388			HM9 X1F5297			HM16 X1F3325			HM22 X1G7689			HM26 X1F5145 [redacted]			TOTAL
	Dec	Apr	Aug	Dec	Apr	Aug	Dec	Apr	Aug	Dec	Apr	Aug	Dec	Apr	Aug	
RHYNCHOCOELA (ribbon worms)																
Micrura leidyi		7	53	13	7	93	67	13	213		7	27	73	13	380	966
ANNELIDA (worms)																
Heteromastus filiformis	33	67	100	67	47	260	680	520	687	53		327	113	180	607	3741
Melinna sp.											127					127
Nereis succinea	7		20	7	433	20	7	33	7	13		7	27	33	60	674
Scoloplos fragilis									13							13
Eteone heteropoda				20			20	7	13	13			627	167	207	1074
Scolecolepides viridis	13	287	320	426	447	227	13	53	33	187	160	93	20	360	47	2686
Streblospio benedicti			20	7		20	60					67	107		5487	5768
Hypaniola grayi															20	20
Tubificoides sp.									20			13		1212	5166	6411
MOLLUSCA (mollusks)																
Ischadium recurvus																0
Congeria leucophaeta		13		7	7											27
Macoma balthica	7	60	53	7	7	67	20	380	1060	7	147	60	640	447	20	2982
Macoma mitchelli	73	60	20	27	13	13	53	87	20	107	53	13	193	80	47	859
Rangia cuneata	133	293	1627	40		2347		13	393	173	40	3007	113		67	8246
ARTHROPODA (crustaceans)																
Balanus improvisus					667											667
Balanus subalbidus																0
Cyathura polita	33	60	293	133	80	293	153	160	900	113	40	300	53	27	287	2925
Cassidinidea lunifrons				7	7											14
Edotea triloba		7		20							7		127	13	80	254
Gammarus palustris																0
Leptocheirus plumulosus	427	567	7	792	7	20	3312	1353	827	2020	2707	27	2140	1760	700	16666
Corophium lacustre				60	33			27	7	60	27	27	87		20	348
Gammarus daiberi																0
Gammarus tigrinus					7								7		20	34
Melita nitida		13	7		193		67	7	93	7	160	7	120	27	47	748
Chirodotea almyra															7	7
Monoculodes edwardsi			7			7			27			27				68
Chironomid sp.	7	7								7	20		67	60		166
Rithropanopeus harrisi					200	27	7		13			7				254
TOTAL NUMBERS	733	1441	2527	1633	2155	3394	4459	2653	4326	2760	3495	4009	4514	4379	13269	55747

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Table 4: Abundance (number/m2) of all benthic invertebrates at 8 nearfield stations for the 6th monitoring year of studies at the Hart/Miller Island containment facility. Stations sampled on December 1986, and April and August 1987.

SPECIES NAME	S1 Dec	S1 Apr	S1 Aug	S2 Dec	S2 Apr	S2 Aug	S3 Dec	S3 Apr	S3 Aug	S4 Dec	S4 Apr	S4 Aug	S5 Dec	S5 Apr	S5 Aug	S6 Dec	S6 Apr	S6 Aug	S7 Dec	S7 Apr	S7 Aug	S8 Dec	S8 Apr	S8 Aug	
RHYNCHOCOELA (ribbon worms)																									
Micrura lediyi					7	13	40	33	120		22	60	13	27	187	73	40	113		7	67	20	33	93	968
ANNELIDA (worms)																									
Heteromastus filfiformis	7	47		20	60	100	280	13	853	433	227	400	273	213	560	1233	420	407	27	200	533	120	147	307	6880
Melinna sp.			106																						106
Nereis succinea				180	393	160	13	7	20	40	13	13	540	20	7	33	13	7	53	67	33	20	33		1665
Scoloplos fragilis																									0
Eteone heteropoda									7	7	27	7			100	173	73	7							401
Scolecolepides viridis	167	2686	213	13	327		213	223	427	153	392	60	7	100	113	140	133	180	13	2327	260	20	173	40	8380
Streblospio benedicti	7		280	7		7			573			27	100	880	60			267			387	20		727	3342
Hypaniola grayi																									0
Tubificoides sp.						7			227			33		807				40			67			60	1241
MOLLUSCA (mollusks)																									
Ischadium recurvus				13	33	107															7				160
Congeria leucophaeta													7						7						14
Macoma balthica			7		7		13	33	120	20	480	27		1160	613	673	1552	587	7	87	7	13	360	193	5959
Macoma mitchelli	13	7		7	60		73	13	73	107	47	7	40	280	113	133	120	13	20	53		133	33	20	1365
Rangia cuneata	33	13	187		13		123	107	407	93	247	4627	27	7	826	20		367	13	20	80	7	7	7	7231
ARTHROPODA (crusteans)																									
Balanus improvisus		7	2882	2246	2113	7						33						20		720				7998	
Balanus subalbidus				7																					7
Cyathura polita		33	360		33	13	123	13	940	133	87	240	167	113	373	180	93	567	53	173	247	80	153	833	5007
Cassidinidea lunifrons				123	20														7						150
Edotea triloba			20				7			13			13	33		107	7								200
Gammarus palustris															7										7
Leptocheirus plumulosus	33	107	473		13		580	620	7	380	847		520	1620		4967	2480	147	73	400	7	427	1453		15154
Corophium lacustre		7		27	20		47	20	7	13	13		333	47		667	7		13	7	7	33			1221
Gammarus daiberi														7											7
Gammarus tigrinus													7												7
Melita nitida				60	60	40				13	7		13	13		27	27		7		20		7		294
Chirodotea almyra	7															7									14
Monoculodes edwardsi			40						33						13			7			20			7	120
TOTAL NUMBERS	267	2907	1686	3396	3539	3040	1519	1082	3927	1418	2409	5561	2240	3606	4672	8513	4992	2742	346	3341	2595	913	2399	2327	69457

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 known to have high survival rates and often reach high densities of individuals (Wells, 1961). The total number of individual organisms collected at the various reference and nearfield stations were quite comparable and ranged for the most part between 1000 and 4000 individuals per square meter. Lowest values for both sets of stations were recorded in December 1986, 267 and 345 individuals per m^2 for nearfield stations S1 and S7, respectively. A low of 733 individuals per m^2 was recorded for reference station HM7. The predominant benthic populations in both areas are similar and consist of detrital feeders which have an ample supply of fine substrates in this region of the bay and particularly around the containment facility (Wells et al., 1984).

Table 2 compares the densities of the numerically dominant species recorded in each area and bottom type for December 1986, April and August 1987. Tables 3 and 4 provide the densities (individuals per m^2) for all stations at all three seasons. During the fifth monitoring year *L. plumulosus* was the overall most abundant species, as it was during the past monitoring study (Pfitzenmeyer and Tenore, 1987), with *S. viridis* being the second most numerous species overall. The clam, *R. cuneata* was also a numerically dominant species as it had been in the years 1974 to 1976 (Pfitzenmeyer and Millsaps, 1984). Low salinity conditions during recruitment periods are particularly favorable for *R. cuneata*.

Salinity and temperature were recorded in April and August and were similar to past observations during these periods. April salinity was about 1 ppt and temperature was 11°C whereas August salinity was 6.0 to 8.1 ppt and temperature ranged from 27 to 29°C.

Species diversity values must be interpreted carefully in analyzing benthic data from the upper bay. Generally in faunal studies, high diversity values, with the number of all species in the population somewhat equally distributed, and no obvious dominance by one or two species reflect a healthy, stable fauna. In contrast, observations at Hart-Miller Island show that the normal condition is for one, two or three species to assume numerical dominance. This dominance is variable from year to year depending on environmental factors, in particular the amount of freshwater entering the Bay from the Susquehanna River. Because of the overwhelming numerical dominance of a few species, diversity values are fairly low in this productive area of the Bay when compared to values obtained elsewhere. Diversity values for each of the quantitative benthic samples for the three different sampling dates are presented in Tables 5, 6, 7.

Again this year, the overall highest species diversity (overall average seasonal value of 2.28; three stations with values greater than 3.00) was found during the summer sampling, in August (Table 7). This pattern was postulated in the First Interpretive Report (Pfitzenmeyer et al., 1982), however the absolute highest species diversity value was obtained in December for station S7, a nearfield shell bottom station. This station had a total of only 52 individuals made up of 14 different species. The largest number of species recorded for any one station was 18 at the Back River (HM26) reference site in August and the lowest number of species, 7, was

Table 5. Number of species and individuals per three grabs (0.05 m^2 each) found at corresponding stations for December 1986. Also shown are bottom substrates, species diversity (H1), and dominance factor (S.I.).

	SUBSTRATE	NO. SPECIES	NO. INDIVIDUALS	SPECIES DIVERSITY (H1)	DOMINANCE S.I.
NEARFIELD					
S1	Sand	7	40	1.7890	0.4262
S2	Shell	12	511	1.0724	0.7069
S3	Silt/Clay	12	247	2.6845	0.2058
S4	Silt/Clay	13	214	2.7790	0.1947
S5	Silt/Clay	16	336	2.9769	0.1616
S6	Silt/Clay	16	1277	2.1531	0.3754
S7	Shell	14	52	3.3702	0.1198
S8	Silt/Clay	12	137	2.5294	0.2684
REFERENCE					
HM16	Silt/Clay	12	669	1.3638	0.5771
HM 7	Silt/Clay	9	110	1.9294	0.3862
HM22	Silt/Clay	12	420	1.6567	0.5329
HM 9	Shell	15	245	2.2726	0.3151
BACK RIVER REFERENCE					
HM26	Silt/Clay	16	677	2.6426	0.2704
AVERAGE		13	380	2.2476	0.3493

Table 6. Number of species and individuals per three grabs (0.05 m^2 each) found at corresponding stations for April 1987. Also shown are bottom substrate, species diversity (H1), and dominance factor (S.I.).

	SUBSTRATE	NO. SPECIES	NO. INDIVIDUALS	SPECIES DIVERSITY (H1)	DOMINANCE S.I.
NEARFIELD					
S1	Sand	8	436	0.5455	0.8561
S2	Shell	15	528	1.9350	0.4343
S3	Silt/Clay	10	164	1.9573	0.3793
S4	Silt/Clay	12	363	2.6196	0.2093
S5	Silt/Clay	13	541	2.1225	0.3167
S6	Silt/Clay	13	749	1.9763	0.3525
S7	Shell	10	501	1.6195	0.5072
S8	Silt/Clay	10	360	1.9868	0.4028
REFERENCE					
HM16	Silt/Clay	12	398	2.1428	0.3245
HM 7	Silt/Clay	12	216	2.4718	0.2435
HM22	Silt/Clay	12	524	1.4288	0.6082
HM 9	Shell	15	323	2.6802	0.1982
BACK RIVER REFERENCE					
HM26	Silt/Clay	13	657	2.4268	0.2591
AVERAGE		12	443	1.9934	0.3917

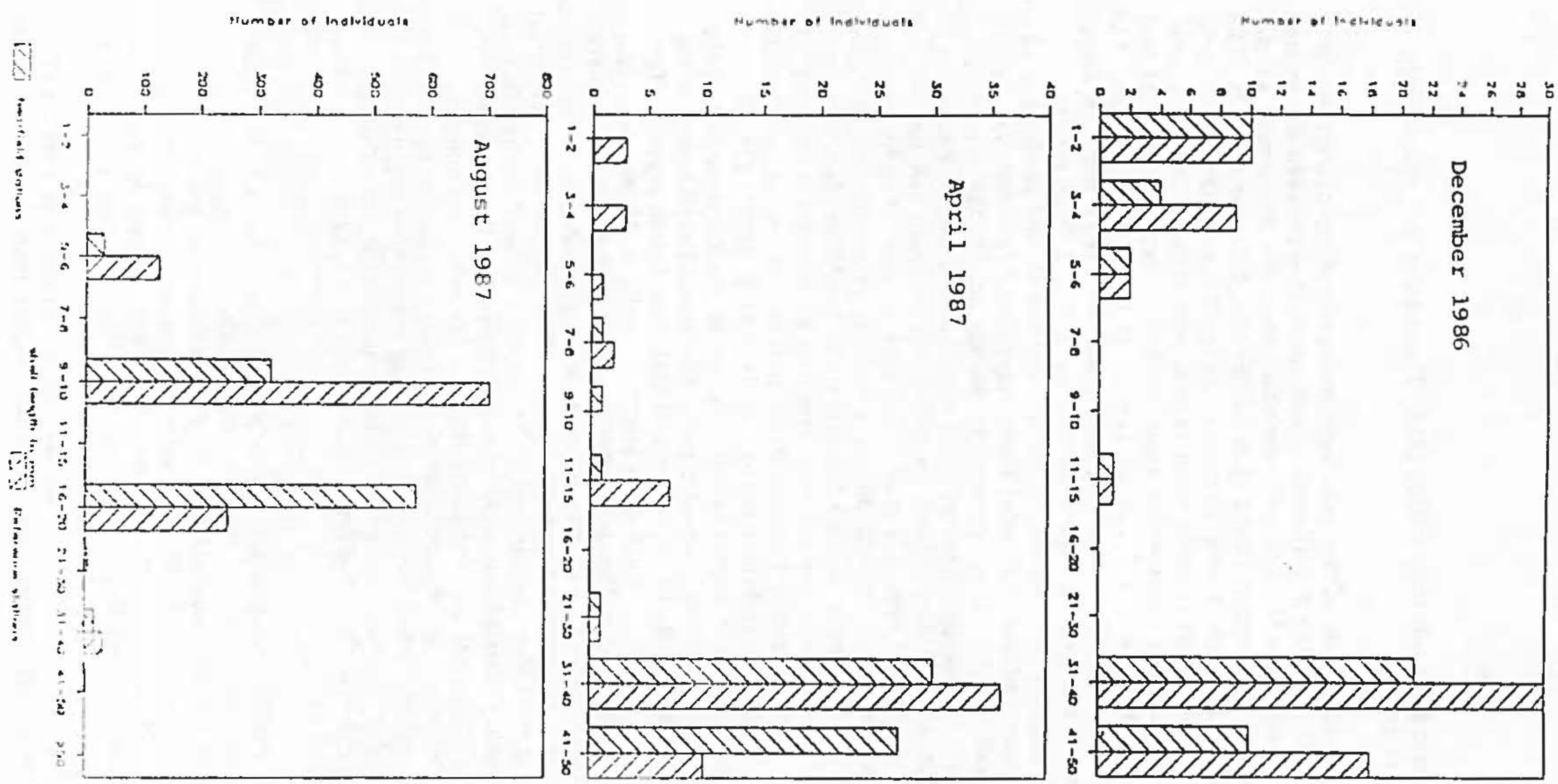
Table 7. Number of species and individuals per three grabs (0.05 m^2 each) found at corresponding stations for August 1987. Also shown are bottom substrate, species diversity (H1), and dominance factor (S.I.).

	SUBSTRATE	NO. SPECIES	NO. INDIVIDUALS	SPECIES DIVERSITY (H1)	DOMINANCE S.I.
NEARFIELD					
S1	Sand	9	253	2.6362	0.1848
S2	Shell	10	456	1.5300	0.5135
S3	Silt/Clay	15	589	3.0084	0.1585
S4	Silt/Clay	12	838	1.0918	0.6933
S5	Silt/Clay	14	701	3.0853	0.1380
S6	Silt/Clay	14	411	3.0116	0.1473
S7	Shell	16	389	2.9714	0.1659
S8	Silt/Clay	11	349	2.3696	0.2530
REFERENCE					
HM16	Silt/Clay	16	649	2.7710	0.1763
HM 7	Silt/Clay	12	379	1.8002	0.4466
HM22	Silt/Clay	15	601	1.4945	0.5766
HM 9	Shell	12	509	1.7070	0.4974
BACK RIVER REFERENCE					
HM26	Silt/Clay	18	1190	2.1101	0.3293
AVERAGE		13	563	2.2759	0.3293

recorded for the nearfield sand substrate station (S1). This station (S1) consistently had the lowest number of species.

The shell lengths of 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 (Figs. 3, 4, 5). The most abundant clam was *R. cuneata* which essentially is represented by two cohorts in the Hart-Miller Island Region (Fig. 3). The largest and most numerous clams had a length range of 31 to 40 mm in December and April. It is believed that this cohort is made up of several year classes. The next most abundant group was the 41-50 mm clams which again most likely represent several year classes and are the maximum size which *R. cuneata* reaches in this area of the bay. The smaller size group of *R. cuneata* in December and April, was less than 6 mm. In August, a major population increase was evident (note scale change in Fig. 3 from tens to hundreds of individuals) and the most numerous size groups had shifted to clams 9-10 and 16-20 mm in size. The observed size shift most likely represented favorable low salinity survival and grow up conditions for clams spawned in the spring. In the case of *M. balthica* (Fig. 4) a progressive increase in average size was observed over the sampling period with most abundant average size 1-2 mm in December, rising to 3-4 and 5-7 mm in April and finally reaching 11-15 mm in August. The high number of individuals maintained over this period indicated that conditions were very favorable for *M. balthica* growth and survival. The growth rates observed in this study for *M. balthica* of about 2.0 mm per month are cmpararable to growth rates reported by Holland et. al. (1987) of 1.9 to 2.3 mm per month at their middle Potomac River stations, where salinities would be closet to those encountered at Hart-Miller Island. Holland et al. (1987) did report higher growth rates for *M. balthica* in higher salinity regions of the Potomac and in the mainstem of Chesapeake Bay. However, they also noted that overall shell length at the end of the growing season was similar for both low and high mesohaline regions. The third most abundant mollusk, *M. mitchelli*, had a much lower either *R. cuneata* or *M. balthica* and in December and April the size classes were fairly evenly distributed over size ranges of 1-15 mm, however in August only the 8-10 mm size range of clams remained at both nearfield and references stations with a small number of 16-20 mm clams located at the reference sites only. There was a general decline in both numbers and overall frequency distribution of *M. mitchelli* indicating less favorable conditions for this species in this region of the Bay than for the other two species. With the previous exception noted, no major differences between reference and nearfield areas could be observed from the frequency distributions for these three species of bivalve mollusks. The smaller total number of individuals collected at the reference stations was most likely due to the fact that fewer reference stations were sampled, four versus eight nearfield stations.

The 1986-1987 results with *M. balthica* and *M. mitchelli* are in contrast to last years report wherein several consecutive years of above normal salinities during the summer spawning season resulted in a larger population of *M. mitchelli* than *M. balthica*. The observed size range of *M. mitchelli* in 85-86 was similar to that we observed this year ranging from 1 to 15 mm. Pfitzenmeyer and Tenore (1987) reported that *M. balthica* was less numerous than *M. mitchelli* at all areas during the 1985-1986 sampling period except for the nearfield stations in August 86, when a cohort of 4-10 mm sized individuals represented the summer 1986 recruitment. During the current sampling in 1986-1987, the *M. balthica* population density was usually some 2-3 times higher than the *M. mitchelli* population.



Length frequencies for Rangia cuneata

Figure 3: Length frequency distribution for the clam, Rangia cuneata, for December 1986 and April and August 1987. Total number of individuals for all nearfield and reference stations.

Length frequency of M. balthica

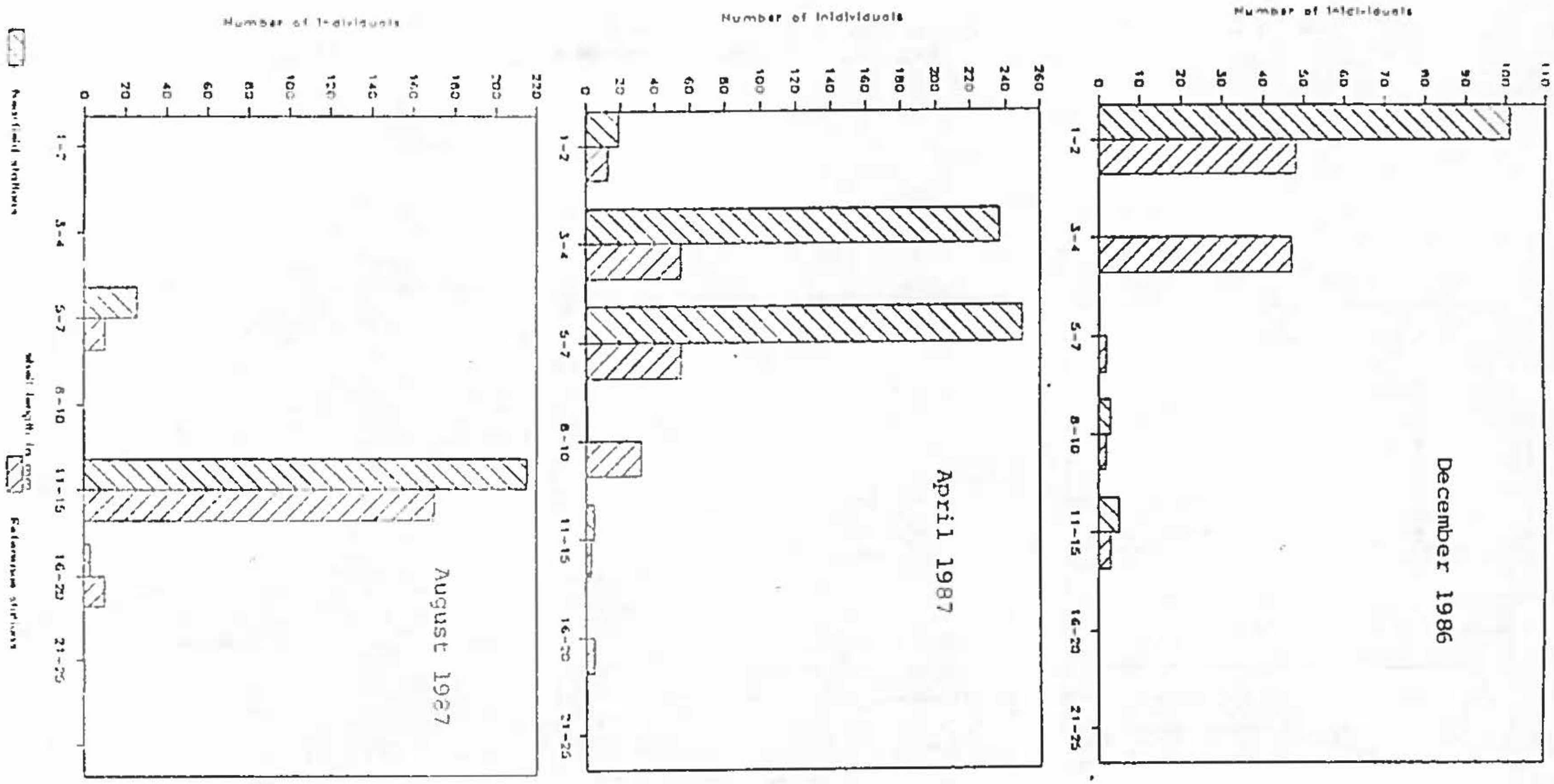
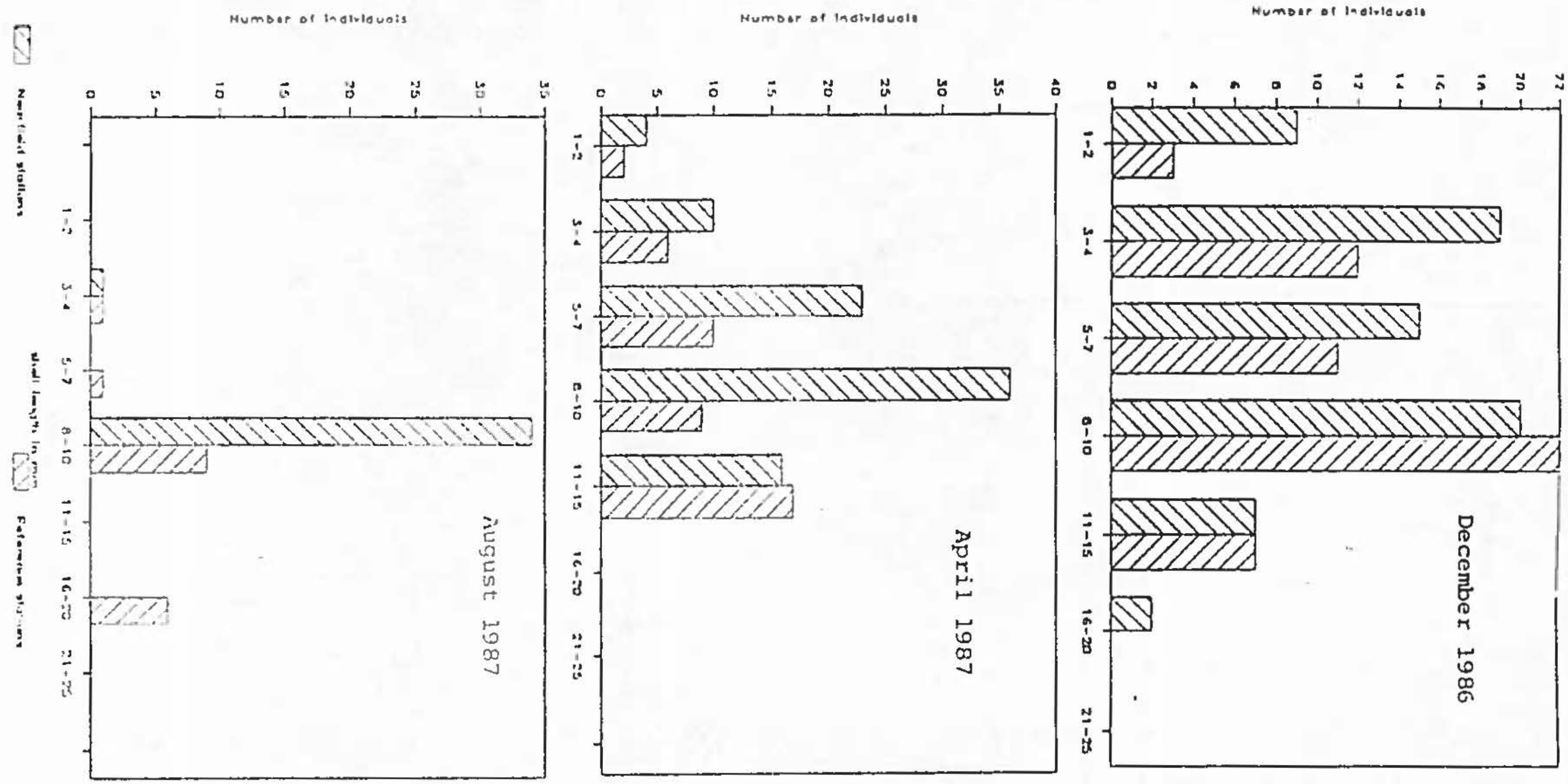


Figure 4: Length frequency distribution of the clam, Macoma balthica, for December 1986, April 1987 and August 1987. Total number of individuals for all nearfield and reference stations.



Length frequency for M. mitchelli

Figure 5: Length frequency distribution of the clam, Macoma mitchelli, for December 1986, April 1987 and August 1987. Total number of individuals for all nearfield and reference stations.

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. 6-8). Initially each station was considered to be a cluster of its own at each step (amalgamated distance) the clusters with the shortest distance between them were combined (amalgamated) and treated as one cluster. This progression of combining clusters continued until all the stations were combined into one cluster. Cluster analysis in past studies at Hart-Miller Island clearly indicated a faunal response to bottom type (Pfitzenmeyer, 1985). Thus any unusual groupings of stations tend to suggest changes are occurring due to factors other than bottom type and further examinations of these stations is required. Most of the time, experience and familarity with the area under study can help to explain away the differences. However, when they cannot be explained, extraneous factors must be investigated further.

In December, the basic grouping of the stations consisted of an initial joining of silt/clay reference (HM7 and HM22) and nearfield (S3 and S4) stations (Fig. 6) which were closely joined together along with other reference and nearfield stations of both silt/clay and shell/sand bottom types. This similarity is highly desirable and is an indication of no obvious anomalous activity. It also indicates an appropriate selection of reference stations. Station S2, a shell station, was the last to join the dendrogram and had the overall lowest diversity index and the highest dominance level with greater than 70% of the population consisting of the barnacle, *B. improvisus*.

Based on the 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 with respect to the reference stations.

In April, the basic grouping was again formed by a joining of silt/clay nearfield (S5, S6, S8) and reference (HM16) stations (Fig. 7), although the exact stations making up the innermost grouping were different from the inner group in December. The remaining silt/clay nearfield (S8, S3, S4) and reference (HM16, HM22) stations were the next to join, followed by the Back River silt/clay station (HM26) which was selected, not as a reference station, but for its occasionally unusual faunal distribution. The shell and sand bottom stations (S2-HM9, S1-S7) formed the two outer connecting arms of the dendrogram. August represented the season of greatest recruitment for most of the benthic species, but it 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 reference, soft brown, silt/clay, stations formed the shortest amalgamated distances in the dendrogram (Fig. 8). In this case they formed two inner groupings of stations, and the reference shell station HM9 occurred in this inner cluster in close association with HM7, HM22, and S4. Nearfield sand station S1 formed the outer edge of the second cluster, comprised of S3, S8, S6, HM16 and S5. Another nearfield shell station S7 comprised the connecting arm between the two inner clusters. The final nearfield shell station to join this cluster was S2. Last to join the dendrogram was the Back River station (HM26), known for its unusual fauna, even though the station has soft silt/clay sediments more like the

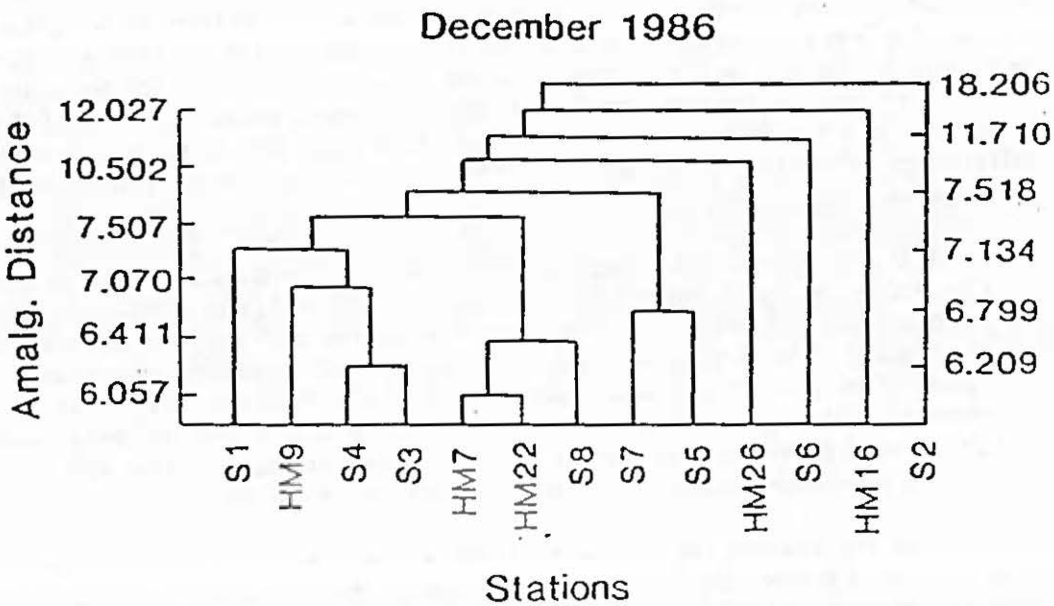


Figure 6: Cluster analysis of all Hart-Miller Island sampling stations in December 1986.

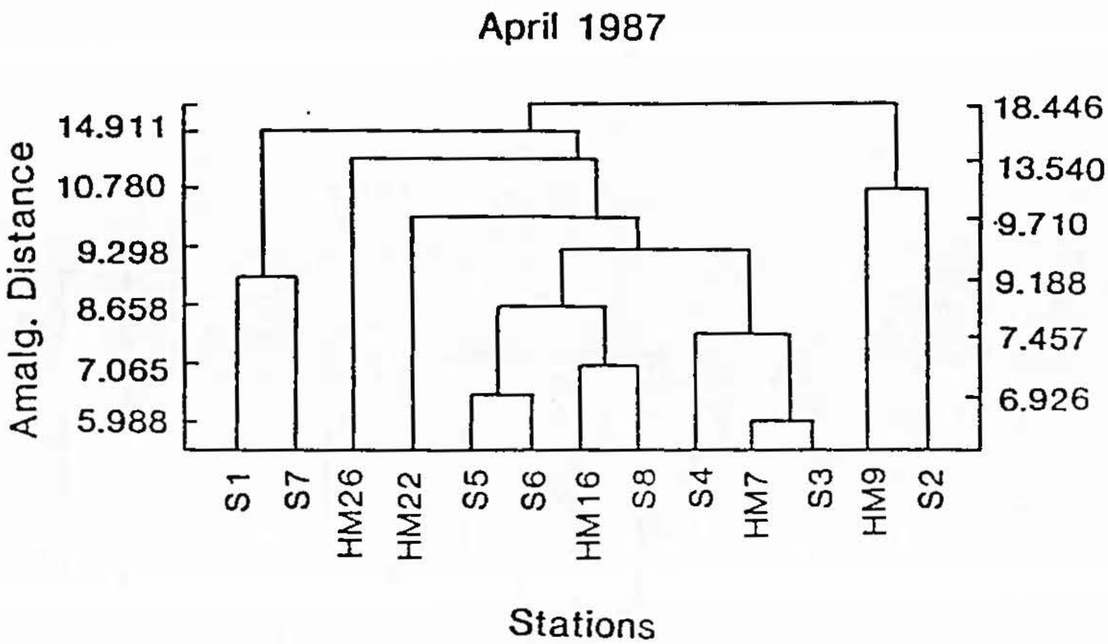


Figure 7: Cluster analysis of all Hart-Miller Island sampling stations in April 1987.

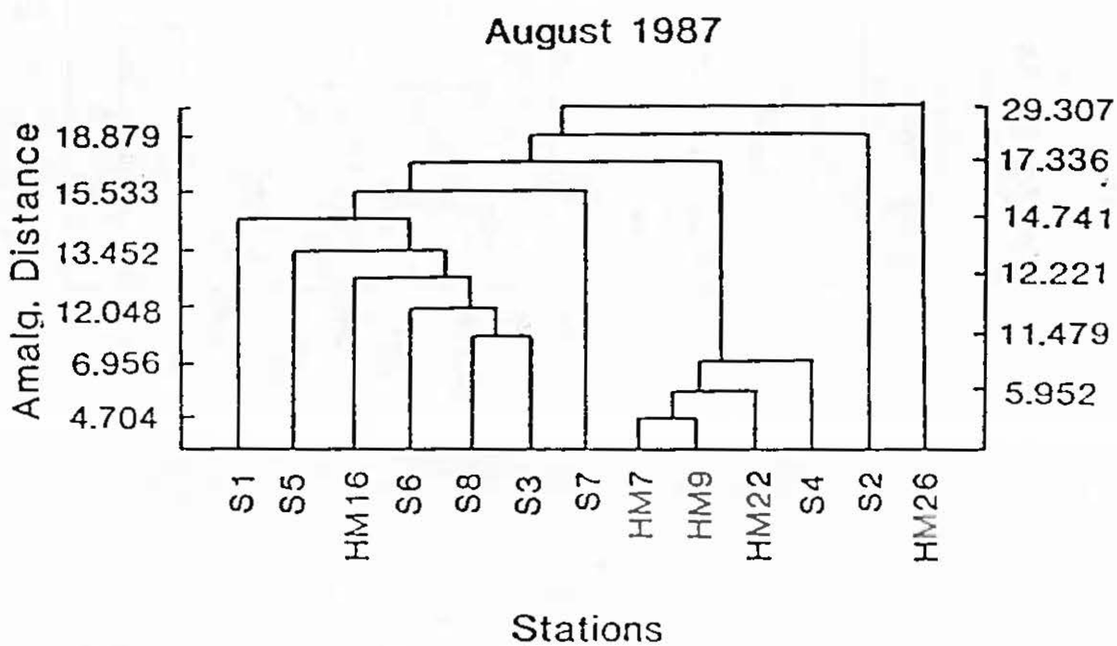


Figure 8: Cluster analysis of all Hart-Miller Island sampling stations in August 1987.

inner clusters. The inherent characteristics of this station were probably the result of Back River water quality, which most likely reaches its heaviest loading in the warm summer months and would influence the faunal composition and keep it separate from the other stations. The clusters formed during this sampling period represented a normal grouping with no unusually isolated stations. These clusters were consistent with earlier studies and 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 were transformed (log) 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. The results of these tests are presented in Tables 8, 9, 10.

In December 1986, the stations were sorted into eight subsets (Table 8). Stations S1, S6, and HM22 fell into significantly different subsets from all the others. Nearfield station S1 had both the lowest number of species and individuals whereas, S6 had both the highest number of species and individuals of all the nearfield stations for this sampling period. The probable cause for the separation of HM22 into its own subset from the other three silt/clay reference stations (HM12, HM7, HM26) which formed a single subset is not readily apparent. However, it was more closely grouped to these other reference stations than it was to the nearfield stations. Station HM9, the shell substrate reference station, was outside of the main reference group and more similar to two nearfield stations S8, a silt/clay station, and S7, a shell bottom. Based on this December analysis and last year's report (Pfitzenmeyer and Tenore, 1987), it appears that there are two groups of stations, the nearfield and the reference stations. Within the two groupings the stations are interrelated. The one-way analysis of variance, F-test, did not indicate significant differences between or within groups of stations.

Six subsets were evident in April (Table 9). The first subset was comprised of five of the eight nearfield stations (S1-S5) and the second subset brought in S6, which was similar to S5. Again HM9, the shell substrate reference station, was similar to the nearfield stations and outside the main group of reference stations. However, it was similar to reference stations HM7 and HM16, which, along with S8 and S7, formed a subset. Finally, S8 and HM16 formed the others during this sampling period. As in December, reference stations and nearfield stations formed discernible groups with only nearfield stations S7 and S8 not significantly different from HM9. In the analysis of variance for this sampling period, there were no significant differences between or within groups of stations.

Analysis of the August 1987 data by this method indicated nothing unusual (Table 10). The Back River station (HM26) was the station most different from the greatest number of stations, due to very large quantities of two species of worms, *Streblospio benedicti* and *Tubificoides* sp. Station HM26 was most similar to HM22, a silt/clay reference station, and HM9, the shell reference station, which together formed the next subset. As in December, reference stations and nearfield stations formed discernible groups with only nearfield stations S7 and S8 not significantly different from HM9. In the analysis of variance for this sampling period, there was no

Table 8. The Student-Neuman-Keuls test of significance among mean number of individuals per station for December 1986. Subsets show grouping of different stations ($P<0.05$). Stations in a separate vertical column and row are significantly different from others.

DECEMBER 1986

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

ANALYSIS OF VARIANCE

SOURCE	D.F.	SUM OF SQ.	MEAN SQ.	F. RATIO	F. PROB.
Between gps.	12	57529.8	4794.2	173.0	0.00
Within gps.	26	720.3	27.7		
TOTAL	38	58250.2			

Table 9. The Student-Neuman-Keuls test of significance among mean number of individuals per station for April 1987. Subsets show grouping of different stations ($P<0.05$). Stations in a separate vertical column and row are significantly different from others.

APRIL 1987

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

ANALYSIS OF VARIANCE

SOURCE	D.F.	SUM OF SQ.	MEAN SQ.	F. RATIO	F. PROB.
Between gps.	12	75935.8	6328.0	30.7	0.00
Within gps.	26	5352.7	205.9		
TOTAL	38	81288.5			

Table 10. The Student-Neuman-Keuls test of significance among mean number of individuals per station for August 1987. Subsets show grouping of different stations (P<0.05). Stations in a separate vertical column and row are significantly different from others.

AUGUST 1987

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

ANALYSIS OF VARIANCE

SOURCE	D.F.	SUM OF SQ.	MEAN SQ.	F. RATIO	F. PROB.
Between gps.	12	79902.2	6658.5	175.9	0.00
Within gps.	26	984.2	37.9		
TOTAL	38	80886.4			

significant difference between or within groups of stations. The remaining subsets, four in all, consisted of the various nearfield stations. The shell stations S2 and S7 were intermixed in groups with silt/clay bottoms. Station S1, the sand substrate station located at the shallowest location (1.5 m), was again isolated from the other nearfield stations, as it had been in December. The isolation of S1 most likely results from its difference in depth and substrate rather than any unusual conditions arising from the containment facility. The analysis of variance for this period again did not indicate any significant difference between or within groups.

Friedman's test for differences in the means of samples taken in similar bottom types (silt/clay only) for nearfield and reference areas was calculated. The results of this non-parametric test are presented in Table 11. Significant differences ($p<0.05$) were found at the nearfield stations surrounding the island during the August sampling period. During this period, station S5 had a high number of individuals, particularly of the clam, *R. cuneata*, which reached densities at this station of over 4000 m^2 compared with less than 1000 m^2 at all the remaining nearfield silt/clay stations. This station is located near the rehandling pier where there is substantial barge and tug activity. Faunal disruption in this area has frequently been observed (Pfitzenmeyer, 1985). Pfitzenmeyer and Tenore (1987) reported an overall lower number of individuals at this station in both December 85 and August 86. Examination of Table 3 again reveals low numbers of individuals at S5 in December 86 and April 87. The high number of *R. cuneata* encountered at this station at this time may possibly signal favorable conditions for settlement and growth of this opportunist species in this normally highly disturbed, low faunal density area. Data from subsequent sampling in December 1987 will reveal if this newly settled population of *Rangia* can persist in this region.

No significant differences were observed between the three reference stations with silt/clay 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, as was observed in the Fifth Year Interpretive report (Pfitzenmeyer and Tenore, 1987). This is probably a result of the two stations, S1 and S5, which show major differences in faunal abundance. No significant difference was indicated in April. At that time, all nearfield and reference stations were statistically equivalent.

As reported, last year the overall affected area of fauna at these two stations was relatively small, since neighboring stations did not indicate similar trends. As previously reported, the difference at station S1, essentially low numbers of species and individuals, is not the result of the containment facility, but the result of an environmentally different area, in terms of depth and substrate. In the case of station S5, the area becomes disturbed through barge activity which washes and scours the bottom and redistributes the fauna. The area can become recolonized with animals when either barge activity lessens and/or conditions are favorable for various opportunistic species.

The results for the epifaunal samples from the pilings surrounding the facility are presented in Table 12. Samples this year were limited to depths of 1.0 to 1.3 m below the surface and at 2-3 m to avoid the region of ice scour, where the fauna becomes depauperate in winter. Thus, a reasonably well-developed fauna occurred on all three sampling dates, and there were no major differences between the upper and lower samples. The densities and distribution of the various epifaunal species on both the

Table 11. Reults of Friedman's non-parametric test for differences in abundances of selected species between stations with silt/clay substrate.

	SOURCE	D.F.	X^2	$X^2(.05)$
DECEMBER				
	Nearfield	4	5.92	9.48
	Reference	2	5.00	5.99
	Nearfield & Reference	7	14.50*	14.06
APRIL				
	Nearfield	4	8.24	9.48
	Reference	2	1.40	5.99
	Nearfield & Reference	7	8.91	14.06
AUGUST				
	Nearfield	4	10.88*	9.48
	Reference	2	1.8	5.99
	Nearfield & Reference	7	21.87*	14.06

*Significant difference at 5% level.

Table 12. Species in descending order of density at the two different depths sampled on the pilings surrounding the containment facility and the reference piling for the three sampling periods.

	Stations R1-R4		Reference R5	
DECEMBER 1986	1-1.3 m	2-3 m	1-1.3 m	2-3 m
	B. improvisus	Corophium	Corophium	Corophium
	B. subalbidus	B. improvisus	Cordylophora	Cordylophora
	Chironomid sp.	Nereis	Nereis	Polydora
	Corophium	Polydora	Polydora	B. improvisus
	Nereis	B. subalbidus	B. subalbidus	B. subalbidus
	Polydora			Victorella
				Nereis
APRIL 1987	1-1.3 m	2-3 m	1-1.3 m	2-3 m
	Corophium	Corophium	Corophium	Corophium
	B. subalbidus	B. subalbidus	Tubificoides	Tubificoides
	Tubificoides	Nereis	B. subalbidus	B. subalbidus
	Chironomid	Scolecolepides		Nereis
	Nereis	Chironomid		
		Cordyolphora		
AUGUST 1987	1-1.3 m	2-3 m	1-1.3 m	2-3 m
	Corophium	Corophium	Corophium	Corophium
	Victorella	Victorella	Victorella	Victorella
	Cordylophora	Cordylophora	Cordylophora	Cordylophora
	B. subalbidus	B. subalbidus	Polydora	Polydora
	B. improvisus	B. improvisus	Nereis	Nereis
	Nereis	Nereis	B. subalbidus	B. subalbidus

nearfield pilings (R1-R4) and the reference piling (R5) are quite similar. Essentially, the same 10 species observed this year were the predominant species last year. As previously reported (Pfitzenmeyer and Tenore, 1987), the most abundant and most widespread species was the amphipod, *Corophium lacustre*. It was the most numerous organism in all but the December shallow nearfield stations, when it was outnumbered by the barnacles, *B. improvisus* and *B. subalbidus*. For all other samples and dates covered in this report, *Corophium* was the most abundant organism. This small crustacean is extremely opportunistic and constructs tubules out of detritus in which it lives a protected existence on the piling. The tubules are quite tough and other colonial forms attach themselves to the tubule network. *Corophium* is not limited to the pilings, but also occurs on shell and/or other hard surfaces on the bottom. No specific zonation of species was observed on the pilings. The same species found at the first meter were also collected at 2-3 m. The area is relatively shallow and no specific depth restrictions would be expected for the common species. Two colonial forms, the bryozoan, *Victorella* and the hydroid, *Cordylophora*, reached their greatest abundance and distribution in August, which reflects their maximal summer reproductive and growth season.

CONCLUSIONS

During the sixth year of sampling and monitoring the benthos at Hart-Miller Island, the sampling locations, sampling techniques and analysis of the data were maintained as close as possible to that for the previous year, in order to eliminate as much variation as possible. Maintenance of sampling locations, techniques and analysis should render differences due to effects of the containment facility more readily apparent.

Indeed results presented in this report are quite similar to those presented in the Fifth Year Interpretive Report. A total of 30 species (compared with 26 last report) were collected in the quantitative grab samples. Five species remain numerically dominant on soft bottoms. These five dominants are the annelids, *S. viridis* and *H. filiformis*, the crustaceans, *L. plumulosus* and *C. polita*, and the clam, *R. cuneata*. On the oyster shell substrates, the barnacle, *Balanus improvisus*, the worm, *N. succinea*, and the crab, *R. harrisi* were the most common inhabitants, with some overlap of the five most abundant soft bottom species occasionally becoming dominant on this substrate as well. Salinity variations on yearly and seasonal time scales appear to determine the position of dominance of the major species.

The average number of individuals per square meter was comparable for the nearfield and the reference stations over the three sampling periods. Pfitzenmeyer and Tenore (1987) reported a greater number of individuals at the nearfield then at the reference stations for the fifth monitoring year, which they attributed to an abundance of finer sediments close to the containment facility. Perhaps the increased barge traffic throughout the region has increased the distribution of fine sediments into the reference areas as well.

The highest average species diversity values were again found during the August sampling period. Predation is generally greatest at this summer period, and Pfitzenmeyer and Tenore (1987) suggested that the most abundant benthos, which are important food organisms for bottom feeding fishes and crabs, are consumed at this time, resulting in more even populations among the different benthic species.

Length frequencies and cohort sizes among the three dominant bivalve species living close to the containment facility were comparable to populations at the reference stations. A major set and grow up of the clam *R. cuneata* occurred in August at nearfield station S5.

Cluster analysis grouped stations of similar faunal composition in response to sediment type. Stations which were isolated from their common grouping during the three sampling periods were not due to facility-related causes. The Back River station and the nearfield sand/oyster substrates (S1 and S2) were 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 nearfield stations with unusual bottom types as well as at one station at the rehandling pier. This station (S5) was located in the area of heavy barge and tug activity and in contrast to the previous year had a much higher number of individual organisms, primarily due to the set and growth of a population of the clam, *R. cuneata*.

Epifaunal species were likewise quite similar in terms of distribution at the nearfield and reference stations for all three sampling periods. Since sampling this year was confined to the region below winter ice scour and low tide dehydration no absence or sparseness of species from the pilings was recorded in April. The richest and most luxuriant populations occurred in August when colonial hydroids and bryozoans reached their peak abundances.

There do not appear to be any discernible differences in the nearfield and reference populations resulting directly from the containment facility itself. The barge activity does appear to churn up and scour the area, but the opportunistic species inhabiting this oligohaline region of the Bay appear to be readily capable of repopulating disturbed areas.

RECOMMENDATIONS

The Hart-Miller Island Containment Facility is now fully operational. It is strongly recommended that the infaunal and epifaunal populations continue to be sampled at the established locations during this continued critical period of maximal operation to ascertain any possible effects. Station locations and sampling techniques should be maintained as close as possible to the two previous years to eliminate sampling variation and permit rapid recognition of effects resulting from the operation of the containment facility.

Project IV
Analytic Services
by
Department of Natural Resources
Tidewater Administration
and
Water Resources Administration

ABSTRACT

Concentrations of six different metals were tested in fish and clam tissue at the Maryland Department of Health and Mental Hygiene Laboratories. Metal concentrations were higher in the clam tissue than the fish tissue. These results were similar those from fifth year monitoring results.

INTRODUCTION

Selected metals and organic contaminants are analyzed in sediments and biota on a continuing basis as a part of the Hart-Miller Island 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 data (Chesapeake Research Consortium 1984) 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 sixth 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 very high concentrations, and 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.

METHODS OF ANALYSIS

Sampling of sediment and biota in the Hart-Miller Island area was performed on five different dates. The sampling was done mainly in the fall and spring to determine seasonal variability. The monitoring programs collected six sets of samples: two of sediment, three of benthic organisms, and three of fish. Each set was subsampled by station and biota types. Metals and organic analyses were to have been conducted on each sample set. The only data received in time for this report were the metals analyses on fish and clam tissue (December 1986, April 1987). The metals analyses on sediment are conducted at the MGS laboratories and the results are contained in the Project II report.

Analyses of organic compounds (pesticides, herbicides, PCB's, and phthalates) will be performed by gas and liquid chromatography, with confirmation of the compounds in a certain percentage of the samples by gas chromatography/mass spectrometry. The samples will be extracted according to recommended EPA methods. The detection limits for the analyses will be consistent with prior data generated by the monitoring program.

Sample Frequency

(6) sediment samples	twice per year =	12
(18) benthic samples	three per year =	54
(24) fish samples	three per year =	72
	Sample Total	138

Fish and clam samples were submitted to the Department of Health and Mental Hygiene, Food Chemistry Laboratory on September 8, 1987 for the determination of six metals (copper, chromium, zinc, nickel, manganese and iron). There were a total. of 13 sixth year samples: 7 fish, and 6 clams. Three samples, numbers 870601-15, 28, and 30 were not found.

Each sample was filleted (fish) or shucked (clams) and then homogenized using a Waring blender. A sample was then weighed, dried, and moisture content determined by weight loss on drying. Another portion of the same sample was weighed and digested for the six metals specified in the request for 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).

RESULTS

The data for the samples that were received tend to indicate that benthic organisms had higher tissue concentrations of metals than fish. Graphical analyses of each of the metals are included. (Figs. 1-6) The station identifications can be compared with the list in Table 1 for coordinates, Resource Monitoring Data Storage System number (RMDSS #), and sample type.

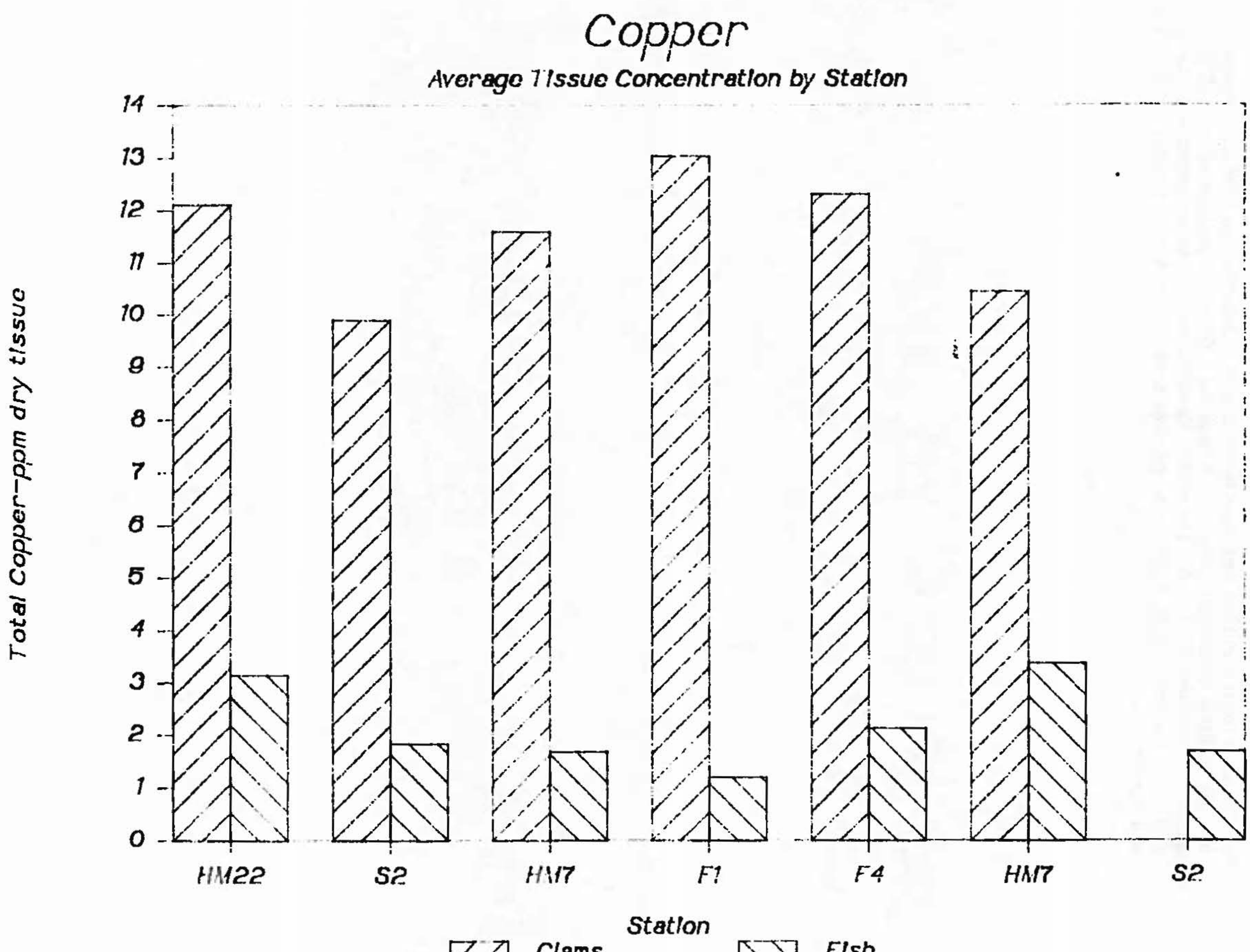

Copper
Average Tissue Concentration by Station
Total Copper–ppm dry tissue
14
13
12
11
10
9
8
7
6
5
4
3
2
1
0
HM22
S2
HM7
F1
F4
HM7
S2
Station
Clams
Fish

Figure 1

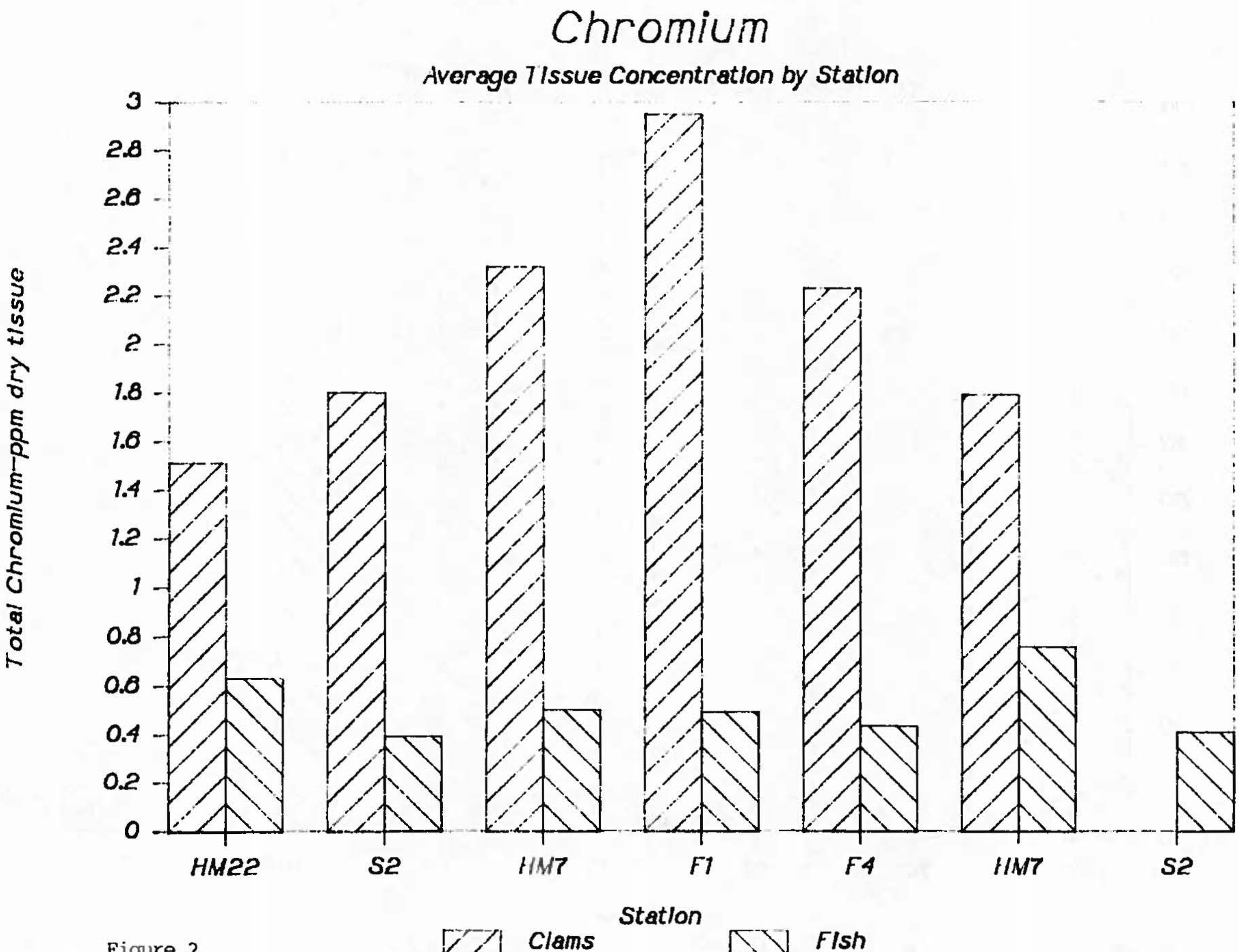
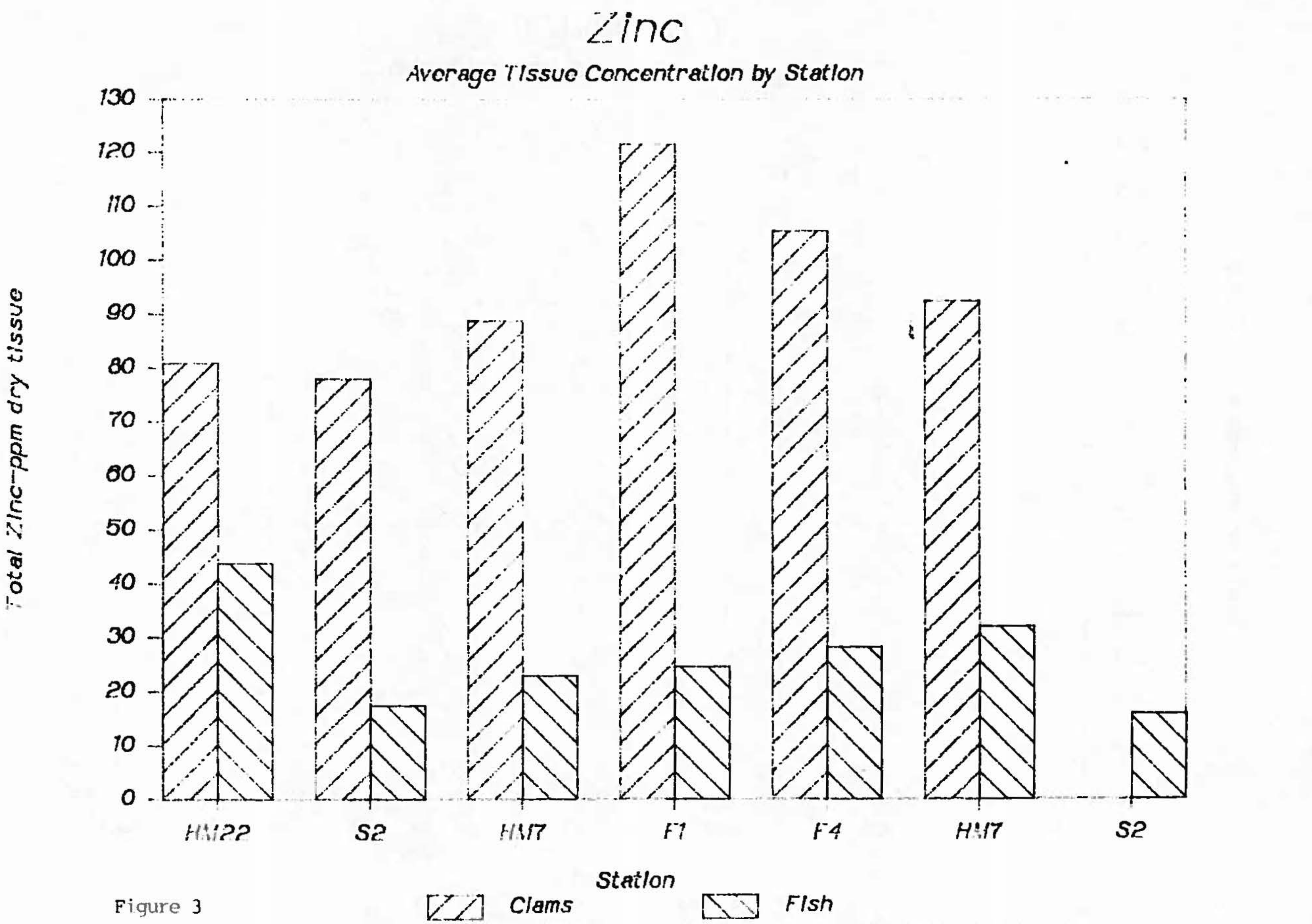

Chromium
Average Tissue Concentration by Station
3
2.8
2.6
2.4
2.2
2
1.8
1.6
1.4
1.2
1
0.8
0.6
0.4
0.2
0
Total Chromium-ppm dry tissue
HM22
S2
HM7
F1
F4
HM7
S2
Station
Clams
Fish

Figure 2



Zinc
Average Tissue Concentration by Station
Total Zinc-ppm dry tissue
130
120
110
100
90
80
70
60
50
40
30
20
10
0
HM22
S2
HM7
F1
F4
HM7
S2
Station
Clams
Fish

Figure 3

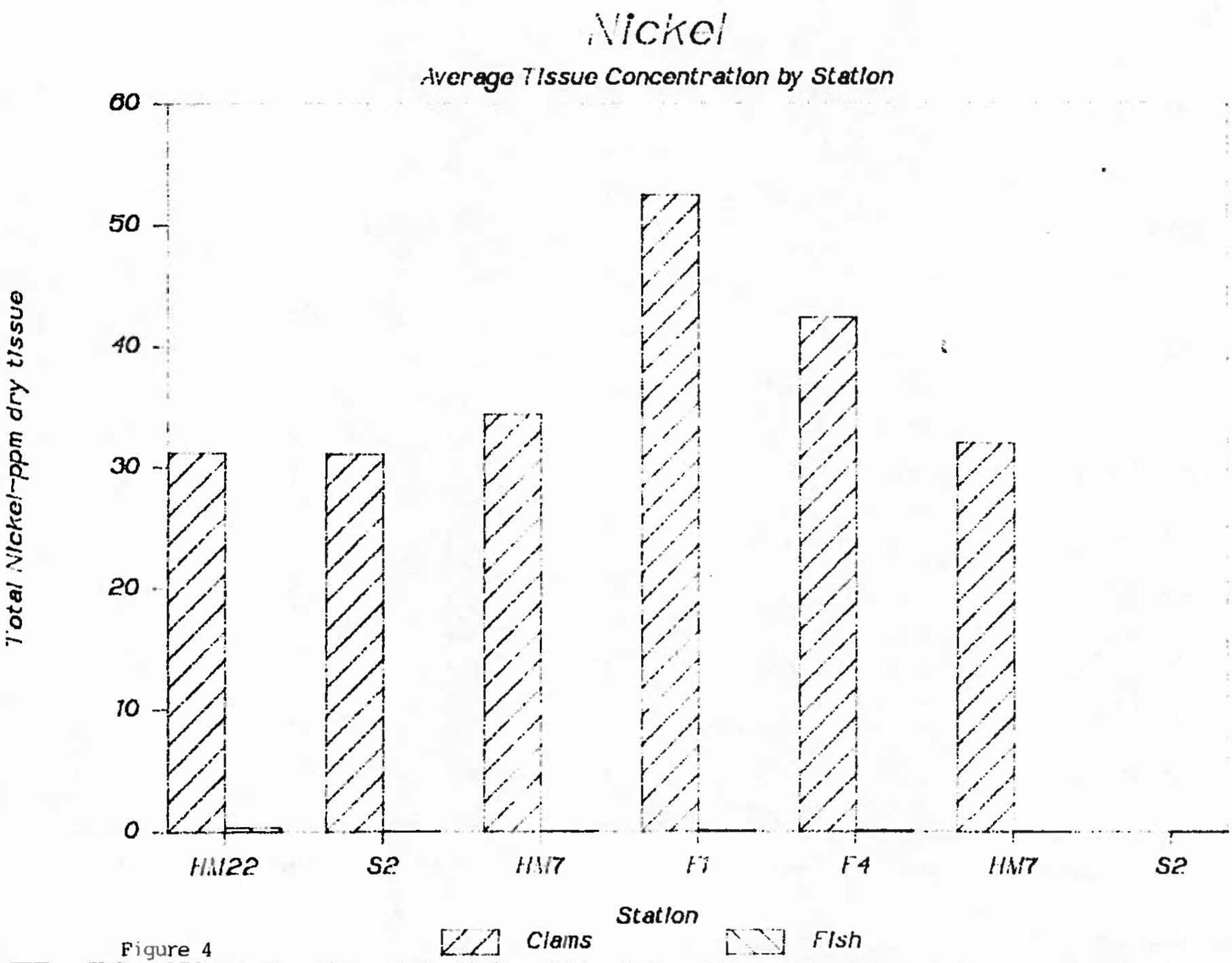

Nickel
Average Tissue Concentration by Station
Total Nickel-ppm dry tissue
0
10
20
30
40
50
60
HM22
S2
HM7
F1
F4
HM7
S2
Station
Clams
Fish

Figure 4

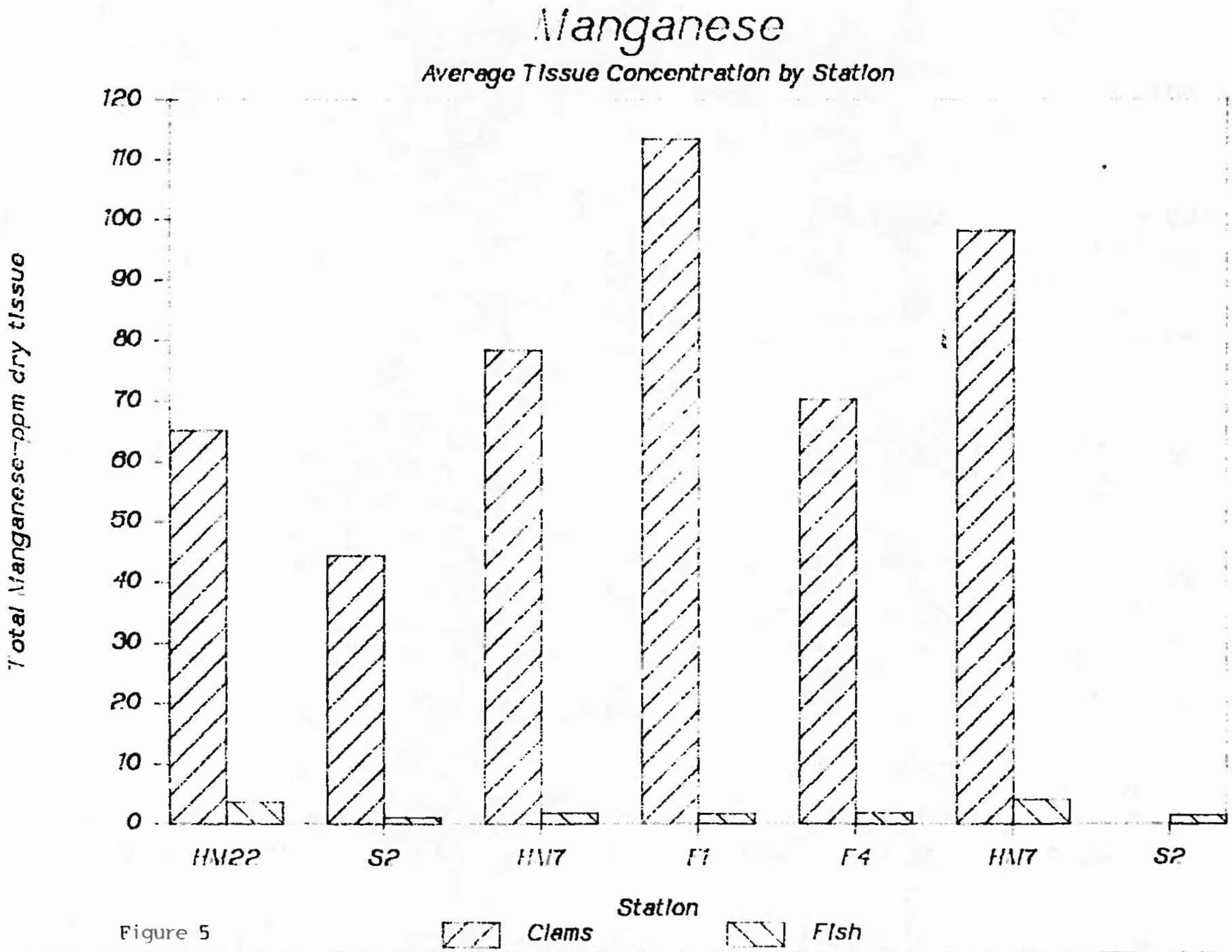

Manganese
Average Tissue Concentration by Station
Total Manganese-ppm dry tissue
120
110
100
90
80
70
60
50
40
30
20
10
0
HM22
S2
HM7
F1
F4
HM7
S2
Station
Clams
Fish

Figure 5

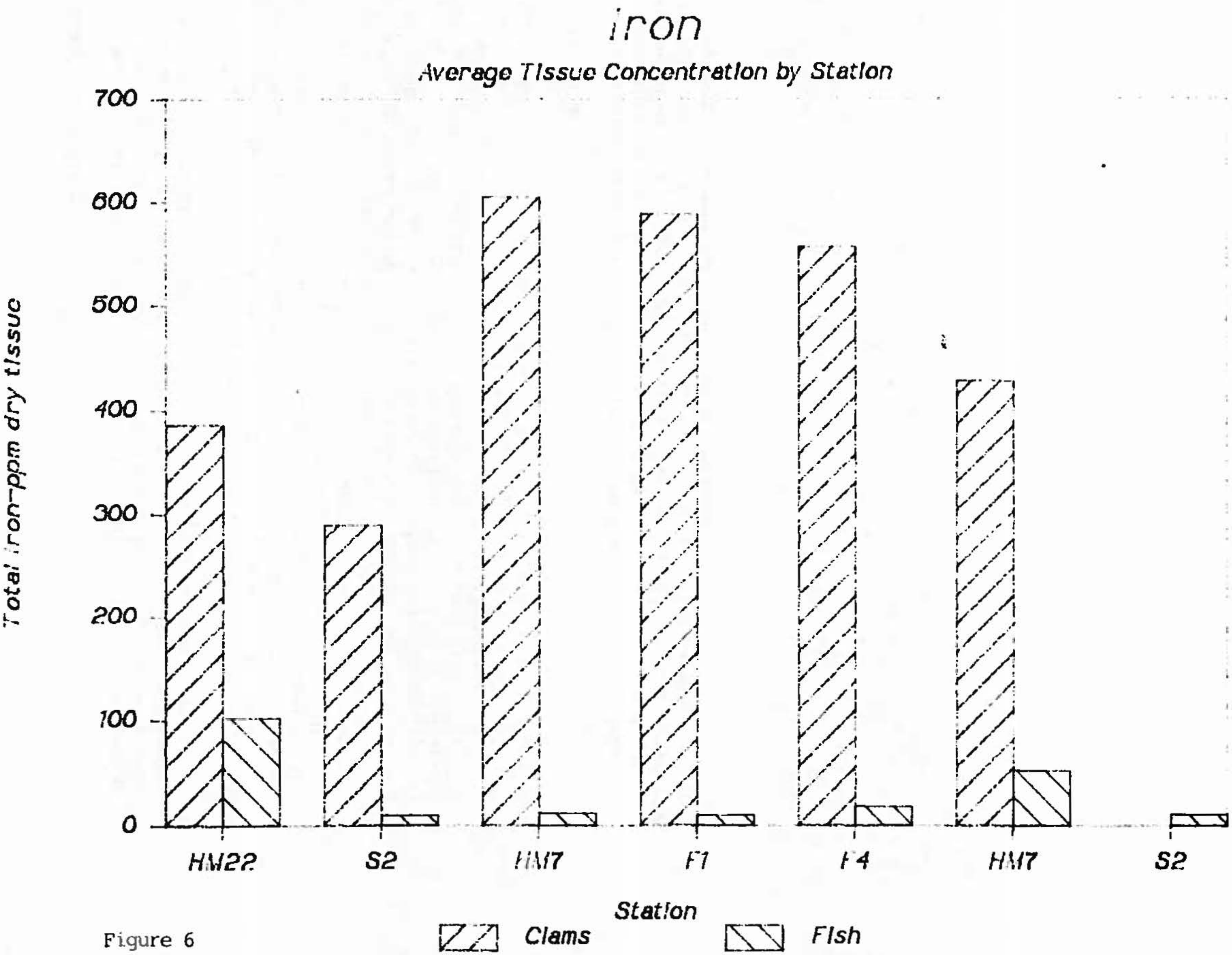

Iron
Average Tissue Concentration by Station
700
600
500
400
300
200
100
0
Total Iron-ppm dry tissue
HM22
S2
HM7
F1
F4
HM7
S2
Station
Clams
Fish

Figure 6

Metals in Clam Tissue

Clams had higher tissue concentrations than fish for all metals (Figs. 1-6). Iron and nickel were particularly high in clam tissue. Differences between stations were negligible compared to differences between taxa. Zinc and iron were both highest in December and April. The average concentrations of all metals were slightly higher in December.

Fish 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.

Metals in Fish Tissue

Overall, tissue concentrations of metals in fish were lower than in clams. Iron concentrations were greater in fish tissue in December than in April. All other metals concentrations were similar for the two sampling periods. Fish tissues had only trace (< 1.0 ppm) amounts of nickel and chromium. Predominant sources of nickel contamination are wastewater treatment and industrial metals processing.

Table 1

STATION ID	LATITUDE	LONGITUDE	RMDSS #*	SAMPLE TYPE
F-1	39 15 42.6	76 22 32.4	XIF5725	FISH
F-2	39 16 15.5	76 20 02.4	XIG6300	FISH
F-3	39 14 24.6	76 21 30.6	XIF4415	FISH
F-4	39 12 41.4	76 24 08.4	XIF2741	FISH
S-2	39 15 25	76 20 35	XIF5406	Rangia
S-4	39 14 40	76 21 28	XIF4715	clams
S-5	39 14 23	76 22 00	XIF4420	Rangia/clams
HM-7	39 16 15	76 20 50	XIF6388	Rangia
HM-9	39 15 33	76 19 53	XIF5297	clams
HM-22	39 16 58	76 18 51	XIG7689	Rangia

* Resource Monitoring Data Storage System number

CONCLUSIONS

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 well be rectified in future monitoring. Seventh year monitoring samples were separated by species.

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 analysis was conducted to test for overall differences in metals concentrations among species and sampling dates. Differences were indicated in all effects, but these results should be viewed with caution. Sampling was very unbalanced in time and space , 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 1986 and 1987 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. Third, the clams live in intimate association with bottom sediments, which have high background levels of metals in the area of the containment facility.

No data were available on organics in biological tissue. These samples are currently being analyzed by the Department of Health. Completion of this analysis is expected to be complete by the end of December 1988. Concentrations of six metals in fish, and clam tissue did not implicate the containment facility as a source of metals contamination to the surrounding Chesapeake Bay environment. 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. 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 will 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.

RECOMMENDATIONS

In future monitoring, each sample of fish for tissue analysis should be confined to one species, clearly and reliably identified. All future organics in biota data will be interpreted by the investigators for Project III- Benthic Studies. Organics in Sediment will continue to be interpreted by Project I- Scientific Coordination and Data Management investigators.

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