Arthur Kill Oil Discharge Study

Volume I
Final Report

Submitted to:
New Jersey Department of Environmental Protection and Energy

Submitted by:
Louis Berger & Associates, Inc.
100 Halsted Street
East Orange, New Jersey

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1.0 INTRODUCTION

On January 1-2, 1990, a 6.7 mile-long under water pipeline, connecting Exxon's Bayway Refinery in Linden, New Jersey to its terminal in Bayonne, New Jersey, ruptured and discharged 567,000 gallons of No. 2 fuel oil into the Arthur Kill, the strait separating Staten Island, New York from New Jersey. The leak occurred at the entrance of Morses Creek, a tributary to the Arthur Kill (Figure 1-1, Spill Number 1). After the Exxon spill, other major spills (>100,000 gallons) and smaller spills (<100,000 gallons) occurred. These spills, shown on Figure 1-1, included: 30,000 gallons of No. 6 industrial oil on February 28 released from the Eklof Barge (Spill 2), 127,764 gallons of No. 2 heating oil on March 6 discharged from the Cibro Savannah (Spill 3), and 260,000 gallons of No. 6 industrial oil on June 7 from the tanker BT Nautilus (Spill 4). During the first half of 1990, over one million gallons of petroleum products had been released into the Arthur Kill and adjacent waters. Subsequently, 40,000 gallons of No. 2 oil were released from the Maritrans Interstate 53 barge on July 18, 1991, as it left its mooring at the Exxon Bayway Refinery.

In response to the January Exxon spill, the States of New York and New Jersey, the City of Elizabeth, the City of New York and the Federal government formed a group of Trustees and other governmental claimants, known as "The Governments." The Governments recognized the need for a comprehensive response to the spill, including immediate cleanup actions and long-term investigations as well as an assessment of the extent and seriousness of the natural resource injury caused by the spill. To address all of these concerns the Governments designed a three-tiered approach, as follows:

> Tier I - Cleanup Action: Cleanup of surface oil slick and, where appropriate, vegetation. Continue monitoring the extent of the spill.
>
> Tier II - Short-term Action: Mapping, sampling and analysis of extent of spill to contribute immediate information for the injury assessment.
>
> Tier III - Long-term Action: Long-term studies designed to determine subtle, long-term chronic effects on the ecosystem. These would also contribute to the injury assessment.

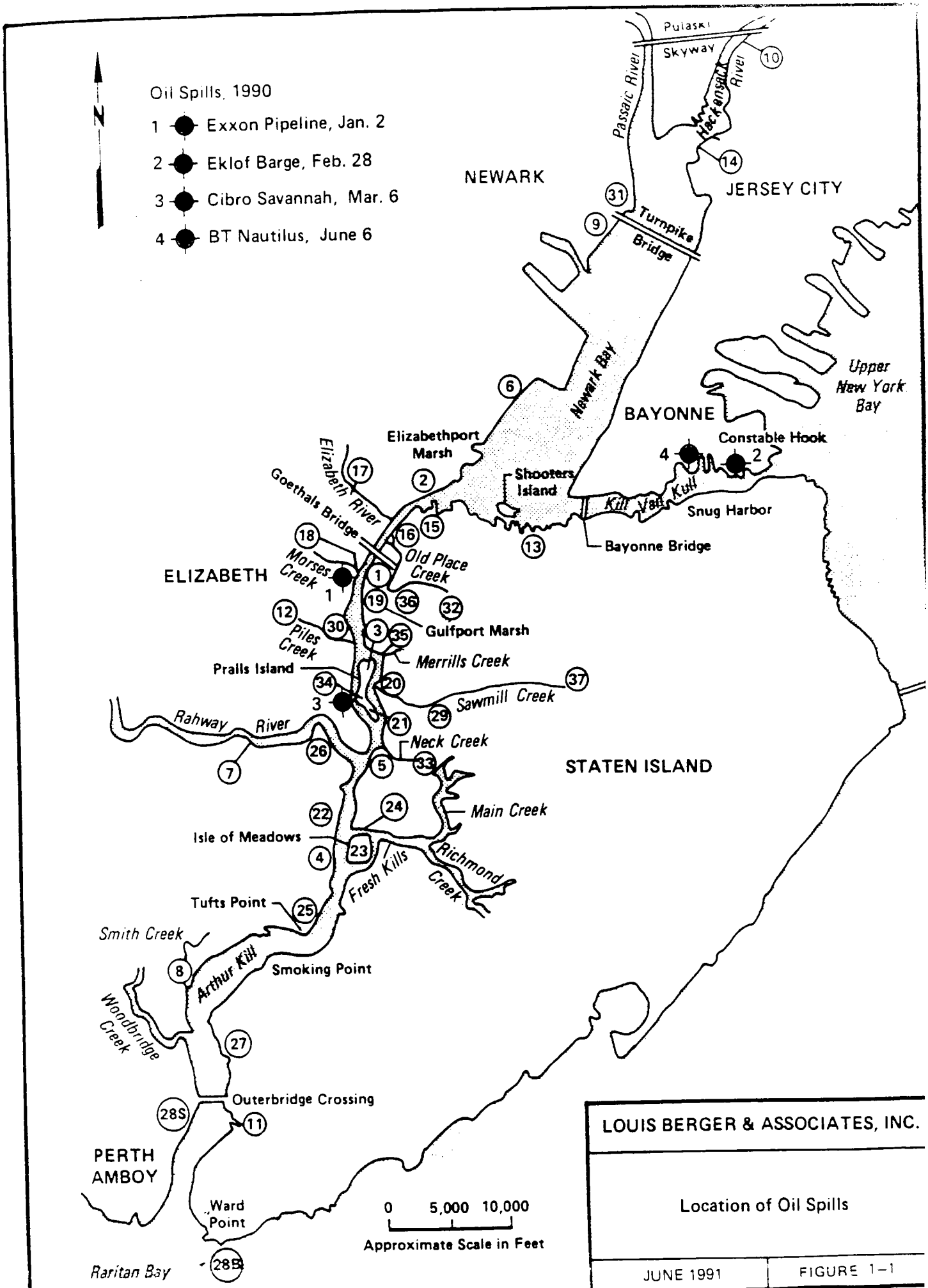
This report covers work accomplished under Tier II, the Short-term impact investigations. Of importance to Tier II are the following objectives:

1. determine the geographic distribution of the spill;
2. determine the occurrence of oil in different habitats in the area;
3. determine the extent and depth of penetration of the oil in sediments;
4. determine the extent of oil contamination in wetlands;
5. characterize the bird population and its habitats;
6. determine the effects of the oil spill on returning migratory bird species, including but not exclusive of, direct effects from oiled habitats, loss of or injury to prey organisms, and loss or modification of habitat;

7. determine exposure of biota to oil through chemical analysis of clams and mussels;
8. determine appropriate analytical approaches to identifying hydrocarbon contamination in the system;
9. develop QA/QC procedures associated with sample collection and analysis; and
10. determine useful background data and analysis of samples collected by agencies and individuals since the spill occurred.

The Governments recognized that these short-term actions are only part of a comprehensive investigation to determine the injury suffered by the Arthur Kill estuary as a result of this incident. Because additional oil spills occurred before and even while various field studies were conducted, not every objective described above could be fulfilled in a spill-specific manner. For example, the results of studies undertaken under Objective 6 may reflect the aggregate impacts of all 1990 spills that occurred in the area before and during the 1990 nesting season.

Louis Berger and Associates, Inc. (LBA) was retained to conduct this study. This final report consists of two volumes. Volume I provides summaries of the following tasks: compilation of existing information; mapping of the spill extent, tidal wetlands and land uses in the area; bottom sediment sampling; biological sampling; and chemical analysis of sediments and benthos. Volume II is an Appendix volume that includes: a description of historical sampling programs, the final reports of subcontractors (Greenhorne and O'Mara, Expert Information Systems, Manomet Bird Observatory, and Rutgers University), sketches of sediment coring stations, selected chemical data and QA/QC procedures.



LOUIS BERGER & ASSOCIATES, INC.

Location of Oil Spills

JUNE 1991 | FIGURE 1-1

2.0 COMPILATION OF EXISTING INFORMATION

Prior to selection of sampling stations, a search was conducted to identify sources of data collected before the spill occurred (pre-spill) and immediately after the spill (post-spill), and to determine the availability of samples for further analysis. The Scope of Services defined in the Request for Proposal for this investigation limited the collection of baseline data to the last two years (i.e., since January 1988). This task contributed to the Governments' evaluation of existing baseline data and to determining which investigations could be usefully continued or repeated for the purpose of quantifying the injuries to natural resources resulting from the spill.

The waters, sediments and biota of the Arthur Kill, Kill van Kull, Newark Bay and tributaries have been and are the subject of many studies for regulatory, academic and natural resource management purposes. A list of investigators and studies in the area were prepared from information available from New Jersey Department of Environmental Protection, New York State Department of Environmental Conservation, New York City Department of Environmental Protection, New York City Department of Parks and Recreation, and Louis Berger & Associates, Inc. The DIALOG database system was searched for additional information. These sources provided names and locations of investigators who may have samples and/or sampling results regarding the condition of the Kill area before and after the Exxon spill of January 1-2, 1990. The names of potential contacts are shown in Table 2-1.

Each of the contacts in Table 2-1 were reached by phone to inquire as to sampling they may have conducted. An initial questionnaire (Table 2-2) was sent to those with potentially pertinent information.

These initial contacts were followed up with written letters and another questionnaire (Table 2-3) requesting more detailed information. Each researcher who was not associated with a public agency was informed of how their information would be represented so that they could make modifications if they so desired.

A catalog of relevant information was then compiled. The information included:

1) sediment and biological samples collected since January 1988,

2) water samples collected since January 1988, and

3) details regarding post-spill samples of sediment, fish, and invertebrates collected in the first-quarter of 1990.

The catalog is provided in Appendix II-A.

2.1 Previous Investigations

The catalog compilation of previous investigations is limited to sampling programs conducted since January 1988. Details are provided in Tables A-1 and A-2 of the catalog (Appendix II-A). These programs are:

J. Burger (Rutgers University)
A. Cristini/K.Cooper (Ramapo College/Rutgers University)
P. Weis/J. Weis (University of Medicine and Dentistry of New Jersey (UMDNJ)/Rutgers University)
J. Kraeuter (Rutgers University)
R. Bopp (Columbia University)
S. Koulish (College of Staten Island)
R. Hires (Stevens Institute of Technology)
Manomet Bird Observatory
Exxon
Louis Berger and Associates, Inc.
Public Service Electric and Gas (PSE&G)
New York City Department of Environmental Protection (NYCDEP)
New Jersey Department of Environmental Protection (NJDEP)
National Oceanographic and Atmospheric Administration (NOAA/ National Marine Fisheries Service (NMFS)
U.S. Army Corps of Engineers (ACOE)
NYC Parks and Recreation
Trust for Public Land
New York State Department of Environmental Conservation (NYSDEC)
Interstate Sanitation Commission

2.2 Catalog of Available Samples

Table A-1 (Appendix II-A) outlines those pre- and post-spill sampling programs that have available samples. Table A-3 (Appendix II-A) includes more details regarding available post-spill sediment, fish, and invertebrate samples.

Pre-spill samples are known to be available from:
J. Burger
P. Weis/J. Weis
J. Kraeuter
NYC DEP

Post-spill samples are known to be available from:
J. Burger
A. Cristini/K. Cooper
P. Weis/J. Weis
Manomet Bird Observatory
NOAA/NMFS
NYS DEC

Table 2-1

CATALOG CONTACTS

1. Joanna Burger
   Nelson Biological Laboratories
   P.O. Box 1059
   Piscataway, NJ 08855-1059
   Phone = 201/932-4318
   Fax = 201/9323-5870

2. Angela Cristini
   Ramapo College
   505 Ramapo Valley Road
   Mahwah, NJ 07430-1680
   Phone = 201/529-7724
   Fax = 201/529-7508

3. Keith Cooper
   JGPT
   Rutgers University
   Piscataway, NJ
   Phone = 201/932-3729

4. John Kraeuter
   Associate Lab Director
   Shellfish Research Laboratory
   P.O. Box 687
   Port Norris, NJ 08349
   Phone = 609/75-0074
   Fax = 609/785-1544

5. Lowell Fritz
   NMFS/REFM
   7600 Sand Point Way, NE
   Seattle, WA 98115
   Phone = 206/526-4246

6. Richard Bopp
   Lamont-Doherty Geological Observatory
   Columbia University
   Palisades, NY 10964
   Phone = 914/359-2900
   Fax = 914/365-3183

Table 2-1 (Cont'd)

CATALOG CONTACTS

7. Peddrick Weis
UMDNJ New Jersey Medical School
Department of Anatomy
100 Bergen Street
Newark, NJ 07103
Phone = 201/456-4409
Fax = 201/504-7489

8. Sasha Koulish
Department of Biology
College of Staten Island
55 Bay Street
Staten Island, NY 10301
Phone = 718/390-7994

9. Richard Hires
Department of Civil and Ocean Engineering
Stevens Institute of Technology
Hoboken, NJ 07030
Phone = 201/420-5733
Fax = 201/420-5352

10. NOAA/NMFS:
Clyde L. MacKenzie, Jr.
NOAA
NMFS, Northeast Fisheries Center
Sandy Hook Laboratory
Highlands, NJ 07732
Phone - 201/872-3000

11. Angela Forndran
New York City Department of Environmental Protection
Bureau of Wastewater Treatment
Wards Island, NY 10035
Phone = 212/860-9388
Fax = 212/369-1135

12. Tom Brosnan
New York City Department of Environmental Protection
Bureau of Wastewater Treatment
Wards Island, NY 10035
Phone = 212/860-9378
Fax = 212/860-9378

13. Trust for Public Land
c/o Carolyn Summers New York City DEP
Phone = 212/669-8859

Table 2-1 (Cont'd)

CATALOG CONTACTS

14. Kathy Parsons
Manomet Bird Observatory
Manomet, Massachusetts 02345
Phone = 617/224-6521
Fax = 508/224-9220

15. Ward Stone
NY State Department of Environmental Conservation
Wildlife Resources Center
Game Farm Road
Delmar, NY 12054
Phone = 518/439-8017

16. Mark Matsil
NY City Parks and Recreation
Director, Natural Resources Group
The Arsenal, Central Park
New York, NY 10021
Phone = 212/360-8201

17. Patricia B. Pechko/John Tavolaro
Operations Division
USACOE
26 Federal Plaza
New York, NY 10278
Phone = 212/264-5622
Fax = 212/264-0523

18. Robert Douglas
Environmental Affairs 17G
PSE&G Company
80 Park Plaza
Newark, NJ 07101
Phone = 201/430-8258

19. Roberta Logotino
EA Engineering, Science, and Technology
The Maple Building
3 Washington Center
Newburgh, NY 12550
Phone = 914/565-8100

*20. Peter Mott
New York City Audubon Society
Phone = 212/691-7483

Table 2-1 (Cont'd)

CATALOG CONTACTS

*21. Gail Ashley
Department of Geological Sciences
Rutgers University
Busch Campus
New Brunswick, NJ 08903
Phone = 201/932-221

*22. Henry Bokuniewicz
Marine Sciences Research Center
State University of New York
Stony Brook, NY 11794
Phone = 516/632-8674

*23. New Jersey Marine Sciences Consortium
c/o Susan Halsey (now at NJDEP)
Phone = 201/872-1300

*24. A. Lee Meyerson
Department of Geology and Meteorology
Kean College of New Jersey
Union, NJ 07083
Phone = 201/527-2064

*25. Andrew Rowan
Coastal Environmental Services
2 Research Way
Princeton, NJ 08540
Phone = 609/987-0966
Fax = 609/987-2443

* These persons were contacted, but did not have any sample data.

Table 2-2

INITIAL QUESTIONNAIRE

Questionnaire Regarding: Samples Collected Since January 1988 in the Arthur Kill, Kill van Kull, and Newark Bay

1. Date collected

2. Type of samples (e.g., sediment, water, etc.; species if biological)

3. Location of samples - please indicate on a map

4. Type of research conducted (e.g., ecology, water quality)

5. Type of analysis of samples (if done)

6. Location of clam or mussel beds

7. Availability of archived samples

8. What QA/QC procedures were used, i.e., sampling method, sample preparation, holding conditions, extraction procedures (if biological samples)

9. Knowledge of personal observations and/or documentation (photos, maps) regarding:

   - Extent of Jan. 2 Exxon spill
   - Oil-related deaths and/or injuries to birds

Table 2-3

FOLLOW-UP QUESTIONNAIRE

1. Sample Location:

   Sample Date:

   Sample Type: [ ] biological [ ] sediment [ ] water

2. Tidal Zone (high intertidal, middle intertidal, low intertidal, subtidal):

   Approximate depth of subtidal:

3. Sampling Device/Methodology:

   Approximate volume of material sampled (cubic inches):

4. Biological: Species?_____

   How much tissue material (approximate) per species (grams)? _____

   Sediment: If corer was used:

   a) inner diameter of coring tube (inches): _____

   b) core depth (inches) _____

   c) was sediment at surface lost or preserved? _____
   inches lost? _____

   d) material of core barrel (PVC, polycarbonate, etc.) _____

   e) core barrel cleaned before use? _____ how? _____

   Water: volume?

6. Preservation of material:

   frozen? _____ temperature? _____ °C

   cold storage? _____ temperature? _____ °C

   room temperature? _____

   Combination? If so, please explain in detail, e.g., number of days/hours of each since sample collection.

7. Were other processing procedures or analysis performed on any part of the sediment or biological sample? If so, please provide details:

3.0 MAPPING STUDIES

An important aspect of the damage assessment was the preparation of accurate maps depicting the locations of spilled oil, potentially affected wetlands, and land uses in the spill area.

3.1 Oil Spill Extent

3.1.1 Methodology

3.1.1.1 Research

All the information displayed on the oil spill extent maps was obtained from secondary sources. This information was in the form of field notes, update sheets, photographs and film footage, personal interviews, and telephone conversations. Contacts were made with the following:

New Jersey Department of Environmental Protection
  Bureau of Emergency Response
  Division of Hazardous Waste Management
  Division of Science and Research
New York State Department of Environmental Conservation
  Region II Office
New York City Department of Environmental Protection
  Division of Hazardous Waste
New York City Department of Parks and Recreation
  Natural Resources Group
United States Coast Guard
  Group New York - Pollution Response
United States Environmental Protection Agency
City of Elizabeth, New Jersey
  Department of Health
New Jersey News Photo
National Broadcasting Company

3.1.1.2 Draft Maps

Information from each source was plotted onto paper reproductions of New Jersey Department of Environmental Protection (NJDEP) orthophotographic quarterquads (scale 1:12,000). Such information included the extent of spill per account, date of each sighting, and severity of impact, if any had been assessed.

3.1.1.3 Comprehensive Maps

The information on the draft maps was then synthesized into four categories of impact: heavy, medium, light and unspecified. The category of impact was determined from what was found in the secondary sources. Heavily oiled areas contained free product, mousse and/or emulsions; medium impact areas contained a thin, continuous layer of oil; lightly oiled areas contained intermittent, thin

layers of oil and/or rainbows; the unspecified category of impact was used if the secondary source was not specific as to impact. In a situation where a single section of shoreline was noted by different observers/field reports to be in two or more impact categories, the more severe category was used.

Three sets of comprehensive maps were produced for the Governments' Technical Committee (GTC). The first set was a color display map of the geographical spill extent and locations of possible sampling sites. At this stage in the process, oil impacts on the Staten Island shoreline appeared as "unspecified" because information from the United States Coast Guard (USCG) did not indicate severity of impact in its field reports, although the USCG considered these areas as heavily impacted. This was considered as the first deliverable, which was reviewed by GTC for completeness.

After GTC review, a second set of maps was prepared. They consisted of 10 black and white NJDEP quarterquads with the four impact categories of geographical spill extent, transects established by LBA in the field inspection (see Section 3.2.1), LBA-recommended sampling sites, and pre- and post-spill sampling of sites of other researchers. Information obtained from New York City and New York State supplemented the USCG information in order to apply impact categories to the Staten Island shoreline. These approved maps were converted to digital form (as discussed in Section 3.3).

3.1.1.4 Time Series Mapping

At the onset of this project, a proposed collection of daily time series maps was to have been compiled. These would have portrayed the day-to-day flow of the contamination. However, this proved not to be possible as there was not sufficient data to support such a series.

3.1.2 Results of Oil Spill Extent and Impact Mapping

After the maps were completed, it was found that the oil released from the Exxon Bayway Refinery affected the Arthur Kill, Kill van Kull, Newark Bay, and their tidal tributaries (Figure 3-1). The oil travelled north into Newark Bay to the mouths of the Passaic River and Hackensack River. The oil extended east in the Kill van Kull to the southern shore of Constable Hook (Bayonne). The southernmost extent of contamination observed in the Arthur Kill was to the Outerbridge Crossing.

Tidal tributaries were thought to be affected to the head of tide. In New Jersey, secondary sources put the farthest approximate extent of oil to the US 1 and 9 viaduct in the City of Elizabeth. Piles Creek was affected as far inland as one-half mile west of the New Jersey Turnpike crossing.

On Staten Island, Old Place Creek was oiled to the I-278 (Staten Island Expressway)/ NY 440 (West Shore Expressway) interchange. Some observers in the area two to three weeks after the spill reported oil in Old Place Creek along its entire length (i.e., beyond the Staten Island Expressway and Goethals Road North). However, there were no contemporaneous field notes of these observations, and thus, they are not reflected in the Spill Extent Map. Sawmill Creek was contaminated to NY 440. Neck Creek was oiled up to Meredith Avenue. Fresh Kills

was impacted to the confluence of Richmond Creek and Main Creek. Booms for the Fresh Kills Landfill at this confluence prevented contamination from entering either waterway.

Most of the western and northern shores of Staten Island were found to be heavily impacted from Smoking Point to the Bayonne Bridge. The shores of Pralls Island, Shooters Island, and the Isle of Meadows were also heavily impacted. Zones of light impact stretched from Smoking Point to the Outerbridge Crossing on the west shore of Staten Island and from the Bayonne Bridge to Snug Harbor on the northern shore.

On the New Jersey shores, zones of heavy impact were found on the southern and western shores of Bayonne, the southern portions of Elizabeth's shoreline, and intermittently along the shore in Linden. Medium oiling was observed sporadically along Bayonne's south shore and the shoreline in Linden and from the Rahway River to Tufts Point. Light impacts were found on New Jersey shores elsewhere in the project area with the exception of the tidal creeks, where heavy oiling was common near the mouths of each creek.

It should be noted that isolated areas of heavy contamination were also found around piers, breakwaters, wreckage, etc. Site transects set up by LBA field crews three months after the spill revealed free product and/or sheens in these areas (see Section 3.2).

3.2 Potentially Affected Wetlands

3.2.1 Field Screening - Preliminary Investigations

3.2.1.1 Methodology

a. Review of Secondary Source Data

Several sources of existing information were reviewed prior to commencement of field examinations to determine the location and extent of wetlands or other natural areas which may have been potentially impacted by the spill. These sources included New York State Department of Environmental Conservation (NYSDEC) Tidal Wetlands Maps, NYSDEC Freshwater Wetlands Maps, New Jersey Department of Environmental Protection Tidelands Maps, U.S. Fish & Wildlife Service National Wetland Inventory Maps, available aerial photography, and notes, reports and personal communications with other agencies or persons involved with the research/investigation. In addition, the draft Spill Extent maps were reviewed to determine the overall study area and the anticipated spill impact area.

b. Field Examination

LBA conducted a field inspection of the spill impact area from March 15-21, 1990. The objective of this investigation was to determine the landward extent of contamination into wetland habitats and other conditions within the impact area. Additionally, LBA was to use the field examination to help select sites for sampling, staging, access, etc. The Cibro Savannah and Eklof spills had already occurred by the time the field inspection was conducted. The field screening procedure itself did not distinguish these three spills.

The field inspection was conducted by two teams, each of which used boats to access sites along the New Jersey and New York shorelines throughout the impact area. The area of field study extended from the Outerbridge Crossing northward to the confluence of the Passaic River and Hackensack River and to Constable Hook, where the Kill van Kull enters Upper New York Bay. Additionally, all other navigable waters, including the Elizabeth River and Rahway River, Fresh Kills, Morses Creek, Neck Creek, Sawmill Creek, Richmond Creek, Main Creek, Woodbridge Creek, Piles Creek, Smith Creek, Old Place Creek and other streams and channels within the impact area, were inspected. Selected inspection sites included all tidal wetlands and non-vegetated beaches along the shoreline in the study area. Sites were categorized and distinguished as industrial edge/bulkhead areas, natural/vegetated areas, and beaches prior to field inspection and verified in the field. Access to areas unnavigable with either the 28-foot R/V VICTORIA or the 20 foot Boston Whaler was made using a 6-foot Avon vulcanized raft with small outboard.

LBA personnel maintained information in field log books. Each crew kept detailed records of findings relative to type of site, vegetative habitat, substrate, dominant plant species, evidence and condition of shellfish, birds and mammals, and other information necessary to accurately describe the characteristics of the site. The crews conducted visual inspections of both undisturbed and disturbed conditions, as well as olfactory inspection of the substrate drawn with Dutch augers, to ascertain the potential presence of hydrocarbon contamination. These findings constitute the primary level of information recorded on the data forms, shown in Figure 3-2.

Having selected a wetland or beach site, investigations were conducted along transects set perpendicular to the shoreline within the intertidal zone. Distances to all data collection points were recorded relative to the high water line which was designated as station 0 (zero). Typically, the first sampling location was at a point along the transect that represented a submerged condition at the greatest possible distance from the mean high water line. Due to the general inaccessibility to subtidal mudflats, records from this position along the transect were not collected. The initial action at each site was to examine the undisturbed water surface for sheen residue of light, fresh oil. For all points along the transects, this sheen was categorized as either high, low or none. These values were established by LBA in the field during preliminary exercises held exclusively to devise a uniform system that each inspection team could utilize during site assessments. Similarly, high, low, or none values for odor, characteristic of the spill material, were established and applied to the undisturbed submerged condition.

After examination of the undisturbed submerged condition at each site, the substrate was disturbed. Disturbance was made by auguring to a depth, typically, of 10 to 12 inches. This disturbance instantly lifted hydrocarbon sheen to the water surface to a varying degree depending on the sampling point and site location. The value of sheen was recorded. An examination of the substrate odor was made to assess the residual odor. This information, as well as depth to and type of substrate, time and date, horizontal distance to mean high water, and vegetative community, was entered into the log book.

The second sampling point along the transect typically was at the shoreline, the line of contact at that time of day of open water and land. Here, as for the submerged data point and all other points landward, the location was evaluated in both an undisturbed and a disturbed condition. Landward data points above the shoreline included the high water line and, usually, intermediate points between the high water and the spring high tide line. These intermediate data points were selected if signs of contamination existed at the high water line. The objective in taking intermediate data points was to locate, more precisely, the landward extent of the contamination in the wetland or on the open beaches.

Subsequent to the field inspections, LBA personnel administered the transfer of the results of the analyses onto orthographic quarterquad maps of the project area.

3.2.1.2 Results of Field Screening Investigations

Using the technique described above, LBA investigated 92 transects along both shores of the Arthur Kill, Kill Van Kull and Newark Bay. As shown in Table 3-1, soils at 35 of 92 transects (38%) in Newark Bay, Arthur Kill, Kill van Kull and the tributaries contained oil in amounts sufficient to produce a substantial sheen when immersed in water. These "high sheen" transects were well distributed throughout the study area, but are concentrated between Howland Hook Terminal west of Shooters Island, and Neck Creek, south of Pralls Island.

3.2.2 Wetland Mapping

This effort included the interpretation of vegetative communities and general shoreline conditions (such as beaches or built conditions) from infrared aerial photography provided by the New Jersey Department of Environmental Protection and the New York State Department of Environmental Conservation. Information regarding existing shoreline conditions that was recorded during the field investigations was incorporated onto the quarterquads during the photo-interpretation and mapping tasks. This interpretation was conducted by Greenhorne and O'Mara, subconsultants to LBA.

Mapping of the natural resources involved the identification of all tidal wetlands and other associated intertidal features in an area ranging from the southern end of the Arthur Kill at the Raritan Bay, north along the Arthur Kill to and including the Newark Bay, extending to the Pulaski Skyway bridge on the Passaic River, and the Truck Route 1 & 9 bridge on the Hackensack River. The project area extended eastward along the Kill Van Kull to the mouth of the Upper New York Bay.

These are not official NYS Tidal Wetland maps and may not be used for the purpose of determining State jurisdiction. Any official change in the location or classification of a wetland must go through the map amendment process as specified in Part 661.17 of the Tidal Wetland Use Regulations for Article 25, including map review by Division of Marine Resources, Bureau of Monitoring and Assessment, in order to be adopted as the NYS wetland boundary.

Furthermore, these maps are not official New Jersey wetland maps. Information on official New Jersey wetland designations may be obtained from NJDEP, Environmental Regulation.

Thirty-nine (39) NJDEP tidelands photo basemaps and twenty (20) NYDEC tidal wetlands photo basemaps, both at a scale of 1:2400, were used. In addition, three (3) NJDEP Freshwater Wetlands quarter-quad photo basemaps, at a scale of 1:12000, were used to map the area of Newark Bay not covered by the NJDEP Tidelands photo basemaps.

The work included the following tasks:

a. Characterize and map all of the intertidal natural resources within the Arthur Kill estuary system. This includes all tidal tributaries of this system upstream to the head-of-tide as determined by the NJDEP Head-of-Tide Atlas and as illustrated on the NYSDEC tidal wetlands maps. The NJDEP Atlas was prepared pursuant to a study conducted by Coast Survey, Ltd.

b. Map the natural resources using the following classification scheme:

HM - high marsh, to be labeled as a polygon.
IM - intertidal or low marsh, to be labeled as a polygon.
SM-1 - tidal flats with a cobble/gravel substrate, to be labeled as a polygon.
SM-2 - tidal flats with a sandy substrate, to be labeled as a polygon.
SM-3 - tidal flats with a muddy substrate, to be labeled as a polygon.
FM - suspected freshwater wetlands, to be labeled as a polygon.
U - uplands to be labeled as a polygon.
UWL - upper wetlands limit, to be labeled as a linear feature.
WL - waterline, to be labeled as a linear feature.
WL/UWL - locations where the waterline and upper wetlands limit are coincidental, to be labeled as a linear feature.

The linear classifications resulted in a continuous upper wetland limit line, labeled as UWL, and a continuous water line, labeled as WL.

c. Identify and map the intertidal natural features using photo analysis and interpretation utilizing the best available color infrared (CIR) photography. The photography available included a series flown in March 1986 taken at low to mid-tide at a scale of 1:58000, a series flown in July 1988 taken at high tide at a scale of 1:60000, and a series flown in September 1989 taken at low to mid-tide at a scale of 1:12000. Photo interpretation was performed on a Bausch & Lomb Zoom 240 Stereo Microscope and a Bausch & Lomb Stereo Zoom Transfer Scope (ZTS). The 1986 and 1988 photography was enlarged by HAS Images, Inc. (Dayton, OH) to a scale of 1:40000 and 1:50000 through E-6 chemistry in a Hope roller transport processor, using ektachrome 6121 duplication film.

d. Upon receiving the photography, a cartographic technician organized the specific flight lines and photographic frames in relation to the individual photo basemaps, taking into consideration factors such as forward overlap and sidelap coverage. The matte finish mylars were taped to every photo basemap, referenced using basemap name and number, and correctly registered to the given basemap coordinates.

e. Map the natural resources, including the engineered shorelines, onto blueline copies of the 1:2400 photo basemaps and 1:12000 quarter-quads. Black ink Rapidograph drafting pens with a .25 point were then used to transfer the lines onto the correctly registered mylars, and Verol carmine red pencils were used to label all features. The minimum waterway mapping unit was made to a width of 10 feet and the polygons were mapped at a width of .02 inches or greater. The upland edge of the delineated lines abut the upland/wetland boundary.

f. The photo interpreters were responsible for edge matching the intertidal mapping units on the overlapping and sidelapping mylars within the project area. These intertidal units, which lie along the outer borders of each mylar overlay, were "tied into" the units on all adjacent overlays to ensure the accuracy and consistency of the map across the project area.

g. A quality control and editing process incorporated measures to ensure the highest standard of accuracy among photo interpreters and output products. This process was organized to be separate from, and operate independently of, the photo interpretation process.

h. A handwritten log was kept describing any unusual situations encountered on a given photomap and the resolution. A separate tracking log sheet was kept for each photomap showing dates and the G&O employee responsible for performing the various delineation tasks. These tasks include initial photo interpretation, inking of the mylar, QA/QC and corrections. The entire completed project was also sent to G&O's headquarters in Greenbelt, MD for final QA/QC.

i. Field verification of the mapped units was conducted to develop a photo interpretation key for the discrimination of signatures associated with vegetative and other natural features. This key is in the form of a handwritten field record book accompanied by blueline copies of the photo basemaps annotating the key ground truth sites by letter.

j. Digitization. One potentially problematic issue dealt with during the digitization process was the matching of the units between the 1:2400 basemaps and the three 1:12000 quarter-quads. An attempt was made during the process to match these lines as closely as possible, but the difference in scale made an exact match impossible. The digitizers matched these lines to the best of their ability, using their best judgment. In addition, the tidal wetlands maps furnished by the NYSDEC

were not originally edge matched or rectified, and this discontinuity created minor edge mismatches. This resulted in some of the lines being altered somewhat to minimize this mismatch, and thereby ensuring a seamless data base.

Section 3.3 provides a detailed discussion of the production of the digital maps, including the presentation of information on vegetative communities and the location of sampling points throughout the project study area.

3.2.3 Ownership and Political Boundaries

The objective of this portion of the study was to identify all land owners and all land uses potentially affected by the spill.

3.2.3.1 Methodology

a. Tax Maps

Index maps of each city/municipality in the spill area were examined to ascertain which individual maps were needed. Over 300 tax maps were obtained.

b. Selection of Affected Properties

Any property in the study area abutting the affected water bodies or tidal tributaries was identified. It should be noted that the final extent of the overall study area was not set until the wetland mapping task was completed. Since the wetland delineation occurred simultaneously with the selection of affected properties, the study areas for the two tasks are not identical.

The study area in each municipality was as follows:

Bayonne:	from the eastern tip of Constable Hook, west along the south shore, around Bergen Hook, and north along the west shore to the boundary with Jersey City
Jersey City:	from the boundary with Bayonne, north along the west shore to the Jersey City Public Works properties above Droyer's Point
Newark:	from the Pulaski Skyway south along the east shore to the boundary with Elizabeth
Elizabeth:	from the boundary with Newark, south along the east shore to the boundary with Linden; upstream on the Elizabeth River to the South First Street crossing
Linden:	from the boundary with Elizabeth, south along the east shore to the boundary with Carteret (the Rahway River); upstream on Piles Creek to one-half mile west of the New Jersey Turnpike crossing and upstream on the Rahway River to the boundary with Rahway

Rahway: on the Rahway River from the boundaries with Linden and Woodbridge to the Milton Avenue crossing on the North Branch and one-half mile upstream on the South Branch

Carteret: from the boundary with Linden (the Rahway River) south along the east shore around Tufts Point to the boundary with Woodbridge; upstream on the Rahway River to the boundary with Woodbridge

Woodbridge: from the boundary with Carteret south along the east shore to the boundary with Perth Amboy; upstream on Smith Creek to an unnamed macadam road and upstream on the Rahway River from the boundary with Carteret to the boundary with Rahway

Staten Island: from just west of the Staten Island Ferry terminal, along the north and west shores, to just north of Tottenville; properties were selected upstream on: Old Place Creek up to the Goethals Bridge toll plaza; and Sawmill Creek and Neck Creek and Fresh Kills to the NY 440 crossings

A list of block and lot (property) numbers was generated.

c. Ownership Information

Visits were made to the tax assessor or board offices in each municipality and ownership information was gathered for each property listed. This included the owner's name and address, property location, property size and property classification. Appendix II-B provides a property ownership listing.

d. Land Use Clusters

Land use clusters were formed using the property classifications (Table 3-2). These classifications were grouped into 11 comprehensive land use categories with common use codes to allow congruity between New Jersey and New York records (Table 3-3). Adjacent properties with the same use codes were grouped into clusters which were given a common geocode (see Section 3.3 and Table 3-4). A property with less than 100 feet of shoreline and a different use code was included in a larger adjacent cluster, although its use code was not changed. Conversely, a property which had more than 100 feet of shoreline and a different use code than adjacent properties was mapped as an individual cluster. The resulting clusters were then mapped onto NJDEP quarterquads for later digitizing. At no time were property lines or political boundaries surveyed.

Using the common use codes mentioned above, each cluster was then assigned a unique four-digit geocode for identification. The geocode identified which state each cluster was located in, the predominant land use (letter code) and an identification number (Table 3-4).

3.2.3.2 Political Boundaries

Political (municipal, county and state) boundaries were mapped from United States Geological Survey 7.5 minute quadrangles.

3.2.3.3 Riparian Grants

Historically, any lands in New Jersey once flowed by the high tide were considered property of the State. Private ownership of these lands (now water grants) was obtained from the State through grants and purchases. Within the study area, much of the land was turned over to private ownership through time. In any case, the ownership was noted in the tax records. Additionally, impacts to water grants (areas between the shore and United States pier and bulkhead lines) were impossible to assess. Thus, riparian grants were not recorded for either state.

3.3 Production of Digital Maps

Two processes occurred simultaneously and were later integrated to produce the final product. One process involved digitizing all the information plotted on the tidelands maps and quarterquads. This included vegetative communities, spill impact, land use clusters, political boundaries and sampling points. The other involved geocoding all this information.

The digitizing was done on a Numonics 2200 series "E"-size digitizer with a Tektronics 4301 work station. The work was completed using the Arc/Info, Version 5.0.1., geographic information system (GIS) program. All the work was done using New Jersey State Plane coordinates. Deliveries to NJDEP were in that system. Deliveries to New York State Department of Environmental Conservation (NYSDEC) were in New York State Plane coordinates.

Vegetative communities and land use clusters were digitized as two separate output files. The vegetative communities were digitized as polygons while the shorelines (waterline) and upper wetland limits were digitized as arcs. The land use clusters, political boundaries and spill impacts were also digitized as arcs. The sampling points were digitized as points.

Vegetative community polygons were coded with the land cover code used on the manuscript maps (Table 3-5). Waterline and upper wetland boundary arcs were similarly coded. This required the construction of a network coverage as the polygons had to be coded differently than the arcs. The land use clusters were identified using the land use geocodes used on the manuscript maps. Spill impact areas were coded according to the level of oiling (high, medium, low, unclassified and none). The sampling points were given a unique identifier which was provided on the manuscript map.

The land use cluster (ownership) information was coded and entered as data strings into a LOTUS 1-2-3 spreadsheet. Once all the digitizing was done, the work was integrated and imported into a GIS. These files were then delivered

to NJDEP on a 9-track tape in the Arc/Info Export format. These files were delivered to NYSDEC in the same export format, but on a tape cartridge. In addition to the codes delivered in a digital format, a printed file of codes was also produced. Appendix IIC provides the details of the conversion of manuscript maps into a digital format.

Table 3-1

Frequency of Oil Sheens Observed in Sediments

	High	Low	None	Total Sites
New Jersey	16	15	22	53
New York	19	7	13	39
Total	35	22	35	92

Source: Louis Berger and Associates, Inc., 1991

Table 3-2

SAMPLE PROPERTY TAX CLASS CODES

NEW JERSEY:

- 1 - Vacant Land
- 2 - Residential
- 4A - Commercial
- 4B - Industrial
- 15C - Public Property

NEW YORK:

- E - Warehouses
  - 1 - Fireproof
  - 3 - Semi-fireproof
  - 4 - Frame, Metal
  - 9 - Miscellaneous
- F - Factory and Industrial Buildings
  - 1 - Heavy Manufacturing (Fireproof)
  - 2 - Special Construction (Printing Plant, etc., Fireproof)
  - 8 - Tank Farms
  - 9 - Miscellaneous
- V - Vacant Land
  - 0 - Vacant Land Zoned for One, Two, or Three Family Homes
  - 1 - Private Owner
  - 7 - Port of New York Authority
  - 8 - State and U.S.
  - 9 - Miscellaneous (Department of Real Estate and other Public Places)

Source: New Jersey and New York State tax records, 1990.

Table 3-3

COMPREHENSIVE LAND USE CATEGORIES

F - Federal

S - State

O - cOunty

M - Municipal

I - Industrial

C - Commercial

T - Transportation, communication, utilities (TCU)

E - rights-of-way (Easements) not included in TCU

R - Residential

V - Vacant

H - otHer

Table 3-4

LAND USE GEOCODES

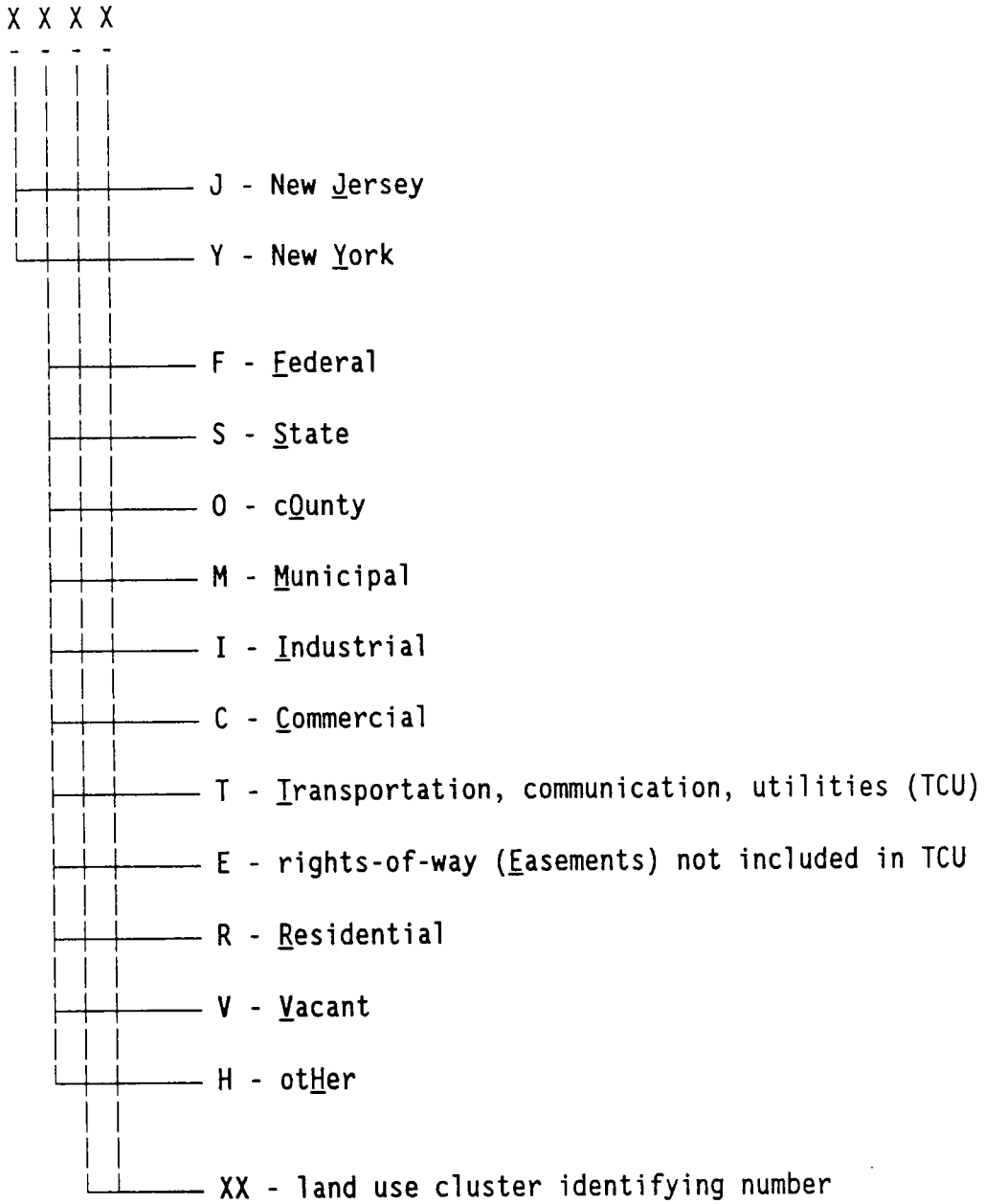


Table 3-5

LAND COVER CODES

HM	- high marsh
IM	- intertidal or low marsh
SM-1	- tidal flats (cobble/gravel substrate)
SM-2	- tidal flats (sandy substrate)
SM-3	- tidal flats (muddy substrate)
FM	- (suspected) freshwater wetlands
U	- uplands
UWL	- upper wetland limit
WL	- water line
WL/UWL	- water line and upper wetland limit, congruent

LOUIS BERGER & ASSOCIATES, INC.

ARTHUR KILL OIL DISCHARGE STUDY

SITE No. _____ DATE: _____ TIME Arrival: _____

CREW: _____

LOCATION: _____

_____

DESCRIPTION: ___ Bulkhead ___ Rip-Rap ___ Marsh
___ Beach (sandy) ___ Mudflat ___ Other _____

Comments: _____

_____

DISTANCE Horizontal (feet)	INITIAL OBSERVATIONS ODOR Hi	Lo	No	SHEEN Hi	Lo	No	DISTURBANCE ODOR Hi	Lo	No	SHEEN Hi	Lo	No	COMMENTS
Spring High Water													
High Water (0 feet)													

4.0 SAMPLING PROGRAMS

4.1 Field Sampling Programs

Field sampling was composed of the following integrated programs:

1 - sediment sampling via coring;
2 - benthic sampling, specifically for two species of mussels and two species of clam;
3 - counts of live and dead ribbed mussels;
4 - bird population studies on Pralls Island, Isle of Meadows and Shooters Island;
5 - finfish sampling; and
6 - behavioral studies for fiddler crabs.

In addition, sediments and benthos collected in Programs 1 and 2 were subjected to chemical analysis by laboratory fingerprinting techniques. The following sections describe the programs in detail.

4.1.1 Selection of Sampling Sites

The selection of sampling stations was based on the results of the preliminary spill extent map, information available from other researchers, the likely presence of fined-grained sediments, locations of the Exxon and Cibro Savannah spills, the potential presence of species of interest, and hydrologic diversity of the waterways.

Thirty-seven (37) stations were recommended, reviewed and agreed upon by LBA and the Governments. The names and locations of these stations are shown in Table 4-1 and Figure 4-1. The stations were divided into several categories, as follows:

11 Intensive Sampling Stations (affected and control stations):

- 3 in areas of high spill incidence
- 3 in areas of medium spill incidence
- 3 in areas of low spill incidence
- 2 in areas of no spill incidence (control stations)

26 Non-Intensive/Additional Sampling Stations:

- 13 geographically spread along both shores of the Arthur Kill and Newark Bay
- 13 located at the mouth, or upstream, of tributaries to the Arthur Kill and Newark Bay (Elizabeth River, Rahway River, Hackensack River, Morses Creek, Piles Creek, Old Place Creek, Merrills Creek, Sawmill Creek and Neck Creek)

The degree/intensity of the sampling programs differed between intensive stations and additional stations, as described in the following sections.

The sediment and benthic sampling programs were carried out at the same stations (with the exception of Ward Point) within 24 to 36 hours of one another. Because the Ward Point station (No. 28) revealed no fine-grained sediments, sediment sampling for this station was relocated to Ploughshare Point (28S). The benthic sampling remained at Ward Point (28B) because of the abundance of clams.

4.2 Sediment Sampling

4.2.1 Sediment Sampling Procedures

4.2.1.1 General

At the 11 intensive sampling stations, sediment was collected from four tidal zones: high, medium and low intertidal and subtidal. Samples were collected from 2 types of sites: affected stations and control stations. At the affected stations and control stations, samples along three transects (1,2,3) were taken from each of the four tidal zones (Table 4-2). In addition, three discrete QA/QC cores were taken from the low intertidal zone. At the 26 additional stations, three cores were collected only from the medium intertidal zone. Stations were accessed from land and boat (R/V VICTORIA) as appropriate to the location, tides, and substrate.

Sediment collection was carried out with a custom-designed corer built at the Woods Hole Oceanographic Institution. The primary focus of the sediment collection was to obtain site-representative, undisturbed sediment samples, collected in a consistent manner between all sites and tidal zones. The designed corer that was used met these specifications.

The corer consisted of a stainless steel corer head, a PVC core tube (4.25-inch inner diameter, 20-inch length), a stainless steel core catcher, and a stainless steel core cutter (Figure 4-2).

4.2.1.2 Core Tube Cleaning and Preparation

All core tubes and interchangeable core catchers and core cutters were thoroughly cleaned in the laboratory before each use, following the procedure below:

1. brush with non-phosphate detergent and tap water
2. brush with tap water only and tap water rinse
3. deionized water rinse
4. 10 percent nitric acid rinse
5. deionized water rinse
6. hexane rinse (optima grade)
7. deionized water rinse
8. acetone (pesticide grade) rinse
9. total air dry
10. deionized water rinse

After drying, these parts were wrapped individually in baked aluminum foil. A record was kept of the technician performing the procedure as well as the date and time. The cleaning of equipment initiated the chain of custody procedure. The core tubes were numbered sequentially. One rinseate sample was collected for analysis for every batch of 20 tubes cleaned. The analysis of the rinseate blanks was identical to the analysis of the samples. For core catchers and core cutters, one rinseate sample was collected per day. Thirteen percent of the core tube rinseates were analyzed and 20 percent of the cutter/catcher rinseates were analyzed. The others were archived. In addition, 20 percent of the rinseates from knives were analyzed.

In the field, each core tube was used only once per coring attempt. If the first attempt failed, another cleaned tube was used. Different laboratory-cleaned core catchers and cutters were used for each different tidal zone. Between different core locations within a tidal zone, the core catchers and cutters were cleaned in the field following steps 2 and 3 of the cleaning procedure above. The corer head was cleaned between coring attempts by steps 2 and 3.

4.2.1.3 Selection of the Core Location

Upon arrival at the stations, relevant information pertaining to the station was recorded in logs and maps sketched of each coring station. (see Appendix II-D for redrawn sketches). The focus of recording this information was to be able to return to the site, if needed, and identify the approximate location of each collected core. The locations of the different intertidal zones were based on tidal information from the National Oceanographic and Atmospheric Administration (NOAA, 1989).

According to this tidal information, the tidal zones for the study area are listed below. The three intertidal zones were determined by dividing the entire intertidal zone into three equal parts (Figure 4-3).

Arthur Kill and Newark Bay (tidal range: 5.0 - 5.3 feet)

High Intertidal:	0 - 1.7	feet below mean high water
Medium Intertidal:	1.7 - 3.4	feet below mean high water
Low Intertidal:	3.4 - 5.1	feet below mean high water
Subtidal:	> 5.1	feet below mean high water

Kill van Kull and Shooters Island (tidal range: 4.5 - 4.6 feet)

High Intertidal:	0 - 1.5	feet below mean high water
Medium Intertidal:	1.5 - 3.0	feet below mean high water
Low Intertidal:	3.0 - 4.5	feet below mean high water
Subtidal:	> 4.5	feet below mean high water

In the field, the identification of intertidal zones was primarily based on the average tidal cycle for the region. The average tidal cycle was computed from detailed tidal elevation measurements recorded over five 24-hour periods between February 25 and March 1, 1990 (Figure 4-4A). These tidal elevations were recorded at 6-minute intervals at the gaging station at Bergen Point in New York by the U.S. Army Corps of Engineers. These data were shifted so that peaks of low and

high water overlapped for each 24 hour cycle. The five overlapping daily cycles were then averaged into one tidal curve (Figure 4-4B). Dividing the total tidal range by a factor of three resulted in the approximate time for which the land/water interface was within the low, medium, and high intertidal zones. Starting at the time of low water and proceeding to the time of the next low water, the land/water interface is within the three different intertidal zones at the following approximate times (Figure 4-4B):

Flooding Flow:

Low Intertidal	0-100 minutes after low water
Medium Intertidal	100-180 minutes after low water
High Intertidal	180-335 minutes after low water

Ebbing Flow:

High Intertidal	0-145 minutes after high water
Medium Intertidal	145-230 minutes after high water
Low Intertidal	230-400 minutes after high water

Times of low and high water for each sampling day were determined from NOAA (1989). The position of the land/water interface within the intertidal zone was determined using the average tidal cycle curve (Figure 4-4B).

A core within a specific intertidal zone was taken at a computed distance below or above the water level, depending on what time the field team arrived at the station. For example, if low water was reported at 8:00 a.m. for a specific location, and a core was to be taken at 10:30 a.m. (i.e., 150 minutes later), the average tidal cycle indicated that the land/water interface 150 minutes after low water would be in the middle of the intertidal zone. Therefore, a core from the medium intertidal zone would be taken at the land/water interface. Based on the NOAA (1989) data presented earlier, a core from the high intertidal zone would be taken at about 1.7 feet above the water surface; a core from the low intertidal zone would be taken at about 1.7 feet below the water surface; and a core from the subtidal zone would be taken at least 3.4 feet below the water surface. The depth in relation to the water surface and the sampling time were recorded for each core.

Adjustments for the exact core location were made in the field to accommodate for daily variability in tidal elevation including spring and neap tides. The different intertidal zones were also generally distinguishable by sediment, plant composition, and slope (Figure 4-5). The high intertidal zone was characterized by a high concentration of marsh grasses (typically flattened), a gradual slope, and hard sediment surface. The medium intertidal zone was characterized by a lower concentration of marsh grasses, a generally steep slope, and burrows. Signs of sediment erosion due to strong peak flow velocities were evident in this zone, i.e., by exposure of grass roots. The low intertidal zone was characterized by the absence of plant cover and gentle slopes. Three cores were taken within each different tidal zone. The distance between each core varied from site to site as a result of local conditions.

4.2.1.4 Coring

Corer assembly: Baked aluminum foil was placed over the top of a laboratory-cleaned core tube. The core tube was then inserted into the corer head and fastened with a stainless steel bolt. A clean core cutter and core catcher were connected to the bottom end of the core tube. For coring operation with the boom of the coring platform on the R/V VICTORIA, an overpenetration protection board was attached to the outside of the corer head (Figure 4-2).

Coring operation: Typically, for above water and 0-2 feet below water coring, the corer was inserted into the sediment by hand (Figures 4-5 and 4-6). For coring in a water depth of >2 feet, the boom of the R/V VICTORIA was used (Figure 4-2).

Core capping: At the top, the corer head and aluminum foil were removed. There was no need for removal of head-space water from cores taken below the water surface, since water drained by itself during core recovery. The core was then checked for adequate length (>30 cm), and lack of overpenetration. The core surface, was checked for lack of disturbance. In the case of disturbances or overpenetration, the core was retaken. In the case of a core length of <30cm, usually due to a hard substrate, a second core was taken. If it appeared that a hard substrate was the reason for the lack of penetration, the second core was typically kept, even if shorter than 30 cm.

Baked aluminum foil and then a tight-fitting core cap were placed over the top of the core tube. The cap was fastened to the core barrel with tape. At the core bottom, the core catcher and cutter were removed with an aluminum-foil covered core extrusion post (Figure 4-7). The filled core tube was then moved over a core cap. The cap was attached to the core barrel with duct tape. The core was not placed into a horizontal position during the coring procedure. It remained in a vertical position, top side up, until frozen for at least 12 hours. The stainless steel handles, catcher and cutter were cleaned following each use (Figure 4-8).

Core labeling: The cores were labeled with two identical preprinted labels. The first label was placed on the top core cap, the second label on the side of the core barrel. The chain-of-custody forms were completed concurrent with coring, including the core barrel number and the label.

Core storage: The cores were placed upright into an insulated storage container with dry ice. Upon arrival in the sample preparation room, the cores were placed upright into a freezer.

4.2.1.5 Labeling

Each core was identifiable by a number on the core barrel and by two identical site-specific labels in two different places on the capped core (Figure 4-8).

Number on core barrel: Each core barrel was marked by an individual number on the outside of the barrel before the cleaning of the empty barrel. Numbers were in sequential order from 1 to 248. These numbers were recorded in the chain-of-custody along with the site-specific labels for each core.

Site-specific labels: Each core was marked twice with the site-specific label after the core barrels were capped and sealed. These labels were preprinted prior to the field sampling. The labels contained the following information:

All cores

Core Owner	DEP
Core stations	
Affected stations	01 - 09
Control stations	10 - 11
Additional stations	12 - 37

Affected and Control Stations

Tidal Zones	
High intertidal	Hi
Medium intertidal	Me
Low intertidal	Lo
Subtidal	Su
Transects	
Transect 1	1
Transect 2	2
Transect 3	3

Duplicate QA/QC sample in low intertidal zone: (QA)

Additional Stations

All cores for the additional stations were taken from the medium intertidal zone. The three cores for each additional station were labeled in consecutive order (i.e., 1, 2, 3).

One additional station was chosen for a QA/QC sample. Three cores were taken, one each from the eastern, central, and western core locations.

4.2.2 Sample Preparation

Sediment cores were extruded and sectioned in a sample preparation room maintained on the premises of Louis Berger and Associates, Inc. The cores were placed upright in a freezer upon return from the field. A temperature log was kept, with temperatures entered twice daily. Temperature ranged from -18 °C to -4 °C.

Cores were removed from the freezer and allowed to defrost to facilitate extrusion. If this was difficult, warm tap water was applied to the outer core tube surface. Working surfaces were covered with baked aluminum foil. Chemically cleaned stainless steel knives and forceps, and the aluminum foil,

were the only instruments or material to come in contact with sediment during the cutting and sample preparation process.

Cores were placed in a specially designed extrusion device which pushed the core out in increments that were sectioned by depth from surface as follows:

0-2 cm	10-15 cm
2-4 cm	15-20 cm
4-6 cm	20-25 cm
6-8 cm	25-30 cm
8-10 cm	(every 5 cm to end)

The outer 3-5 mm of each sample was scraped and discarded. This was done to eliminate any contamination along the length of the core due to the extrusion. The three 0-2 cm sections in each zone were composited into one sample. The remaining sections were not composited.

After each section of a single core was cut and placed into ICHEM Series 300 jars provided by the analytical lab, knives and tweezers were wiped with Kim-wipes and rinsed with deionized water. After sectioning of each core was completed, the aluminum foil on working surfaces was replaced, and knives and forceps were cleaned as follows, with steps 6 and 8 reversed midway in the sample preparation work.

1. non-phosphate detergent and tap water rinse
2. tap water rinse
3. deionized water rinse
4. 10 percent nitric acid rinse
5. deionized water rinse
6. acetone rinse
7. air dry
8. deionized water rinse
9. hexane rinse
10. deionized water rinse

A sample log sheet (Table 4-3) was completed for each core. These records provided information regarding visual observations (presence of grasses/roots, shell material, grain-size, etc.) and odor.

The surfaces of some cores were inclined. Cutting a 2 cm section at an incline is difficult and introduces error. To minimize this, the following methodology was developed. If the incline was moderate, samples for the upper 8 cm were cut in 3 sections (0-2 cm, 2-6 cm, 6-8 cm) as shown in Figure 4-9A. If severely inclined, slicing was done normally, as shown in Figure 4-9B. For such a core, there is very little sediment per sample for the inclined zone. If the terminal section of the cutting was less than 5 cm, it was discarded.

Each sample was placed into ICHEM Series 300 jars provided by the analytical laboratory. These were then placed in coolers with dry ice and shipped to the lab.

4.3 Biological Sampling

4.3.1 Benthic Invertebrates

Sampling involved efforts to collect four species of bivalves for chemical analysis at a total of 37 sampling sites in the study area. Species targeted for collection and retention for tissue analysis included the soft-shelled clam (Mya arenaria), hard-shelled clam (Mercenaria mercenaria), blue mussel (Mytilus edulis) and ribbed mussel (Geukensia demissus). All biological sampling was conducted within 24 to 36 hours of sediment sampling at the same sampling site. Of the 37 sampling locations, 11 were intensive sampling sites where four separate tidal zones were sampled for each of the targeted species. At an additional 25 sampling sites, the high intertidal zone was sampled for the four targeted species. A ribbed mussel survey was also conducted in the high intertidal zone at 36 sites. For the site at Ward Point, only the medium intertidal zone was sampled, specifically for soft-shelled clams (Figure 4-1).

4.3.1.1 Methodology

As for sediment sampling, the four separate tidal zones sampled were subtidal, low intertidal, medium intertidal and high intertidal (Figure 4-3). For purposes of this investigation, the subtidal zone was defined as the area below low tide which is always inundated. The subtidal zone was sampled in waters no deeper than 12 feet. This was done to maximize sampling of preferred bivalve habitat and avoid the channel of the Arthur Kill.

The mean high water line was estimated in the field by the landward extent of Spartina alterniflora and visible debris drift lines.

Bivalves were collected using a number of methods designed to efficiently collect surface dwelling, burrowing, or attached species in varying depths of water and types of substrate. In the high intertidal zone, species were collected by hand from surface sediments, rocks and debris, as well as excavated using shovels and a 4-inch diameter gravity corer to a depth of 18 inches. After initial attempts to use the gravity corer as a benthic sampler yielded poor results, it was no longer used. In the unconsolidated substrates of the medium intertidal zone, species were collected using an 18 tooth Rhode Island clam rake with 3-inch long teeth and 24-foot handle, a 6-inch square Ponar grab sampler, and a 3-inch diameter mud auger. In consolidated substrates, the Ponar, mud auger, shovel and clam rake were used. If the medium intertidal zone was exposed during sampling and accessible by foot, the shovel and mud auger were used exclusively. In the low intertidal and subtidal zones, a clam dredge, Ponar grab, clam rake, and corer were employed to collect bivalves. Samples were rinsed in the field over fine mesh sieves and sorted by species. This was also performed for samples taken from the medium intertidal zone when this zone was submerged during sampling.

a. Intensive Sampling Sites

At each of the 11 intensive sampling sites, all four bivalve species, if present, were collected, identified, sorted and quantified for each of the four tidal zones, and retained for potential tissue analysis. When bivalve numbers were low, the level of effort for bivalve collection consisted of two person-hours

for each of the 11 intensive sampling locations. A survey of ribbed mussels was also conducted in the high intertidal zone.

b. Additional Sampling Sites

A total of 26 additional sampling sites were sampled. At 25 of these sites only the high intertidal zone was sampled for the specified four bivalve species. When encountered, individuals were collected and retained. A survey of ribbed mussels was also conducted within the high intertidal zone (see next section). At the additional sampling site at Ward Point, the medium intertidal zone was sampled for soft-shell clams. These clams were collected and retained for future analysis. When the number of bivalves were low, the level of effort for bivalve collection consisted of one person-hour at each additional sampling site.

c. Ribbed Mussel Survey

A ribbed mussel survey was conducted in the high intertidal zone at 36 sites to enumerate the number of attached and unattached open shells (dead) and closed shells (live) of the ribbed mussel. Open shells were categorized into whole shells (both halves still connected) and half shells (separated). Five subsamples of one square meter were taken at randomly selected sites at each sampling location. A random numbers table was employed to ensure random placement of the subsamples. After receiving five random numbers, the field person(s) would begin at the landward edge of the high intertidal zone and walk the same number of paces as the first random number in a direction parallel to the landward edge of the zone. This position marked the first subsample location. The initial direction chosen was made by the field investigator. After completing that sample, the field person(s) would walk one to five paces toward the water's edge, depending upon the width of the zone, and then walk the number of paces corresponding to the next random number in a direction opposite that chosen for the previous sample. This method was repeated for each random subsample placement and guaranteed that subsamples were collected throughout the entire zone.

At two of the additional sampling sites, Site Nos. 22 and 27, the sample area was reduced in size due to the high density of ribbed mussels throughout the sample area. This was done to avoid injuring the existing mussel bed and to keep the amount of time spent at each sampling site uniform. If a visual estimate of the square meter area appeared to have a uniform density of ribbed mussels (both live and dead), and one quarter of the sampling area contained approximately one hundred live mussels with very few dead ones, then the counting of the subsample ended at a quarter meter square. If fewer than one hundred live mussels were counted, an additional quarter meter square area was sampled.

At one additional site, Site No. 28B (Ward Point), a ribbed mussel survey was not conducted. Only soft-shelled clams were designated for collection.

4.3.1.2 Sample Preparation

All of the specimens retained were identified and enumerated, wrapped in aluminum foil and placed in zip-lock bags. The samples were then placed into coolers containing dry ice. The samples were kept in dry ice while in transit to the sample preparation room maintained at the premises of LBA where they were placed

into a freezer kept at -18°C to -4°C. During delivery to the analytical lab for hydrocarbons analysis, samples were placed into coolers with dry ice.

Sample labels detailed sample identification codes consistent with sediment sample codes (location, date), species, quantity, and storage method. For each sample, data forms recorded the above information in addition to date and time of sampling, substrate type and tidal zone. Information documenting the absence of bivalves where samples could not be obtained was also recorded on data sheets. The samples were shipped to the laboratory within two days of collection along with the appropriate chain of custody forms.

4.3.1.3 Observations and Sampling Results

Sampling began on April 18, 1990 and was completed on May 14, 1990, requiring 13 field days. Neither the hard-shelled clam (Mercenaria mercenaria) nor the blue mussel (Mytilus edulis) were observed at any station. The substrates encountered at each site were described in the field in general terms. At most of the sites, the high intertidal zone consisted of thick root mats of Spartina alterniflora which ranged in width of approximately 10 feet to 50 feet. In some instances, areas of unvegetated mucks with good to poor surface drainage were present between and among the root mats. The root mats usually were associated with live Spartina on the surface, but root mats without live surface vegetation also were noted. When present, ribbed mussels were associated with both forms of the root mats. In some areas, ribbed mussels had colonized areas of exposed muck with good surface drainage.

Within the medium intertidal zone, substrates were more varied, consisting of muck, sandy muck and sand. In several areas, root mats that had eroded from the high intertidal zone were encountered during sampling. The low intertidal zone had a similar range in substrates.

The subtidal zone consisted almost entirely of muck, though a clayey sand substrate was encountered at one site. The live soft-shelled clams were collected from substrates of sand or sandy muck.

The results of the sampling program have been presented in Tables 4-4 and 4-5. Table 4-4 presents the results of the sampling effort to collect four targeted bivalve species at the 11 intensive sites and 26 additional sites. Table 4-5 presents the results of the ribbed mussel survey in the high intertidal zone for 36 sites.

a. Intensive Sampling Sites

At Site No. 1 only 29 live ribbed mussels were retained as sample specimens from the high intertidal zone. Ribbed mussels were not encountered in samples from any other zone. Live soft-shelled clams were not present in samples from any of the four sampling zones, though small soft-shelled clam shells had been observed in most of the samples from the subtidal zone. In addition, worms and mud whelks were also observed in samples from the subtidal zone.

At Site No. 2, a total of 127 live ribbed mussels were collected and retained as sample specimens from the high intertidal zone. Ribbed mussels were not present in samples from any other zone. Fourteen live soft-shelled clams were collected and retained as sample specimens from the medium intertidal zone. Only whole and half shells of this species were observed in samples from the low and subtidal zones. Mud snails were also observed in samples from the subtidal zone.

A total of 84 ribbed mussel were collected and retained as specimens from the high intertidal zone at Site No. 3. Ribbed mussels were not present in samples from any other zone. No live soft-shelled clams were present in samples at this site, though shells were encountered in samples from the low intertidal and subtidal zones. Mud snails were again observed in samples from the subtidal zone.

At Site No. 4, 150 ribbed mussels were collected and retained as specimens from the high intertidal zone. Ribbed mussels were not present in samples from any other zone. Only one live, small soft-shelled clam was collected in the intertidal zone. Shells from this species were noted in the samples from the low intertidal zone. Mud snails were observed in the samples from the subtidal zone.

At Site No. 5, a total of 145 ribbed mussels were collected and retained as specimens from the high intertidal zone. Ribbed mussels were not present in samples from any other zone, nor were live soft-shelled clams. Soft-shelled clam shells were only observed in samples from the subtidal zone, along with mud snails and one live surf clam (Spisula solidissima).

At Site No. 6, 125 ribbed mussels were collected and retained as specimens from the high intertidal zone. An additional 3 ribbed mussels were collected from the medium intertidal zone but were not retained because it appeared that they had been transported to the site from another location. They were attached to a root mat of Spartina which probably had been eroded away from a larger mat within the high intertidal zone. Only one live, small soft-shelled clam was collected at this site within the low intertidal zone. This specimen was not retained because of a cracked shell. Empty shells from this species and mud snails were observed in samples from the low intertidal and subtidal zones.

A total of 116 ribbed mussels were collected and retained as specimens from the high intertidal zone at Site No. 7. Ribbed mussels were not encountered in samples from other zones. Samples from the medium and low intertidal zones did not contain any live soft-shelled clams or shells. Empty shells of soft-shelled clams were observed in samples from the subtidal zone.

At Site No. 8, 100 ribbed mussels were collected and retained as specimens within the high intertidal zones. Within the remaining zones, ribbed mussels were not present in any of the samples. A total of 6 soft-shelled clams were collected within the medium intertidal zone. Mud snails and worms were also observed in samples from this zone. Samples from the low intertidal and subtidal zones contained shells from soft-shelled clams, mud snails and worms.

The high intertidal zone at Site No. 9 contained only rip-rap, bricks and debris and was absent of any ribbed mussel habitat. Ribbed mussels were not present in samples from any other zone. One live, small soft-shelled clam was collected in the medium and low intertidal zones and the subtidal zone. Unidentified bivalves,

worms, mud snails and empty shells of the soft-shelled clam were observed in samples from the low intertidal zone. Empty shells of the soft shelled clam were observed in samples from the subtidal zone.

At Site No. 10, a total of 30 ribbed mussels were collected and retained as specimens from the high intertidal zone. One ribbed mussel was collected but not retained from samples from the medium intertidal zone. Unidentified bivalves, worms, mud snails and empty shells of the soft-shelled clam were observed in samples from the low intertidal zone. No live soft-shelled clams were found in the low intertidal zone. Soft-shelled clam shells and one live, small soft-shelled clam was collected in samples from the subtidal zone.

At Site No. 11, 100 ribbed mussels were collected and retained as specimens from the high intertidal zone. Ribbed mussels were not present in samples from other zones. Soft-shelled clam shells were observed in samples from each of the other zones. Worms, mud snails and unidentified bivalves were observed in samples from the low intertidal and subtidal zones. A total of 5 live, small soft-shelled clams were collected in samples from the subtidal zone.

b. Additional Sampling Sites

At 25 additional sites, only ribbed mussels were generally encountered and collected within the high intertidal zone. The number of ribbed mussels retained for tissue analysis ranged from a low of 1 to a high of 125. (Table 4-4). At three sampling sites, Nos. 14, 17 and 18, no ribbed mussels were found. At six sites, Nos. 15, 19, 25, 30, 35 and 37, less than 20 live ribbed mussels were collected as samples. The five ribbed mussels collected at site No. 25 were lost and not sent to the lab. Site No. 28B was sampled in the medium intertidal zone only for soft-shelled clams. A total of 72 live specimens were collected.

c. Ribbed Mussel Survey

The results of the ribbed mussel survey, conducted at both intensive and additional sites, is presented in Table 4-5. The table summarizes the total number of live, dead whole shells, and half shells of ribbed mussels counted within a defined sample area. Also included are calculations of the density of live and dead whole shells per square meter, and the percentage of dead mussels. The number of half shells were not used in calculating the density of mussels or the percentage of dead mussels.

The five sites (4, 8, 11, 22, 27) with the highest densities (greater than 75 mussels per square meter) also have low percentages of dead mussels (4.7 percent to 18.2 percent). The median density for these sites is 113.3 and the median percent dead whole shells is 10.4. These sites are all located south of the Rahway River on the Arthur Kill. Site 27 had the highest density of mussels at 403.3 per square meter, with 10.6 percent dead mussels. Eight other sites (3, 10, 20, 21, 26, 31, 32, 36) also have low percentages of dead mussels (0 percent to 6.5 percent), but also have lower densities (less than 50 per square meter). These sites are located in areas such as Newark Bay, Hackensack River, Old Place Creek, the mouth of Sawmill Creek, Rahway River and the eastern side of Pralls Island. The ribbed mussel median density is 22 mussels per square meter, with

a range of 2.2 to 42. The median percentage of dead mussels is 4.5, with a range of 0.0 to 6.5.

Nine sites (1, 2, 15, 16, 18, 19, 24, 25, 33) with higher percentages of dead mussels (greater than 50 percent) generally had densities less than 50 ribbed mussels per square meter. These sites are generally clustered between Elizabeth Port Marsh and Gulfport Marsh on the Arthur Kill, and includes the mouth of Old Place Creek. The range in the percentage of dead mussels is from 52.7 percent to 100 percent, with a median of 79 percent. Density ranges from less than 1 to 50.4 ribbed mussels per square meter, with a median density of 10.2. It should be noted that Site Nos. 15 and 18 did not contain any live mussels within the sample area, and contained only 2 and 1 dead whole shells, respectively.

An additional nine sites (5, 6, 7, 12, 13, 23, 29, 34, 35) had more moderate percentages of dead mussels (13 percent to 45.3 percent), with a median of 27.8 percent. The density of ribbed mussels at these sites ranged from 2.8 to 42.3 ribbed mussels per square meter, with a median density of 14 mussels per square meter.

Site locations and characteristics (i.e., exposure to wind and waves, erosion, width of the high intertidal zone, percentage of ground with suitable habitat, salinity ranges of adjacent waters) influence the density of mussels found at each site. Site No. 10, for example, is located close to the entrance of the Hackensack River to Newark Bay. Fluctuations in salinity at this location may make this area less desirable habitat for mussels and hence, the low density of 2.2 ribbed mussels per square meter. Site 34, on the west side of Pralls Island, has a low density because large portions of the sample area are covered by thick, solid tar mats, possibly created by past oil spills. These mats have formed impervious surfaces which do not support life. Portions of the sample areas contained these tar mats, reducing the potential number of mussels counted per square meter.

At four sites (9, 17, 30, 37), neither live mussels nor dead whole shells were found. At Site No. 9, insufficient habitat is present to support ribbed mussels. The substrate in which a bed of Spartina is rooted consists of sand several inches in depth and does not provide a stable substrate to which the mussels can attach. A root mat which would provide a stable substrate had not developed at this site. Site No. 30 also represents an area without suitable habitat. The high intertidal zone consisted of mostly muck and contained sparse amounts of Spartina. Both Site No. 17 on the Elizabeth River, and Site No. 37 on Sawmill Creek are located upstream on both waterways. While a low marsh with appropriate substrates for mussel attachment are present at each site, fluctuations in the salinity of the water at these locations may be intolerable for mussels. At Site No. 14 mussel habitat was not present in the high intertidal zone and a survey could not be taken.

Site No. 28B (Ward Point) was not part of the ribbed mussel survey.

4.3.2 Birds

Three studies were conducted to determine the effects of the spill on birds and bird populations, including an accounting of oil-related bird deaths and injuries

for two months following the spill, changes in reproductive success of aquatic bird species of the area and effects on avian food sources, such as fiddler crabs.

4.3.2.1 Oil-Related Deaths and Injuries

Information regarding oil-related deaths and injuries to birds was gathered in the process of completing the task of compiling data for the sampling catalog. This data was provided by the NYC Parks and Recreation, NYSDEC and U.S. Fish and Wildlife Service, but appears to be data compiled by Exxon and Tri-State Bird Rescue. This data is summarized below.

Through March 7, 1990, the total deaths and injuries were reported as follows:

654 found dead
150 treated (40 died, 110 survived)
total of 694 birds dead

The sites where these birds were found are shown in Table 4-6. Table 4-7 indicates the type and number of birds found dead. Table 4-8 indicates the total number of birds found dead by date.

Waterfowl and gulls are the two major groups of birds killed by the spill. More waterfowl than gulls were found dead from January 3 through 7, 18, 30 and February 6. At other times, through February 22, more gulls than waterfowl were found dead, with the exception of dates when an equal number of gulls and waterfowl were found dead (January 8, 15, 25; February 14 on Table 4-8).

4.3.2.2 Population Studies

The Manomet Bird Observatory (MBO) has conducted research on aquatic bird populations of the Arthur Kill and Kill van Kull for the past five years. The objective of field studies conducted in 1990 was to compare its results with those of the previous four years, i.e., compare data regarding the ecology of the birds prior to and following the January 1990 oil spill. Several other significant releases of oil occurred in the months following the January 1990 spill. The full text of the final report of MBO, entitled "Aquatic Birds of the Arthur Kill: Short-Term Impacts Following Major Oil Spills" is provided in Appendix II-E. The summary of that report follows.

Despite a long history of environmental degradation and wetlands alteration, the Arthur Kill continues to provide important breeding and feeding habitat for aquatic birds, including Snowy Egret, Great Egret, Cattle Egret, Glossy Ibis, Black-crowned Night Heron and Herring Gull. Wader populations continue to increase in size and diversity illustrating the rich ecological potential of the estuary. Strong populations returned to the Arthur Kill in 1990 possibly reflecting high productivity in previous years and favorable wintering conditions.

Nesting was significantly delayed for all species at all three colony-sites. Fewer than one-third of expected nesting attempts occurred in April. In addition, mean hatch dates for Snowy and Cattle Egrets was late in 1990.

Although omnivorous and upland foraging species (i.e., Black-crowned Night Heron, Cattle Egret, Herring Gull) were relatively unaffected in 1990, species foraging primarily in tidal habitats showed lowered reproductive success in several measured parameters.

All wader species examined with one (non-tidal) exception suffered higher chick mortality in 1990 compared to previous years. Snowy Egrets were the most seriously affected with only 25-34 percent of hatched chicks surviving 20 days in the nest. In addition, for some species, chicks died at an earlier age in 1990 compared to prior data.

Higher chick mortality in 1990 can be attributed to a greater proportion of chick deaths occurring in the nest, and by inference, to starvation for Snowy Egrets and Glossy Ibises. In contrast, the greater proportion of Cattle Egret chicks that died in 1990 on Isle of Meadows and were not found on subsequent visits (missing) suggests predation.

Although weight gain did not differ in 1990 for any wader species, culmen growth was significantly slowed for Glossy Ibises and for first-hatched Black-crowned Night-Heron chicks. Culmen growth, especially in the long-billed Glossy Ibis, may be a relatively sensitive indicator of environmental conditions.

Cattle Egrets showed variation in flightline direction over the study period, but no other species did so. No pattern in the several direction changes at two colony-sites is apparent. Although flight rates decreased at several sites for both Snowy Egrets and Glossy Ibises in 1990, rates did not change for Great Egrets-another tidal species (Palmer, 1962).

Depressed flightline rates could result from individuals spending more time at the colony-site or at feeding sites. Because both Snowy Egrets and Glossy Ibises experienced poorer reproductive success and greater chick mortality (especially dead in the nest/starvation events) in 1990, it is likely that adults of these species spent greater time at feeding sites than in previous years.

The analyses of foraging populations and behavior showed no clear differences in 1990 compared to previous years. Although examined habitats were subjected in varying degrees to oil contamination, no avoidance or selection behaviors were observed.

Analyses of foraging data show that some species may be relatively inflexible in adjusting to pollution events. Snowy Egrets and Glossy Ibises were apparently unable to compensate for degraded feeding habitats by selecting new sites or by altering foraging behaviors (strike rate).

4.3.2.3 Food Source Species

Dr. Joanna Burger of Rutgers University conducted studies from April 15 to August 15, 1990, to assess the impacts of the January 2, 1990 oil spill on avian food resources. The specific objectives of the investigation were to assess the availability of avian food resources (i.e., fish and shrimp) for the breeding season, and to examine fiddler crab numbers and behavior.

Two sites were chosen for sampling fish and shrimp by seining in order to document any differences in number, size, and species diversity between 1989 and 1990. Fiddler crab numbers and behavior (e.g., feeding, fighting, position in burrows) were examined at five locations to ascertain if differences existed from site to site.

The Governments have not requested a full statistical analysis of the data collected under these studies, and so no conclusions regarding the availability of avian food resources can be drawn at this time.

The full text of the final report of Dr. Burger, entitled "Assessment of Impacts of Oil Spill on Avian Food Resources" is provided in Appendix II-F. Raw data are available upon request.

REFERENCES:

NOAA, 1989, Tide Tables 1990, High and low water predictions, East Coast of North and South America, including Greenland: National Oceanic and Atmospheric Administration, U.S. Department of Commerce, and National Ocean Service, 289p.

Palmer, R. S., 1962, Handbook of American Birds. Vol. 1: Loons through Flamingos. Yale University Press, New Haven.

Table 4-1

SAMPLING STATION NAMES

	INTENSIVE STATIONS	
1	Goethals - s	NY
2	Elizabethport Marsh	NJ
3	Pralls Island - ne	NY
4	opposite Cedar Point	NJ
5	adjacent to Neck Creek	NY
6	Elizabethport - n	NJ
7	Rahway River - w	NJ
8	adjacent to Smith Creek	NJ
9	Turnpike Bridge - s	NJ
10	Hackensack River	NJ
11	Outerbridge - s	NY

	NON-INTENSIVE/ ADDITIONAL STATIONS	
12	Piles Creek - w	NJ
13	Kill Van Kull - w	NY
14	Droyers Point	NJ
15	Howland	NY
16	Old Place Creek - mouth	NY
17	Elizabeth River - up	NJ
18	Morses Creek	NJ
19	Gulfport Marsh	NY
20	Sawmill Creek - mouth	NY
21	Pralls Island - s	NY
22	Citgo	NJ
23	Isle of Meadows	NY
24	Fresh Kills	NY
25	Tufts Point	NJ
26	Rahway River - up	NJ
27	Kreischerville	NY
28S	Ploughshare Point	NJ
28B	Ward Point	NY
29	Sawmill Creek - up	NY
30	Piles Creek - up	NJ
31	Turnpike Bridge - n	NJ
32	Old Place Creek - in	NY
33	Neck Creek - up	NY
34	Pralls Island - w	NY
35	Merrills Creek	NY
36	Old Place Creek - up	NY
37	Sawmill Creek - in	NY

mouth:	mouth of creek or river
up:	upstream of mouth
in:	most inland of 3 sampling stations
n:	north
s:	south
w:	west
ne:	northeast
NY:	New York
NJ:	New Jersey

Table 4-2
BOTTOM SEDIMENT SAMPLING
(Affected and Control Stations)

A)

TIDAL ZONE	TRANSECTS			COMPOSITES 0–2 cm SAMPLES
	1	2	3	
High Intertidal	▲	▲	▲	1
Medium Intertidal	▲	▲	▲	1
Low Intertidal	▲ ●	▲ ●	▲ ●	2
Subtidal	▲	▲	▲	1
Total Samples per Station (0–2 cm composite)				5

B)

CORE STATIONS	NUMBER OF CORES AT EACH STATION	TOTAL NUMBER OF CORES	NO. OF COMPOSITE SAMPLES (0–2 cm)
Affected (9)	15	135	45
Control (2)	15	30	10
Additional (26)	3	78	26
TOTAL		243	81

▲ Sample Core
● QA/QC Core

Tabular representation of core locations at the affected and control stations (A) and the number of cores collected (B). At the additional stations, only three cores were taken in the medium intertidal zone.

Table 4-3

SEDIMENT LABORATORY LOG SHEET

Date:

Lab Scientist:

Core Label:

Sections Placed into Jars:

Core Length (centimeters): add above section lengths

Grasses/Roots Present? If so, describe distribution.

Shell Material Present? If so, describe.

Noticeable Change in Grain-size with Depth? If so, describe.

Comments:

TABLE 4-4
RESULTS OF THE BENTHIC INVERTEBRATE SAMPLING

Site Name	Site No.	High Intertidal	Medium Intertidal	Low Intertidal	Subtidal
Goethals - s	DEP-1	29RM(A)	0(A,B)	0(B)	0(SCS(B)
Elizabethport Marsh	DEP-2	127RM(A)	14SC(SCS(B,C)	0(SCS(B,C)	0(SCS(B)
Pralls Island - ne	DEP-3	84RM(A,B)	0(B)	0(SCS(B)	0(SCS(B)
opposite Cedar Point	DEP-4	150RM(A,B)	1SC(B,C)	0(SCS(B)	0(B)
adjacent to Neck Creek	DEP-5	145RM(A)	0(C)	0(A,C)	0(SCS(B)
Elizabethport - n	DEP-6	125RM(A)	3RM(A,B)	1SC(SCS(C)	0(SCS(D)
Rahway River - w	DEP-7	116RM(A,B)	0(B)	0(B)	0(SCS(B)
adjacent to Smith Creek	DEP-8	100RM(A,B,C)	6SC(B,C)	0(SCS(B)	0(SCS(B)
Turnpike Bridge - s	DEP-9	0(A,C)	1SC(B,C)	1SC(SCS(B)	1SC(SCS(B)
Hackensack River	DEP-10	30RM(A)	1RM(A,B)	0(SCS(B)	1SC(SCS(B)
Outerbridge - s	DEP-11	100RM(A,B)	0(SCS(B)	0(SCS(B,C)	5SC(SCS(B)
Piles Creek -w	DEP-12	68RM(A)	NA	NA	NA
Kill Van Kull - w	DEP-13	100RM(A,B)	NA	NA	NA
Droyers Point	DEP-14	(1)	NA	NA	NA
Howland	DEP-15	5RM(A,B)	NA	NA	NA
Old Place Creek - mouth	DEP-16	71RM(A)	NA	NA	NA
Elizabeth River - up	DEP-17	0(A,B)	NA	NA	NA
Morses Creek	DEP-18	0(A,B)	NA	NA	NA
Gulfport Marsh	DEP-19	19RM(A,C)	NA	NA	NA
Sawmill Creek - mouth	DEP-20	78RM(A,B)	NA	NA	NA
Pralls Island - s	DEP-21	100RM(A,B)	NA	NA	NA

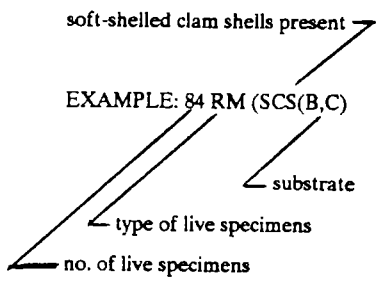
TABLE 4-4 (continued)

Site Name	Site No.	High Intertidal	Medium Intertidal	Low Intertidal	Subtidal
Citgo	DEP-22	100RM(A,B)	NA	NA	NA
Isle of Meadows	DEP-23	110RM(A,B)	NA	NA	NA
Fresh Kills	DEP-24	123RM(A,B)	NA	NA	NA
Tufts Point	DEP-25	5RM(A,C)	NA	NA	NA
Rahway River - up	DEP-26	100RM(A,B)	NA	NA	NA
Kreischerville	DEP-27	125RM(A,B)	NA	NA	NA
Ward Point	DEP-28B	NA	26SC(C)	NA	NA
Sawmill Creek - up	DEP-29	42RM(A,B)	NA	NA	NA
Piles Creek - up	DEP-30	1RM(A,B)	NA	NA	NA
Turnpike Bridge - n	DEP-31	100RM(A,B)	NA	NA	NA
Old Place Creek - in	DEP-32	125RM(A,B)	NA	NA	NA
Neck Creek - up	DEP-33	70RM(A,B)	NA	NA	NA
Pralls Island - w	DEP-34	100RM(A,B)	NA	NA	NA
Merrills Creek	DEP-35	35RM(A,B)	NA	NA	NA
Old Place Creek - up	DEP-36	100RM(A,B)	NA	NA	NA
Sawmill Creek - in	DEP-37	11RM(A,B)	NA	NA	NA

Note (1) : The high intertidal zone consisted of riprap. Natural habitat was not present.

LEGEND

RM=Ribbed Mussel (live)
SC=Soft-Shelled Clam (live)
SCS=Empty Soft-Shelled Clam Shells
A=Root Mat and Sediments
B=Muck
C=Sand
D=Clayey Sand



Source: Louis Berger and Associates, Inc., 1991

TABLE 4-5
RESULTS OF THE RIBBED MUSSEL SURVEY FOR THE HIGH INTERTIDAL ZONE (A)

Site Name	Site No.	Area Sampled (Sq. Meters)	Number of Mussels Counted					
			Live	Dead Whole Shells	Dead Half Shells	Total(1)	Density(2)	% of Dead Mussels(3)
Goethals - s	DEP-1	5	12	36	52	48	9.6	75.0
Elizabethport Marsh	DEP-2	5	46	183	24	229	45.8	79.9
Pralls Island - ne	DEP-3	5	47	3	29	50	10.0	6.0
opposite Cedar Point	DEP-4	5	463	103	7	566	113.2	18.2
adjacent to Neck Creek	DEP-5	5	88	73	37	161	32.2	45.3
Elizabethport - n	DEP-6	5	101	20	12	121	24.2	16.5
Rahway River - w	DEP-7	5	23	15	24	38	7.6	39.5
adjacent to Smith Creek	DEP-8	5	654	80	118	734	146.8	10.9
Turnpike Bridge - s	DEP-9	5	0	0	0	(B)	--	--
Hackensack River	DEP-10	5	11	0	7	11	2.2	0.0
Outerbridge - s	DEP-11	5	363	18	36	381	76.2	4.7
Piles Creek -w	DEP-12	5	17	4	13	21	4.2	19.0
Kill Van Kull - w	DEP-13	5	53	17	24	70	14.0	24.3
Droyers Point	DEP-14	--	--	--	--	(C)	--	--
Howland	DEP-15	5	0	2	4	2	0.4	100.0
Old Place Creek - mouth	DEP-16	5	6	60	7	66	13.2	90.9
Elizabeth River - up	DEP-17	5	0	0	0	(B)	--	--
Morses Creek	DEP-18	5	0	1	1	1	0.2	100.0
Gulfport Marsh	DEP-19	5	2	49	7	51	10.2	96.1
Sawmill Creek - mouth	DEP-20	5	39	2	5	41	8.2	4.9
Pralls Island - s	DEP-21	5	147	2	52	149	29.8	1.3

TABLE 4-5 (continued)

Site Name	Site No.	Area Sampled (Sq. Meters)	Number of Mussels Counted					
			Live	Dead Whole Shells	Dead Half Shells	Total(1)	Density(2)	% of Dead Mussels(3)
Citgo	DEP-22	3.75	353	72	64	425	113.3	16.9
Isle of Meadows	DEP-23	5	153	59	91	212	42.4	27.8
Fresh Kills	DEP-24	5	88	98	38	186	37.2	52.7
Tufts Point	DEP-25	5	10	29	2	39	7.8	74.4
Rahway River - up	DEP-26	5	199	11	34	210	42.0	5.2
Kreischerville	DEP-27	2.75	992	117	62	1109	403.3	10.6
Sawmill Creek - up	DEP-29	5	20	3	3	23	4.6	13.0
Piles Creek - up	DEP-30	5	0	0	1	(B)	--	--
Turnpike Bridge - n	DEP-31	5	98	2	1	100	20.0	2.0
Old Place Creek - in	DEP-32	5	162	7	13	169	33.8	4.1
Neck Creek - up	DEP-33	5	60	192	14	252	50.4	76.2
Pralls Island - w	DEP-34	5	62	24	62	86	17.2	27.9
Merrills Creek	DEP-35	5	9	5	5	14	2.8	35.7
Old Place Creek - up	DEP-36	5	116	8	14	124	24.8	6.5
Sawmill Creek - in	DEP-37	5	0	0	0	(B)	--	--

Legend

(1) Total = Live Mussels + Dead Whole Shells
(2) Density = Total/Area Sampled
(3) % of Dead Mussels = Whole Shells/Total x 100
(A) Results compiled from the biological sampling program conducted between 4/18/90 and 5/14/90
(B) Poor or sparse mussel habitat present at site
(C) Mussel habitat within the high intertidal zone was not present at site

Source: Louis Berger and Associates, Inc., 1991

Table 4-6

TOTAL NUMBER OF BIRDS FOUND DEAD AND ALIVE BY LOCATION
(through February 22, 1990)

LOCATION	DEAD BIRDS	LIVE BIRDS
Sawmill Creek	108	8
Neck Creek	85	8
Pralls Island	88	19
Gulfport	50	2
Isle of Meadows	30	11
Piles Creek	30	9
Staten Island (Gen.)	22	7
Bayway Refinery	12	16
ConEd (Stat. Is.)	59	10
Tufts Pt.	12	2
Old Place Creek	29	0
Smith Creek	4	2
Shooters Island	2	3
Port Reading Marsh	5	0
Elizabethport	13	1
GATX Term.	2	4
Goethals Marsh	1	0
Elizabeth River	1	0
Elizabeth Pt. Pk.	0	1
Newark Bay	0	1
Outerbridge Marsh	1	0
Tremley	3	1
Arthur Kill	4	5
Robbins Reef	2	0
Jamaica Bay	3	0
AMAX	2	0
Carteret	2	0
Perth Amboy	1	0
May's Landing	12	0
CITGO	0	1
Rahway River	6	4
Northville	0	1
Rossville	28	8
Pralls Creek	0	1
Unknown	37	25
TOTAL	654	150

Table 4-7

TYPES AND NUMBER OF BIRDS FOUND DEAD
(through February 22, 1990)

Waterfowl		Number Dead
mallard		136
black duck		76
ruddy duck		3
gadwall		30
Canada goose		16
canvasback		13
bufflehead		8
green winged teal		4
hood merganser		3
common merganser		1
red breasted merganser		1
lesser scaup		3
greater scaup		2
pied-billed grebe		1
northern shoveler		1
	subtotal	298

Gulls		
great black backed gull		106
herring gull		109
ring billed gull		9
Bonaparte's gull		2
unknown gull		73
	subtotal	299

Other		Number Dead
black crowned night heron		12
green heron		3
unknown heron		2
unknown egret		2
double crested cormorant		4
rock dove		8
belted kingfisher		1
crow		1
clapper/king rail		1
unknown rail		1
American woodcock		1
northern harrier		1
other		20
	subtotal	57
	TOTAL =	654

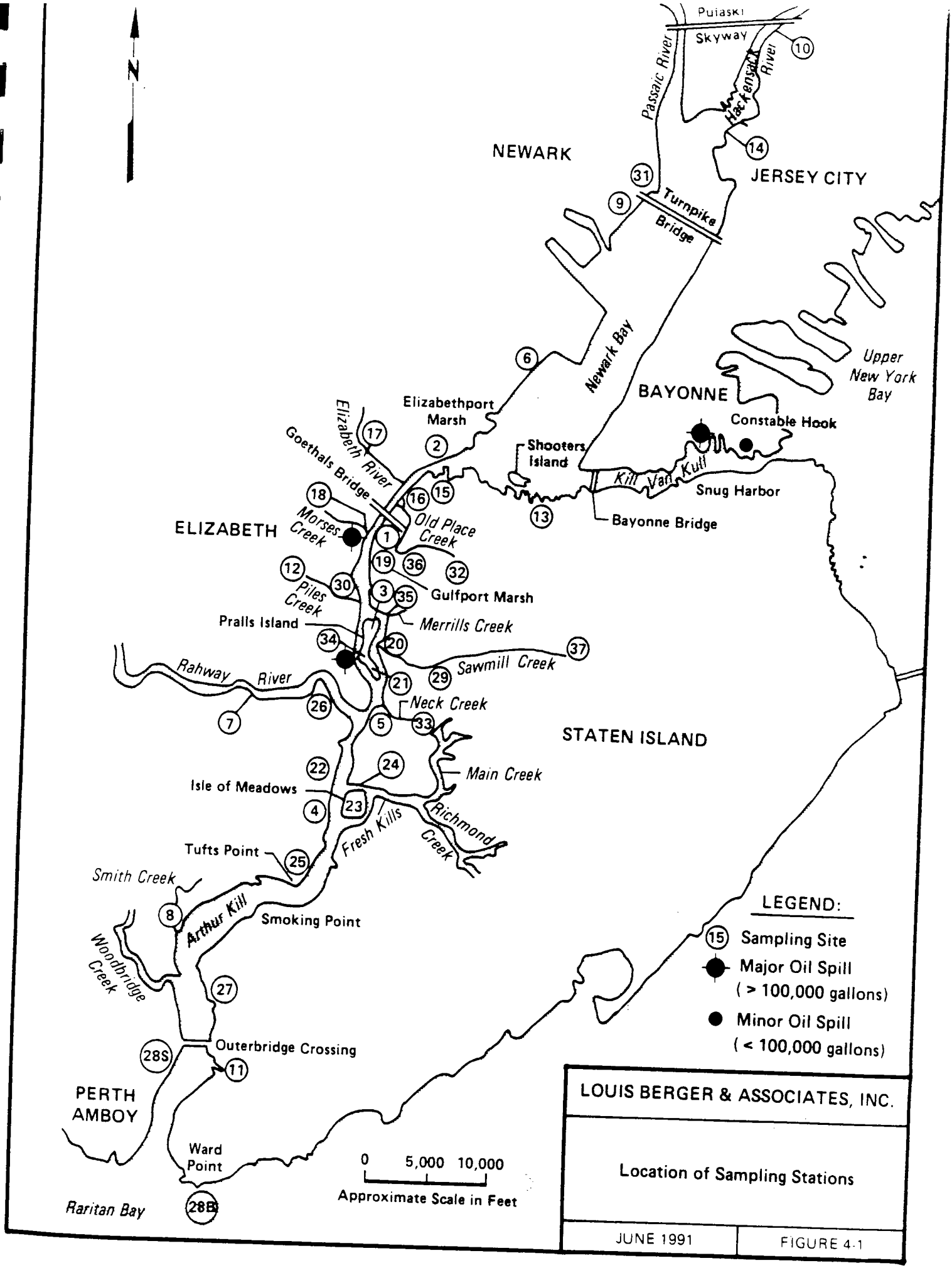
Table 4-8

TOTAL NUMBER OF BIRDS FOUND DEAD BY DATE
(through February 22, 1990) ***

Date	Number	Date	Number
Jan 3	16 *	Jan 27	14
4	9 *	28	5
5	44 *	29	5
6	92 *	30	3 *
7	13 *	31	20
8	32 **		
9	35	Feb 1	10
10	15	2	4
11	45	3	1
12	28	4	no data
13	29	5	6
14	33	6	3 *
15	28 **	7	18
16	31	8	6
17	6	9	2
18	15 *	10	0
19	11		
20	0 (no counts)	11	no data
21	1	12	7
22	17	13	6
23	16	14	2 **
24	6	15	0
25	4 **	16	4
26	9	17	0
		18	no data
		19	no data
		20	1
		21	0
		22	2

TOTAL = 654

* more waterfowl than gulls
** equal number of waterfowl and gulls
*** It is not known if the "0" counts in February are because no counts were taken or no birds were found dead.



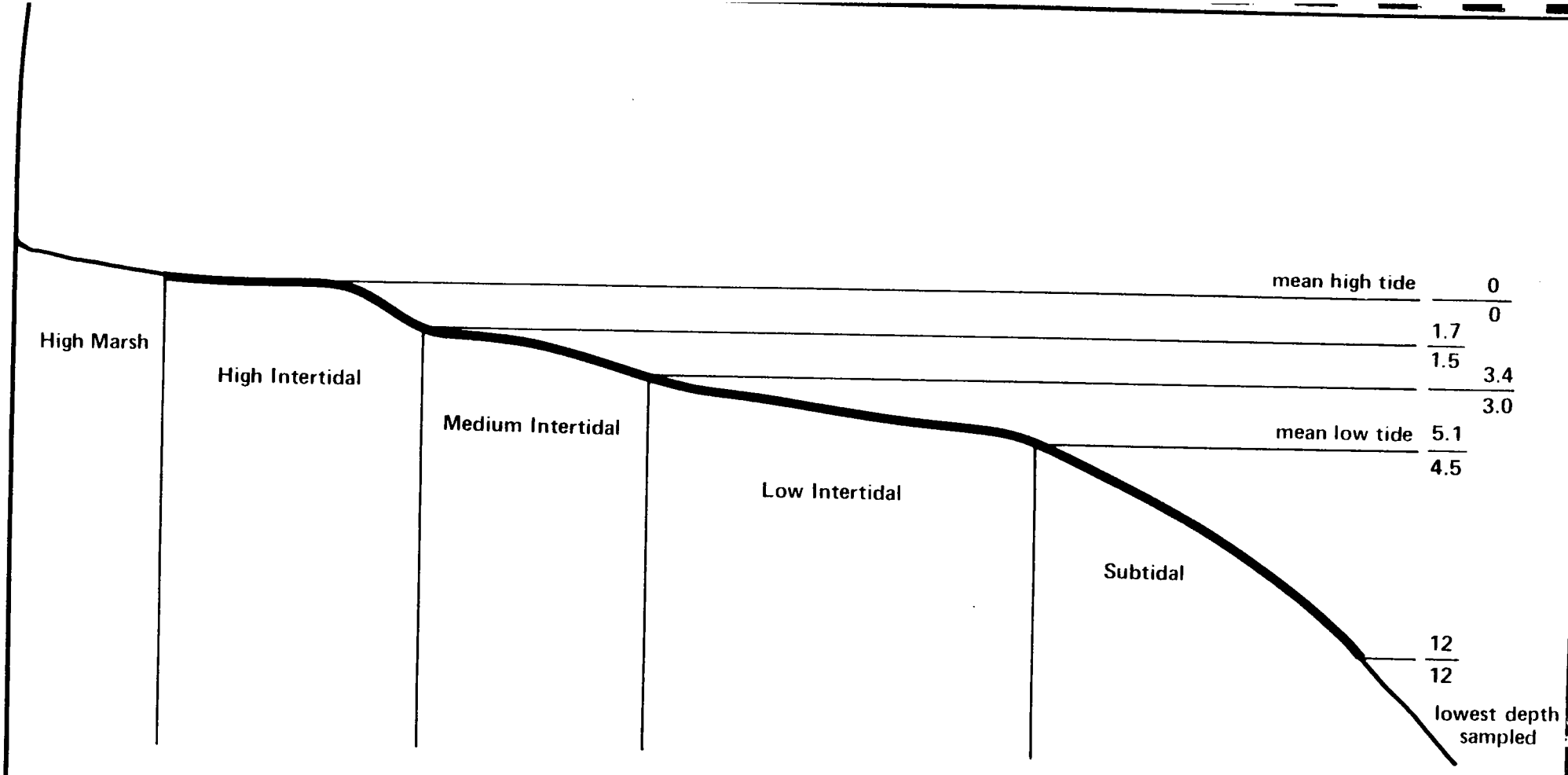
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Location of Sampling Stations

JUNE 1991 | FIGURE 4-1



Fig. 4-2: The custom-built sediment corer, operating off of the R/V Victoria. (Note the overpenetration protection board attached above the handles.)



NOT TO SCALE

LEGEND: (feet below mean high tide)

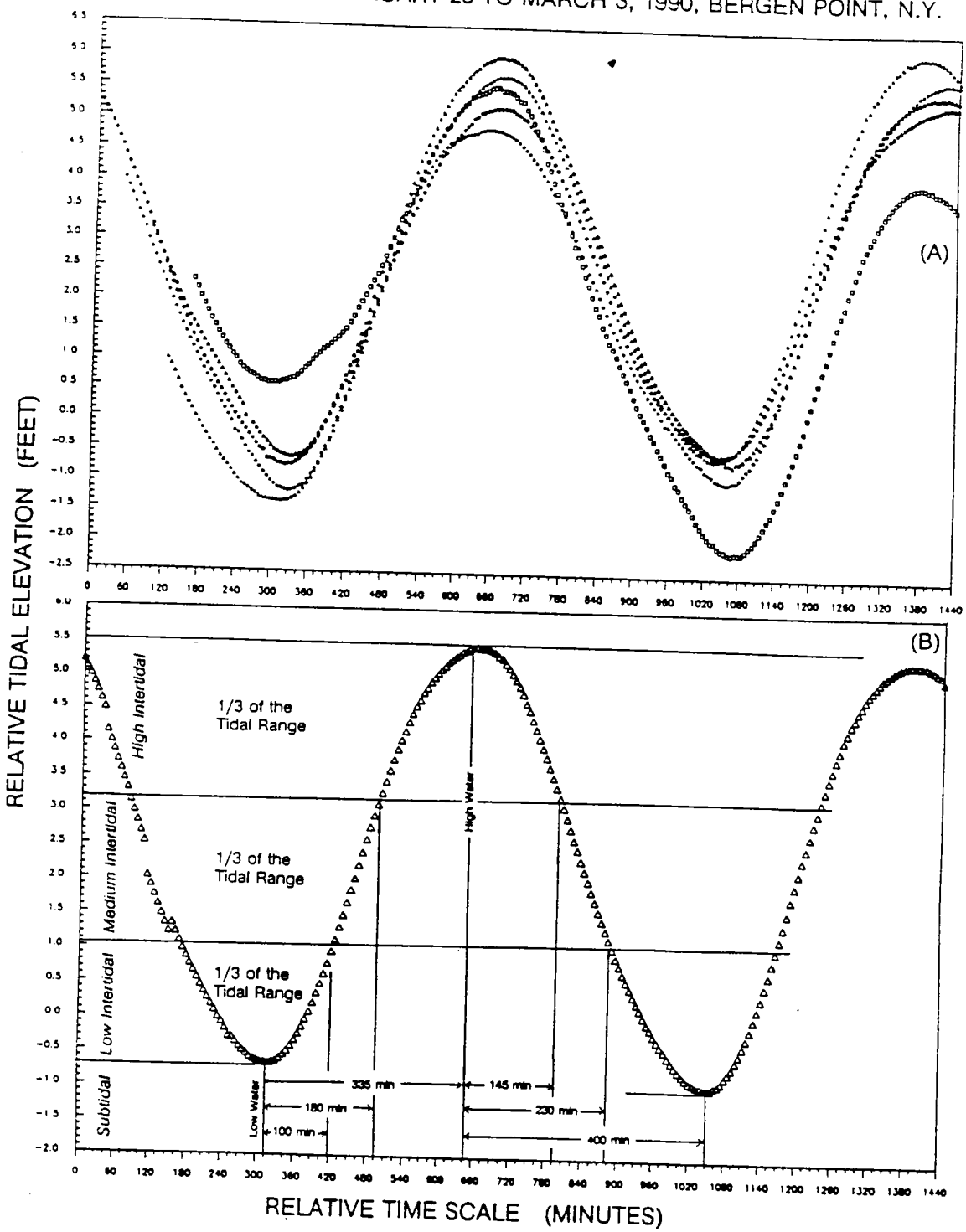
Arthur Kill - Newark Bay

Kill van Kull - Shooters Island

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Sampling Zones
for
Sediment and Benthic Samples

JUNE 1991 | FIGURE 4.3



Computed average tidal cycle based on five 24-hour tidal evaluation measurements at the Bergen Point gaging ststion of the U.S. Army Corps of Engineers: (A) daily tidal cycles are shifted so that high and low water overlap and (B) tidal cycles of (A) were averaged into one cycle for this time period.

FIGURE 4-4

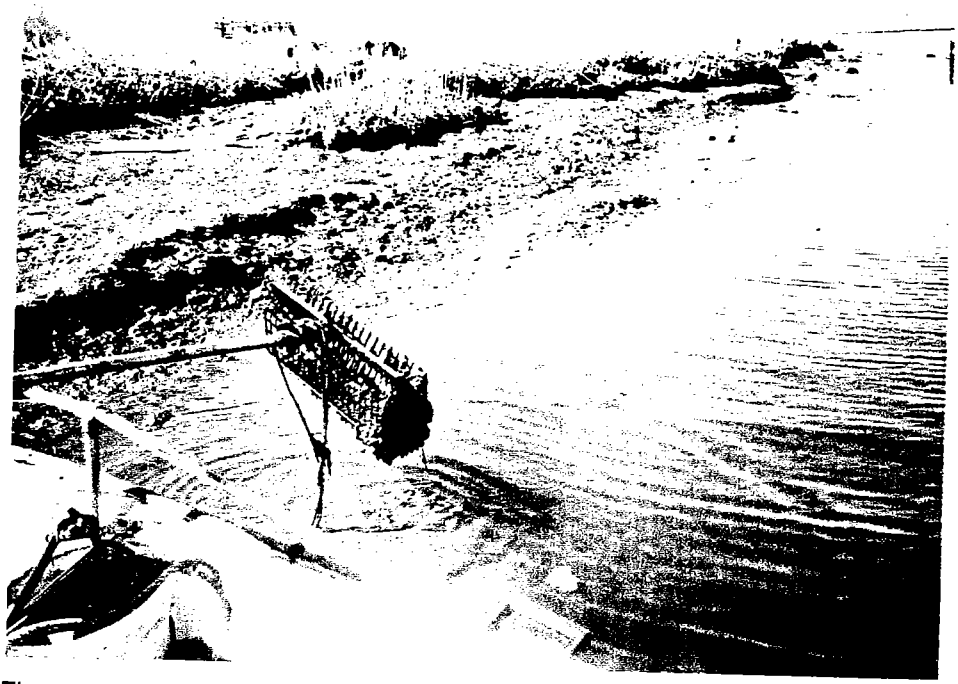


Figure 4-5: The variation of substrates in the intertidal zone includes mud flats, exposed matted muds, and vegetation. The line of trash and elevation change indicate the high water line, whereas the small stand of phragmites in the background marks the spring high water line.



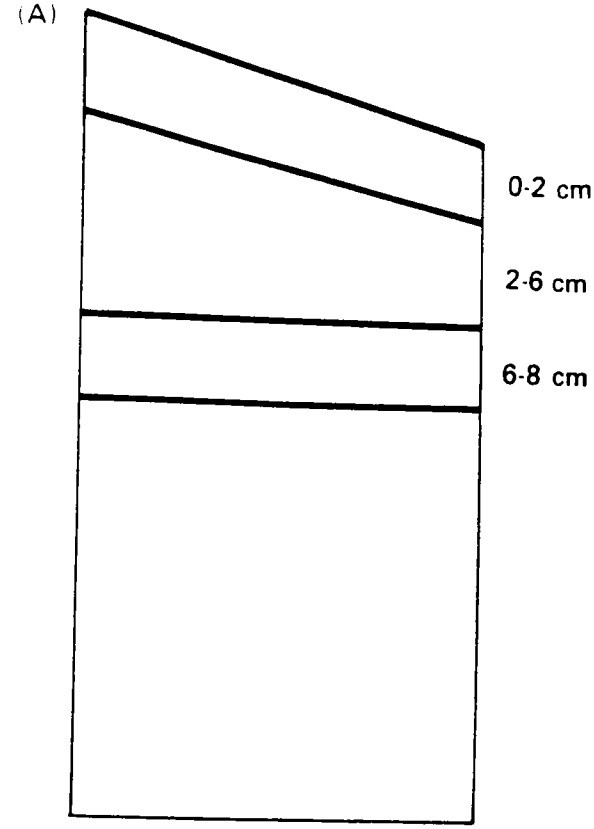
Figure 4-6: Stainless steel core catcher and cutter easily penetrates and holds the sediments collected by manual operation.

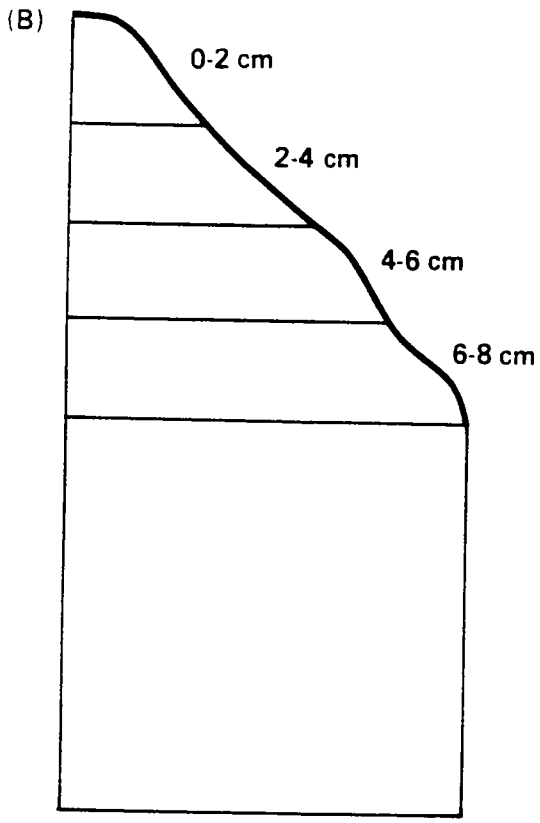


Figure 4-7: After each core was collected, it was removed with an aluminum foil-lined extrusion post where the core remained vertical. After loosening the screws of the cutter,the assembly was pulled down over the post. The core remained in the liner, which was capped, taped and labeled.



Figure 4-8: The stainless steel corer head assembly is cleaned after each coring attempt to prevent cross-contamination of samples.





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Cutting of Inclined Cores

JUNE 1991 | FIGURE 4-9

5.0 CHEMICAL ANALYSIS

5.1 Introduction

In response to the Scope of Services defined in the Request for Proposal for the investigation to support a natural resource injury assessment for the January 1-2, 1990 spill of Exxon No. 2 Fuel Oil into the Arthur Kill, a program to determine appropriate analytical approaches to the identification of petroleum hydrocarbons was undertaken. Enseco ERCO of Cambridge, Massachusetts was the primary laboratory. The Institute of Environmental Studies at Louisiana State University (LSU) was contacted to pursue analytical characterization by GC/MS.

The approach was developed by LBA, in concert with the Governments' Technical Committee, in particular with the New Jersey Department of Environmental Protection, Office of Quality Assurance and the Division of Science and Research. The analytical chemical protocols and procedures described in this Section involve the analysis of sediment and biologic samples collected from areas along the Arthur Kill, and its tributaries, Raritan Bay, Kill van Kull, Newark Bay, and the Hackensack River.

The analytical protocols required to be followed were supplied by the New Jersey Department of Environmental Protection and remain their exclusive property. The two documents are identified as:

1) Identification and Quantitation of Total Petroleum Products in Soil, Document # OQA-QAM-018 12/89, Revision dated April 5, 1990, and

2) Determination of Polynuclear Aromatic Hydrocarbons in Petroleum Hydrocarbons in Petroleum Contaminated Solids Matrices, Document # OQA-QAM-014 12/89, Revision dated April 6, 1990.

The discussion in the following sections refers primarily to QAM document 018 and is based on a determination of total petroleum hydrocarbons by total integration of the Flame Ionization Detector (FID) interfaced with a gas chromatograph (GC). The second document involves utilization of GC/MS which, except for the reference oils, was not used as part of this investigation.

Initially, three reference oils, two Exxon and one Cibro, were analyzed by GC/FID and GC/PID (photoionization detector). Mass spectral characterization was also performed by LSU. LSU ran the reference materials stated above utilizing this method. Appendix II-G contains both the proposal submitted for this work and the actual results submitted. After the initial GC/MS work was completed, use of this technique was discontinued.

Preliminary investigations into the feasibility of using a gas chromatograph interfaced with a flame photometric detector (FPD) in the sulfur mode were also conducted. This work was done by Enseco. At the direction of the GTC, this technique was not continued.

5.2 General Approach

In order to assess the possible effects of petroleum on the environment, analytical methodologies must be employed to determine qualitative identification and quantitation of that product in the matrix of interest - water, sediment, and tissue. Petroleum is a complex mixture of chemical constituents. Included among these constituents are normal and branched or isomeric alkanes, alkenes, cyclic and aromatic hydrocarbons. Other classes of compounds, depending on the crude stock, may also be present. Among these classes can be certain heavy metals, heteroaromatics and mercaptans.

The complexity of the composition of petroleum forms the basis for the chemical identification of petroleum oils. This correlation is fundamentally a comparison of two or more oil samples and the degree to which the samples have been subjected to the effects of biodegradation, evaporation and weather. This occurrence is commonly referred to as weathering.

5.2.1 Instrumentation

Weathered and unweathered suspect or source oils were analyzed by gas chromatography. The resultant chromatograms were compared visually and by means of specific peak-height or peak area ratios. Two samples of oils with identical chemical compositions will have identical instrument responses when analyzed for the entire array of chemical species. This technique of matching is referred to as "fingerprinting". The fingerprinting incorporated into this project employed the use of a FID and a PID, interfaced to a gas chromatograph.

The FID is considered a universal detector because of its high sensitivity, wide linear range and great reliability. Essentially, this detector consists of a small hydrogen flame burning in an excess of air surrounded by an electrostatic field. The organic compounds eluted from the column are burned in this flame. During the combustion, ionic fragments and free electrons are formed and collected. This collection produces an electric current proportional to the number of carbon atoms in the sample component. The FID responds only to ionizable carbons atoms. Response to an FID diminishes with increasing substitution of halogens, amines, and hydroxyl groups.

A PID employs photoionization as the source of the energy which ionizes molecules in the detection chamber. The source at 10.2 electron volts emits photons. If these photons possess sufficient energy, they will free the outermost molecular electron of molecules that are struck. The minimum amount of energy needed to eject the outermost electron is called the molecule's ionization potential. Within the detector is a chamber containing a pair of electrodes. A positive potential is applied to one electrode creating a field which drives the formed cations (positively charged ions) to the collector electrode. The resultant current is proportional to the concentration and is measured. A PID is employed primarily for the analysis of aromatic compounds.

In addition to the fingerprinting with the FID and PID, a second approach utilized a gas chromatograph/mass spectrometer. This method monitors both pyrogenic and petrogenic source hydrocarbons. Pyrogenic hydrocarbons result from the combustion of hydrocarbon from engine exhaust, for example. A petrogenic

hydrocarbon source is from rock, e.g., crude oil. Petrogenic origin is indicated by a pristane/phytane ratio near unity, low carbon preference index and the presence of petrogenically derived pentacyclic triterpanes.

Before performing any data acquisitions, a mass calibration was performed using perfluorotributyl amine in the full scan mode. Prior to analysis, a five point calibration curve was acquired to demonstrate that the instrument and the analyte's response is linear. This is referred to as the linear dynamic range of the detector. All analyses must fall within this range, or the sample must be diluted in such a way that the response will fall within the linear range.

5.2.2 Extraction of Biological Samples

The available tissue was homogenized using a Cuisinart, spiked with the appropriate surrogate (ortho-terphenyl), digested with 10 N (Normal) potassium hydroxide and methanol in a 1:1 mixture at 9° C for 2 hours. The sample was then extracted with hexane. The eluate was dried with sodium sulfate, concentrated, and subjected to an alumina cleanup. The two fractions, aliphatic and aromatic, were combined for analysis. The elutriates were then reduced in volume and injected into the GC/FID using d_{10} phenanthrene as the quantitation standard.

Biogenic and other naturally occurring materials will cause interferences in the analysis of tissue extracts. Alumina cleanup is used as a means to eliminate matrix interference.

5.2.3 Laboratory Bottles

All bottles in which sediment samples were stored were shipped from Enseco East Laboratory in Somerset, New Jersey. ICHEM bottles, Series 300 were utilized.

5.2.4 Sediment Compositing and Aliquoting

The 0 to 2 centimeter section of each core from each transect was combined in ICHEM Series 300 bottles and shipped to the laboratory for homogenization, compositing and aliquoting. All biological material e.g., grasses, leaves, and shells and rocks greater than one centimeter in diameter, were discarded. The sample was scraped into a cone and divided into quarters. The two diagonally opposite quarters were combined and mixed thoroughly. Then the sample was combined into one pile and quartered. From these quarters, the aliquots were assigned: three for archiving and one for fingerprinting by the laboratory chosen for this analysis, Enseco ERCO of Cambridge, Massachusetts.

5.2.5 Extraction of Sediment Samples

Approximately 30 grams of sediment was extracted with methylene chloride using a soxhlet extractor. Prior to extraction, a surrogate, ortho-terphenyl (OTP), was added to all samples. A second standard, androstane, was then added to the extract. The percent recovery of the OTP was calculated from the androstane. This percent recovery is a measure of the extraction efficiency. The extract was dried with anhydrous sodium sulfate and analyzed by gas chromatography. At no time is correction for extraction efficiency done.

It is generally accepted that the extraction efficiency is sediment and product dependent. The hydrocarbons adsorbed onto clay particles in fine sediments are less easily extracted than those associated with sandy sediment. Low and medium boiling range products may be more easily extracted than very high boiling components.

5.3 Fingerprinting by GC/FID and PID Moisture Content

5.3.1 Moisture Content

Percent moisture was determined for all sediment samples and the analytical results corrected for percent moisture. Thus, the results for the sediment are reported on a dry weight basis. The moisture determination for biologic samples was not done. Thus, those results are reported on an "as is" basis.

5.3.2 Total Petroleum Hydrocarbons

The extract was injected into a gas chromatograph equipped with either an FID or PID. In both cases, the instruments were equipped with a boiling point column. This column is a DB-5, 30 meters in length with a 0.32 millimeter internal diameter and 0.25 micrometer film thickness. The column was initially held at 35° C for 5 minutes, programmed at 4 degrees a minute to 290° C and held for 10 minutes. The temperature of the injection port was 275° C and the temperature of the detector was 325° C. An initial five point calibration - 2, 5, 10, 20, and 50 ng/ul (nanograms per microliter) - was set up on the FID. Individual normal paraffins from heptane to hexatriacontane were selected as calibration compounds. The total petroleum hydrocarbons were calculated relative to androstane and determined from the total area of both the resolved and unresolved peaks. The only peaks subtracted from the total area included the extracting solvent peaks and peaks attributable to septum contamination. These were so indicated on the chromatograms.

The results of the total petroleum hydrocarbon concentrations found in sediment and biologic samples are given in Table 5-1.

It should be noted that sediment samples DEP 06 SU and DEP 30 ME were not analyzed. DEP 06 was lost in the preparation laboratory and DEP 30 was lost when the container was broken in the analytical laboratory.

5.3.3 Relative Retention Time

In addition to the quantitative determination of the total petroleum hydrocarbons present in each sample, sediment or biologic, the NJDEP methodology stated the requirement of the determination of relative retention time ratios. The retention time is the time in which an analyte or, in the case of unresolved peaks, the analytes, elute from the gas chromatograph. The retention time is a function of the chromatographic column, its substrate, liquid phase, length and inner diameter, the flow rate of the carrier gas, temperature of the column, and the nature of the analytes, e.g., polar or nonpolar.

The retention times are calculated relative to one peak consistently found in the chromogram. This results in a determination of retention time relative to one analyte. The analyte chosen was added to the sample as the surrogate. In this case, ortho-terphenyl (OTP) was used. This peak is well resolved and present in all samples. For these analyses, eight alkanes, 6 normal or unbranched and 2 isomeric or branched, were chosen. Specifically, they were:

nC_{14}, nC_{15}, nC_{16}, nC_{17}, pristane (2,6,10,14-tetramethylpentadecane or an isomeric C_{19}), nC_{18}, phytane (2,6,10,14-tetramethylhexadecane or isomeric C_{20}), nC_{19}

Appendices I-H and I-I labelled Relative Retention Time Ratios, Sediment and Biologic, respectively, are found at the end of this volume.

5.3.4 Ratios

In addition to the time that the peak elutes from the column, another parameter, area, is measured. Assuming linearity, the area of the peak is directly proportional to the quantity of the analyte. This assumes the peaks are well resolved peaks, not commingled or mixed with other co-eluting analytes. The methodology indicated that the integrated area of the peak found in the samples was to be ratioed to the area of that analyte in the reference source material. The resultant ratio is ratioed again to the internal standard, chosen to be hexadecane (nC_{16}). The process is called a double ratioing technique.

The ratios determined by this method are found in Appendices I-H and I-I. The first Appendix is for the sediment samples, the second for the biologic. The following sediment sample areas were not subjected to the ratioing technique described above -- DEP 08 LO (including LO(QA)), ME, and HI; DEP 10 SU and HI; DEP 13 ME 1,2,3; DEP 22 ME, DEP 25 ME; and DEP 27 ME. The biological sample associated with DEP 07 HI RM was also not subjected to the ratioing procedure.

When the qualitative analysis (i.e., the actual chromatogram), and the associated integrated areas did not indicate the presence of fuel oil, ratioing was not done. The determination of the absence of fuel oil was evident from the lack of peaks in the C_{14} to C_{19} range. If no peaks were found at the retention time expected for the specific analyte, ratioing was not possible. Furthermore, as is evident in some samples (e.g., sediment samples DEP 09 HI 1,2,3; DEP 14 ME 1,2,3; and DEP 31 ME 1,2,3), the absence of the C_{16} peak resulted in an error determination when those results were subjected to double ratioing. This error results from dividing by zero. The same situation existed for some biologic samples(e.g., DEP 03 HI; DEP 04 HI; DEP 06 HI; DEP 12 HI; DEP 20 HI; DEP 22 HI; DEP 27 HI; DEP 28 ME; DEP 29 HI; and DEP 36 HI).

This technique was applied only to the analyses of the FID chromatograms, and as described above, only to alkanes. No aromatic compounds were included in this analysis.

5.3.5 Comparison of Environmental Samples to Spilled Oils

Petroleum products are complex mixtures of chemicals, and as such, analytical characterization (both qualitative and quantitative) can be difficult. This is especially so for environmental samples as opposed to neat products. Environmental samples are those samples released to the environment and exposed to a wide range of physical conditions, such as weather (wind, rain, temperature) and chemical conditions (exposure to other compounds and any associated synergistic changes).

Success in analytical characterization of an environmental sample is often better if the sample collected is fresh. The effects of weathering due to volatization and/or oxidation will be less, thereby increasing the probability of matching the spilled product to the reference source.

The methodologies employed in this study focused on the cut of the fuel product, commonly referred to as the "heart cut". It is generally accepted that this fraction is more resistant to changes attributable to weathering (e.g., the loss of the lighter boiling components), and will therefore be more representative of the spilled product. However, this does not mean that the fraction cannot be affected by other influences.

The presence of unresolved components and the possibility of other chemical sources that can respond to the detector can make identification difficult. The presence of other products can skew the fingerprint such that identification is difficult. Co-eluting compounds may also obscure the fingerprint, making both the qualitative and quantitative identification difficult.

With the above in mind, this study determined the distribution of normal and isomeric alkanes, specifically pristane and phytane, by the GC/FID method described previously. The resulting chromatograms were used to compare the oil in the neat samples (from the Exxon pipeline) with petroleum hydrocarbons found in the environmental samples. The purpose of the comparison was to identify the presence of Exxon's oil in the environmental samples under the assumption that other potential contamination sources, both natural and manmade, may be present.

Because environmental samples will show a loss of components that occurred through evaporation (weathering) or biodegradation, the GC data were processed and interpreted in three ways. First, a qualitative evaluation of the oil type was made, be it gasoline, kerosene, No. 2, No. 4, No. 6, residual or biological in origin. The sample was not contaminated by fuel oil if the chromatogram had no peaks between C_{14} and C_{19}, inclusive. The second level of interpretation was a double ratio comparison, as described previously, of the analytes in the C_{14} to C_{19} range, and pristane and phytane. Each chromatogram area in the environmental sample was compared to a similar area in Exxon's product and in a sample from the Cibro Savannah barge, and scaled to the ratio achieved for C_{16}. Lastly, due to their relative resistance to weathering, the ratio of the isoprenoids (pristane and phytane) were also computed for each environmental sample and compared to a similar ratio in the Exxon product and the Cibro sample.

The results are shown in Table 5-2.

The most distinguishing feature of the fingerprinting results is the difference between the pristane/phytane ratios found in the Exxon products and the Cibro Savannah sample. The pristane/phytane ratio in the Exxon samples were .97 and .98, indicating the hydrocarbon source was primarily from rock (i.e., from crude oil). The pristane/phytane ratio in the Cibro sample was 1.61, indicating the possible presence of combustion by-products, possibly from the fire aboard the ship. Table 5-2 also illustrates wide sample variability in the presence and concentration of analytes in the C_{14} to C_{19} range indicative of the released oil.

The following conclusions were reached based on the review of these data. If the key analytes were not present in the sample, then contamination was not No. 2 oil and thus, not from the spill. If concentrations of the key analytes in the sample were present but in proportions different from that in the spilled product, then contaminant origin could not be determined by this technique. Consequently, a match to Exxon's oil was made only if:

(i) the contaminant was identifiable as No. 2 oil;
(ii) the pristane/phytane ratio was no more than 10 percent above Exxon's ration of .97; and
(iii) at least 5 of 7 double ratios were the same as Exxon's double ratios.

This last criterion was considered satisfied if each double ratio in the sample was within 20 percent of Exxon's double ratios. Application of these matching criteria to Table 5-2 indicates that contamination at the following eight sites appear to be associated with the spilled oil:

Site 1-Goethals-S
Site 2-Elizabethport Marsh
Site 5-adjacent to Neck Creek
Site 15-Howland
Site 16-Old Place Creek-mouth
Site 29-Sawmill Creek-up
Site 33-Neck Creek-up
Site 34-Pralls Island-west

If the last of the three criteria is relaxed to 4 of 7 double ratios, then the sample at Site 23-Isle of Meadows could be considered a match to Exxon's oil. If the criterion is relaxed to 3 of 7 double ratios, Site 19-Gulfport Marsh is a match. If 2 of 7 double ratios are sufficient, then Site 3-Pralls Island-ne, Site 6-Elizabethport-n and Site 9-Turnpike Bridge-s are additional matches. If 1 of 7 double ratios are sufficient, Site 24-Fresh Kills and Site 35-Merrill Creek would be additional matches.

5.4 Biomarker Analysis by GC/MS

A supplementary technique that was to be incorporated into the study involved the examination of biomarkers as detected by GC/MS. As indicated previously, this determination was conducted by Louisiana State University. Biomarkers are a means to correlate a sample to a source rock, if the product was virgin crude, as well as to attribute an environmental sample to a reference material. Biomarker information can also be useful in determining the thermal maturity of the oil and the possible extent to which a sample has undergone biodegradation.

A biomarker is an organic compound found in a petroleum sample whose carbon skeleton suggests an unambiguous link to some natural product in the sample's history. The determination of which biomarker to use should include an evaluation of what material is in the reference sample at a high enough concentration such that it is easily detected. In addition, the material should be unique to that reference sample. It is also advantageous to choose a biomarker that remains relatively stable when exposed to biological activity and temperature changes.

The effectiveness of utilizing GC/MS in the differentiation between and among the reference oils was to be evaluated. Two Exxon and one Cibro oil was submitted for analysis.

The GC/MS was operated in the SCAN mode allowing for a general view of the compounds present in the sample. Then, the Selective Ion Monitoring, or SIM, mode was utilized. This mode involves a more careful and planned monitoring of specific retention time windows with the mass spectrometer. SIM generally allows a lower detection limit of trace constituents. The third aspect of this analysis was a comparison of source fingerprinting ratios. This involved alkanes and polycyclic aromatic hydrocarbons, including those containing sulfur.

Two major differences between the source samples, two Exxon and one Cibro, were found (see Appendix I-G). They were in the sulfur content and the extracted ion chromatogram (EIC) profile in the degradative resistant compounds. Further characterization utilizing this technique may prove to be a useful method in delineating future oil spills, especially if sediments are sampled soon after the spill.

5.5 Quality Assurance

5.5.1 Quality Assurance Samples

Quality Assurance and Quality Control samples were utilized both during the field sampling, as well as throughout the analytical procedures in the laboratory. The requirements are designed to establish a program to maintain sample integrity to the extent possible. QA/QC samples are intended to provide control over the sampling conditions, both collection and transport, as well as the analyses steps, from log in, through extraction, to analysis.

As indicated in Section 4.2.1.2, quality assurance samples including rinseate samples, foil and Ottawa Sand were analyzed in the course of the project. Appendix I-F and Table 5-3 contain the results of these analyses.

Laboratory quality assurance samples, including blanks, blank spikes and duplicate control samples, were utilized to gauge and track laboratory controlled errors, such as sample preparation (compositing and homogenization) and instrument detection and quantitation.

Appendices I-D, I-E, and I-F contain the tabulated results of the blank spikes associated with the sample batch, the blank spike duplicate and the calculated

relative percent difference (RPD), and as indicated on Appendix I-D, the associated method blank.

5.5.2 Holding Times

As the samples were maintained frozen (minus 20 degrees C plus or minus 10 degrees), holding time from time of collection until extraction or analysis would have little or no effect on the qualitative determination of the total petroleum hydrocarbons determined. As the petroleum product of interest was a medium weight distillate, rather than the light end products such as gasoline or naphtha, loss of volatiles, paraffins or aromatics, from this controlled sample storage would also be minimal. Although it is desirable to designate holding time considerations so that analytical variables can be minimized, its effect on the usability of the data, both qualitatively and quantitatively, is minimal.

For the sediment samples, 80 of 81 collected were extracted (one was lost in a laboratory accident), and 14 percent (11 of 80) met the criteria of extraction within 10 days of receipt at the laboratory. This criterion was specified in the analytical methodology, OQA-QAM-018 12/89, Revision 4/5/90. None of the 35 tissue samples collected were extracted within the 10-day holding time. Appendix I-B contains this information, the date of sampling, VTSR (Verified Time of Sample Receipt), the extraction date, and the dates for the analyses on both the FIO and PID.

A 40-day holding time was specified in the aforementioned methodology for the analysis of the extract by either FID or PID. For sediment, 75 percent of the samples met this criterion for the FID analysis, and 66 percent for the PID. For tissue, 91 percent met the holding time criteria for the FID, and 83 percent for the PID.

5.5.3 Surrogate Recovery

Surrogates are organic compounds similar to the analytes of interest in their chemical behavior, but which are not normally found in environmental samples. A surrogate is used to monitor the effect of the matrix on the accuracy of the analysis by measuring its percent recovery. (In no case, was correction of other analytes performed based on the percent recovery of the surrogate.)

For this analysis, ortho-terphenyl (OTP) was used as the surrogate. Its recovery was calculated from the standard androstane, that was added to the extract.

The limits of 60 to 120 percent recovery were defined as the control limits for this investigation (i.e., sample was considered acceptable if surrogate recovery was within these limits). For the sediment samples analyzed, 26 percent (21 samples) of the analytical results fell within the limits. Five percent (4 samples) failed as the numerical results were outside the defined limits, and in 69 percent (55 samples) of the samples, the surrogates were unrecoverable as a result of required sample dilution. Dilution of the samples was required when the quantity of the analytes in the extract exceeded the linear dynamic range of the detector. Thus, quantitation according to the calibration limits previously described would not be possible. The visual determination of peak ratios would also not be possible, as the signal attenuation was not large enough

to keep all the peaks on scale. For the 35 tissue samples with sufficient sample volume to extract and analyze, 87 percent of the surrogates (30 samples) were within control limits, 13 percent (5 samples) failed as the numerical results were outside the limits, and none failed as a result of dilution, as dilution was not required in this matrix.

5.5.4 Field Duplicates

Representativeness and comparability are quality characteristics. Among the considerations in environmental sampling and analysis is the degree to which the sample collected and analyzed is representative of the whole. Results represent the material only as well as the sample represents the total body of material. The whole can be the sampling point, a process condition, or an environmental condition. In the scope of services performed for this investigation, the shoreline of the Arthur Kill, the Kill van Kull and their tributaries are considered the sampling environs. Field duplicates (co-located samples) were collected at the low intertidal zone at the 11 intensive sampling sites, at the medium intertidal zone at an additional site (mouth of Old Place Creek), and for one set of tissues. Overall, this corresponds to duplicate sediment samples being collected at 12 of 36 sites (33 percent). As indicted on Table 5-4, in which the average total petroleum hydrocarbon detected in the co-located samples are listed, as well as the calculation of the relative percent difference in the two analyses, sample variability is high. In particular, the relative percent difference between co-located samples exceeds 30 percent for 10 of the 13 samples collected. The only QA samples within 10 percent are the tissue samples at Outerbridge (Site No. 11) and the sediment samples at Rahway River-West (Site No. 7). The greatest variability occurred at Goethals (No. 1) and Neck Creek (No. 5).

These results must be kept in context of both the sample matrix and sampling conditions. Although there is no obvious pattern to the quantity found, it must be considered that the values found are relatively low, and can result from one sample containing a small amount of additional product being analyzed.

5.5.5 Usability of the GC Data

The objective of the study is integral in defining the usability of the data. The objectives were twofold - 1) determine the presence of petroleum product and the qualitative identification as to product type, and 2) compare the analytical results to the references available. The reference samples included two from the Exxon pipeline and one from the Cibro Savannah.

The results of chemical analyses provided information on the qualitative identification of the hydrocarbon product. These qualitative identifications, as well as the quantitation were primarily derived from the FID analysis rather than the PID analysis, due to the apparent lower quality and, therefore, the usability of the data generated from the PID.

As the laboratory was unable to set up the gas chromatograph to split the column effluent between the PID and the FID, they utilized two instruments to analyze the extract. Direct overlay comparison was not possible as the column and instrument conditions were not exact enough, as evidenced by the difference in

retention time for the analytes. Quantitation was also not done on the PID. These factors seriously limit the use of the PID data, although they do not negate the usefulness of the technique in the overall evaluation of petroleum chemistry. Note, for example, the large unresolved peaks in the PID chromatogram for the Cibro sample which do not appear in either of the Exxon samples, and the compounds with retention times less than 20 minutes which appear in the Exxon samples, but not in the Cibro sample (Figures 5-2 through 5-4).

Another technique was the use of the Flame Photometric Detector (FPD) in the sulfur mode. Those chromatograms are shown in Figures 5-5 through 5-7. The chromatograms show differences in source products, particularly for compounds with retention times between 12 and 16 minutes. Due to time constraints, however, environmental samples were not analyzed by FPD in the scope of this project study. The promise shown by this technique is supported by the preliminary assessment of the reference samples utilizing GC/MS, which also show discernible differences in the sulfur components of the oils. Appendix II-G Section 4 contains the method and the results of this analysis on the reference oils.

Table 5-1
Oil Discharge Study/Arthur Kill
Total Petroleum Hydrocarbons (ug/g)

Site #	Site Name	Sediment (By Tidal Zone) HI	ME	LO1	LO2	SU	Benthic HI	Spill Impact
1	Goethals - s	12,000	6,900	210	3,300	1,700	150	H
2	Elizabethport Marsh	27,000	330	190	450	3,100	200 210 (ME)	H
3	Pralls Island - ne	1,400	420	1,600	910	560	110	H
4	opposite Cedar Point	410	1,000	2,200	5,100	1,600	160	M
5	adjacent to Neck Creek	120,000	1,400	120	360	2,500	280	M
6	Elizabethport - n	500	160	660	920	NA	100 140 (ME) 230 (LO)	M
7	Rahway River - w	6,700	5,300	3,000	2,800	4,500	430	L
8	adjacent to Smith Creek	520	360	160	95	310	990	L
9	Turnpike Bridge - s	1,300	310	480	670	680	NA	L
10	Hackensack River	560	1,500	430	750	420	800	N

Table 5-1
Oil Discharge Study/Arthur Kill
Total Petroleum Hydrocarbons (ug/g)

Site #	Site Name	Sediment (By Tidal Zone) HI	ME	LO1	LO2	SU	Benthic HI	Spill Impact
11	Outerbridge - s	920	290	1,100	910	1,000	73/67	N
12	Piles Creek - w		3,700				780	N
13	Kill Van Kull - w		880				1,200	H
14	Droyers Point		190				NA	N
15	Howland		2,200				290	H
16	Old Place Creek - mouth		3,000 1,900				140	H
17	Elizabeth River - up		1,400				NA	H
18	Morses Creek		57,000				NA	H
19	Gulfport Marsh		360				180	H
20	Sawmill Creek - mouth		1,100				110	H

Table 5-1
Oil Discharge Study/Arthur Kill
Total Petroleum Hydrocarbons (ug/g)

Site #	Site Name	Sediment (By Tidal Zone) HI	ME	LO1	LO2	SU	Benthic HI	Spill Impact
21	Pralls Island - s		170				150	H
22	Citgo		1,300				660	M
23	Isle of Meadows		430				180	H
24	Fresh Kills		210				330	H
25	Tufts Point		370				NA	M
26	Rahway River - up		2,300				70	M
27	Kreischerville		290				60	L
28	Ploughshare & (B) Ward Point		450				240	N
29	Sawmill Creek - up		3,400				86	H
30	Piles Creek - up		NA				NA	M
31	Turnpike Bridge - n		600				1,400	L

Table 5-1
Oil Discharge Study/Arthur Kill
Total Petroleum Hydrocarbons (ug/g)

Site #	Site Name	Sediment (By Tidal Zone) HI	ME	LO1	LO2	SU	Benthic HI	Spill Impact
32	Old Place Creek - in		2,300				68	H
33	Neck Creek - up		7,200				930	H
34	Pralls Island - w		12,000				130	H
35	Merrills Creek		1,400				740	H
36	Old Place Creek - up		3,400				770	H
37	Sawmill Creek - in		180				1300	L

Key to Spill Impact Column
H: High level of oil observed
M: Moderate level of oil observed
L: Low level of oil observed
N: No oil observed/Control Site
NA: Not Available

Key to Sediment Zones
HI: High Intertidal
ME: Medium Intertidal
LO: Low Intertidal
SU: Subtidal

Source: Louis Berger and Associates, Inc., 1991

TABLE 5-2
FINGERPRINT MATCHING
OF
SEDIMENT SAMPLES

Station	Station No. and Sampling Zone	No. 2	Double Ratios		Pristane/ Phytane Ratio
			To EXXON	To Cibro	
Goethals - s	01-HI	Y	4	5	.98
Goethals - s	01-ME	Y	5	5	1.04
Goethals - s	01-LO	Y	2	3	1.10
Goethals - s	01-LO-QA	Y	6	5	1.02
Goethals - s	01-SU	Y	1	2	.90
Elizabethport Marsh	02-HI	Y	1	4	1.03
Elizabethport Marsh	02-ME	Y	5	3	.65
Elizabethport Marsh	02-LO	N	0	0	.63
Elizabethport Marsh	02-LO-QA	Y	5	4	.84
Elizabethport Marsh	02-SU	Y*	0	0	1.62
Pralls Island - ne	03-HI	N	0	1	.64
Pralls Island - ne	03-ME	N	1	2	.08
Pralls Island - ne	03-LO	N	0	0	.96
Pralls Island - ne	03-LO-QA	Y*	2	2	.98
Pralls Island - ne	03-SU	N	0	0	1.04
opposite Cedar Point	04-HI	N	0	0	.97
opposite Cedar Point	04-ME	N	1	1	.73
opposite Cedar Point	04-LO	N	0	0	.46
opposite Cedar Point	04-LO-QA	Y*	0	0	.24
opposite Cedar Point	04-SU	Y*	0	0	.61
adjacent to Neck Creek	05-HI	N	4	5	.89
adjacent to Neck Creek	05-ME	Y	7	4	1.06

Station	Station No. and Sampling Zone	No. 2	Double Ratios		Pristane/ Phytane Ratio
			To EXXON	To Cibro	
adjacent to Neck Creek	05-LO	N	2	1	.91
adjacent to Neck Creek	05-LO-QA	Y	2	4	1.04
adjacent to Neck Creek	05-SU	N	1	1	2.55
Elizabethport - n	06-HI	Y*	2	2	.77
Elizabethport - n	06-ME	N	0	0	1.03
Elizabethport - n	06-LO	N	1	1	1.38
Elizabethport - n	06-LO-QA	N	0	0	NA
Rahway River - w	07-HI	N	0	0	1.15
Rahway River - w	07-ME	N	0	0	1.43
Rahway River - w	07-LO	N	2	2	.57
Rahway River - w	07-LO-QA	N	2	2	.97
Rahway River - w	07-SU	N	1	1	1.01
adjacent to Smith Creek	08-HI	N	0	0	NA
adjacent to Smith Creek	08-ME	N	0	0	NA
adjacent to Smith Creek	08-LO	N	0	0	NA
adjacent to Smith Creek	08-LO-QA	N	0	0	NA
adjacent to Smith Creek	08-SU	N	0	1	.62
Turnpike Bridge - s	09-HI	N	0	0	.48
Turnpike Bridge - s	09-ME	Y*	1	1	.93
Turnpike Bridge - s	09-LO	Y*	2	2	.86
Turnpike Bridge - s	09-LO-QA	N	2	1	.58
Turnpike Bridge - s	09-SU	Y*	1	1	1.55
Hackensack River	10-HI	N	0	0	NA
Hackensack River	10-ME	N	0	0	1.25
Hackensack River	10-LO	N	1	1	.50

Station	Station No. and Sampling Zone	No. 2	Double Ratios To EXXON	Double Ratios To Cibro	Pristane/ Phytane Ratio
Hackensack River	10-LO-QA	N	0	0	.63
Hackensack River	10-SU	N	0	0	NA
Outerbridge - s	11-HI	N	0	0	.33
Outerbridge - s	11-ME	N	1	1	.87
Outerbridge - s	11-LO	N	1	1	1.72
Outerbridge - s	11-LO-QA	N	0	1	.69
Outerbridge - s	11-SU	N	0	1	1.59
Piles Creek - w	12-ME	N	0	0	NA
Kill Van Kull - w	13-ME	N	0	0	NA
Droyers Point	14-ME	N	0	0	.77
Howland	15-ME	Y	5	3	.64
Old Place Creek - mouth	16-ME	N	0	0	.50
Old Place Creek - mouth	16-ME-QA	Y	6	5	.87
Elizabeth River - up	17-ME	N	1	1	.95
Morses Creek	18-ME	N	0	1	NA
Gulfport Marsh	19-ME	Y*	3	5	.81
Sawmill Creek - mouth	20-ME	N	3	3	.71
Pralls Island - s	21-ME	N	1	1	.40
Citgo	22-ME	N	0	0	NA
Isle of Meadows	23-ME	Y	4	5	1.06
Fresh Kills	24-ME	Y*	1	2	.84
Tufts Point	25-ME	N	0	0	NA
Rahway River - up	26-ME	Y*	4	5	1.29
Kreischerville	27-ME	N			NA
Ploughshare Point	28-ME	N	0	0	NA

Station	Station No. and Sampling Zone	No. 2	Double Ratios To EXXON	Double Ratios To Cibro	Pristane/ Phytane Ratio
Sawmill Creek - up	29-ME	Y	7	4	.94
Piles Creek - up	30-ME		Cancelled		
Turnpike Bridge - n	31-ME	N	0	0	NA
Old Place Creek - in	32-ME	N	4	4	.79
Neck Creek - up	33-ME	Y	5	5	.96
Pralls Island - w	34-ME	Y	6	5	.64
Merrill Creek	35-ME	Y	1	1	.94
Old Place Creek - up	36-ME	N	0	0	NA
Sawmill Creek - in	37-HI	N	0	0	NA
EXXON-#1	RF-1-EX	Y	7	5	.98
EXXON-BWY	RF-2-EX	Y	7	4	.97
CIBRO (retain)	RF-CIB	Y	5	7	1.61

No.2 Oil - Identified by qualitative review of GC-FID chromatograms

Double Ratios - the number in this column indicates the number of ratios (out of 7) within 20% of the Exxon (or Cibro) standard

* - interpretation made by NJDEP-OQA

NA - fuel oil or analyte not present

Table 5-3

QUALITY ASSURANCE SAMPLES

RINSEATES *			ALUMINUM ** FOIL	OTTAWA*** SAND
Core Liners	Core Cutter/Catcher	Knife		
	mg/l	mg/l	ug	ug/g
ND (4/19)	ND (4/17)	ND (4/19	ND (4/27	ND
ND (4/26)	ND (5/3)	ND (5/7)	140 (4/26)	
	ND (5/3)		49 (4/27)	
			50 (4/30)	
			240 (4/30)	

Note: The date indicates when the rinseate of foil was sampled and sent to the lab (in 1990).

* Detection limit 0.50 mg/l
** Detection limit 12 ug
*** Detection limit 12 ug/g

Table 5-4

CO-LOCATED SAMPLES

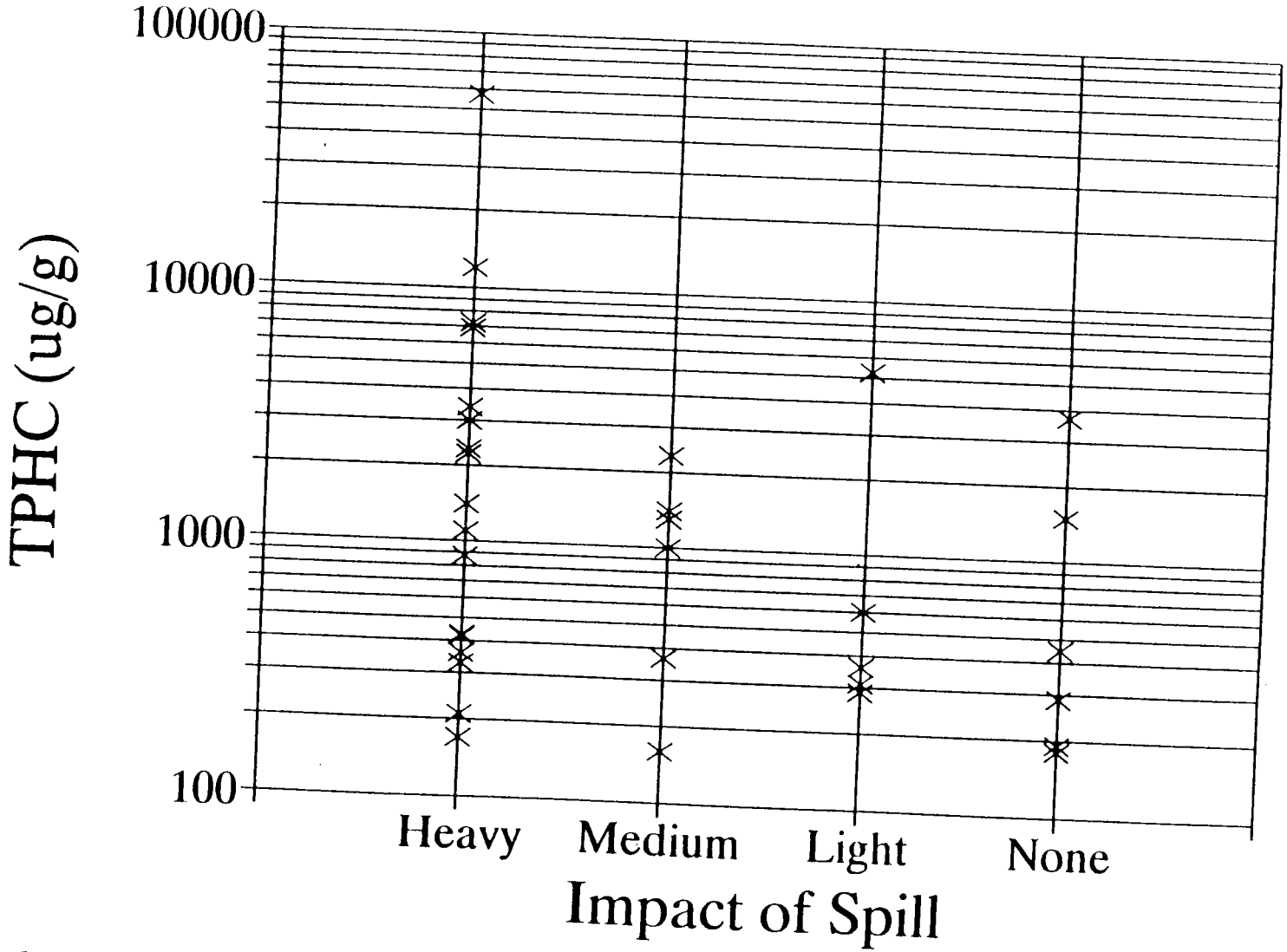
RELATIVE PERCENT DIFFERENCE

Sediment and Tissue Samples

DEP-ID/ Map Location	TPH in ug/g Average	Relative Percent Difference
01-LO Goethals - s	1755	176
02-LO Elizabethport Marsh	320	81
03-LO Pralls Island - ne	1255	55
04-LO opposite Cedar Point	3650	79
05-LO adjacent to Neck Creek	240	100
06-LO Elizabethport - n	790	33
07-LO Rahway River - w	2900	6.9
08-LO adjacent to Smith Creek	128	51
09-LO Turnpike Bridge - s	575	33
10-LO Hackensack River	590	54
11-LO Outerbridge - s	1000	20
11-HI (tissue) Outerbridge - s	70	8.6
16-ME Old Place Creek - mouth	2450	45

TPH - Total Petroleum Hydrocarbons

TPHC In Sediments
Medium Intertidal Zone



	Heavy	Medium	Light	None
Mean (Geometric)	1114.01	792.54	634.60	539.91

FIGURE 5.1

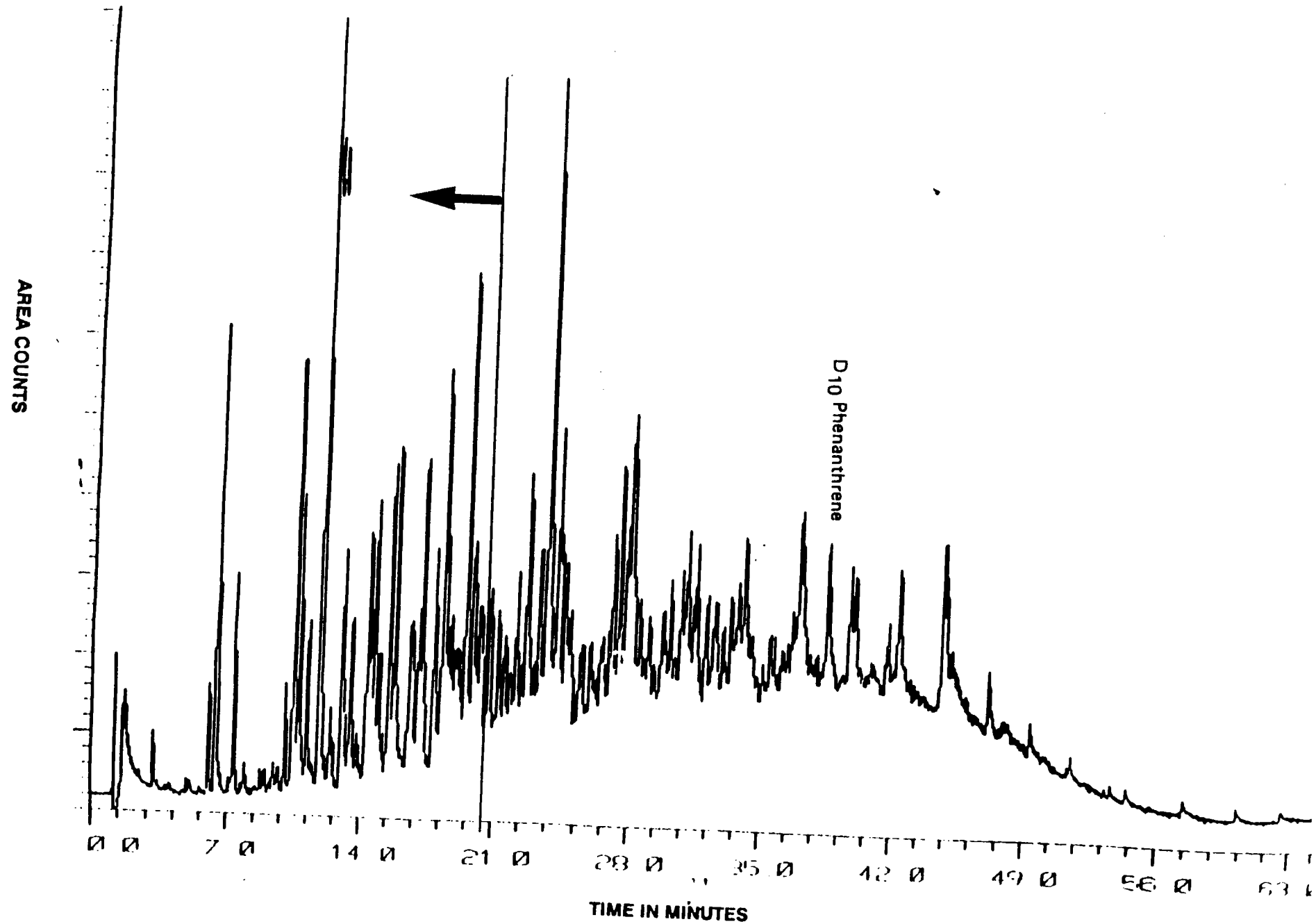


FIGURE 5-2
GC/PID CHROMATOGRAM
OF SAMPLE 1 - EXXON

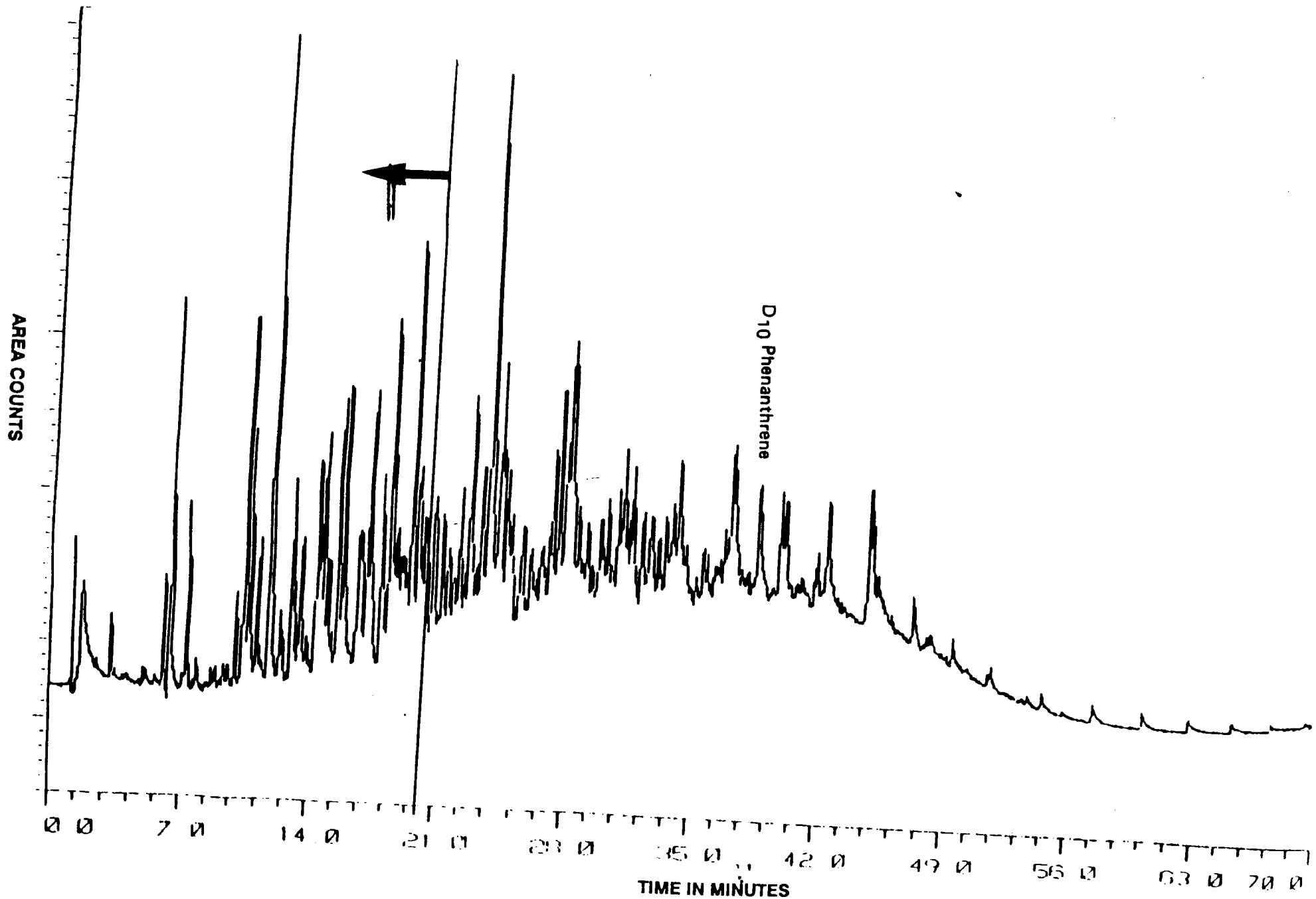


FIGURE 5-3
GC/PID CHROMATOGRAI
OF SAMPLE 2 - EXXON

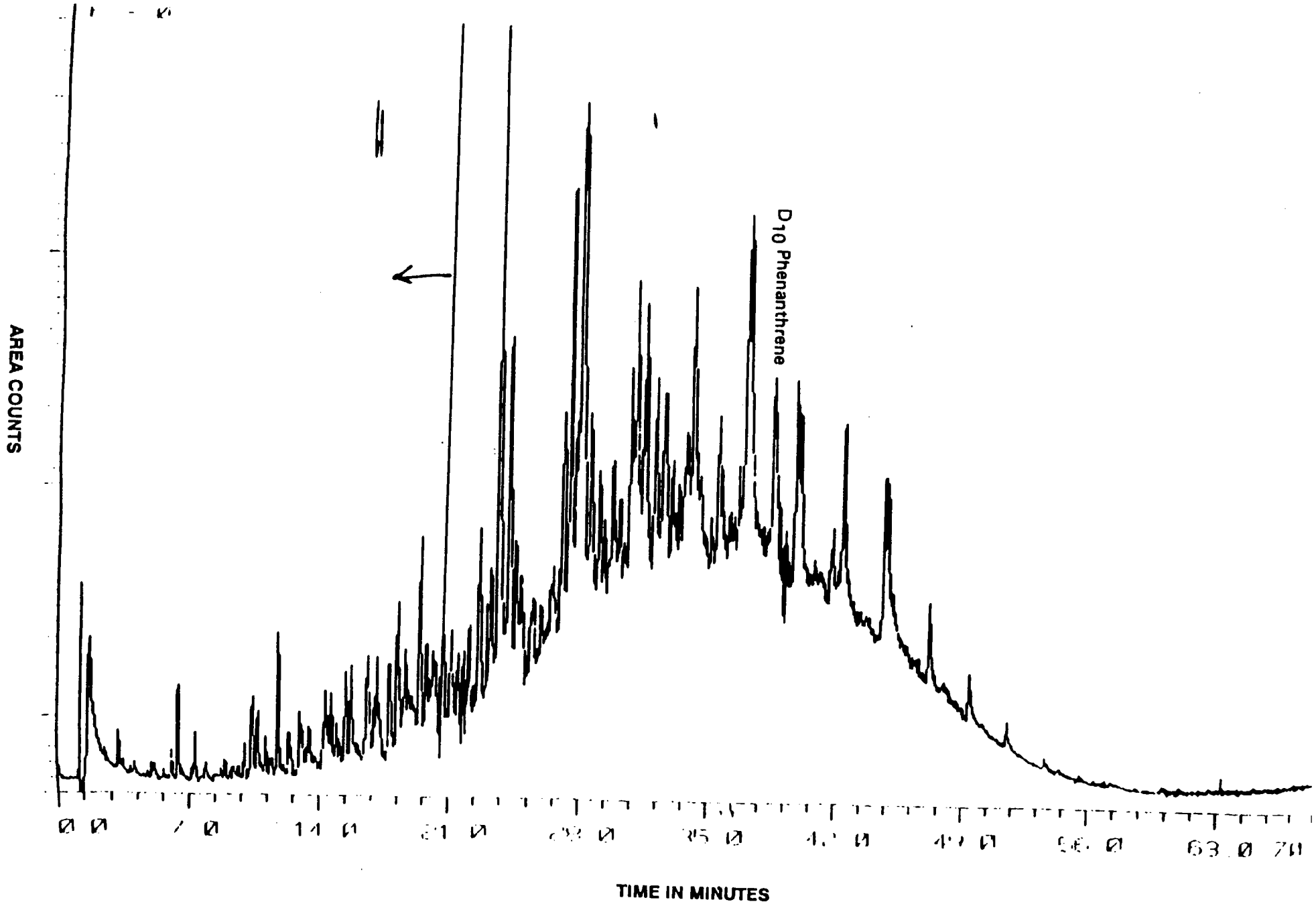
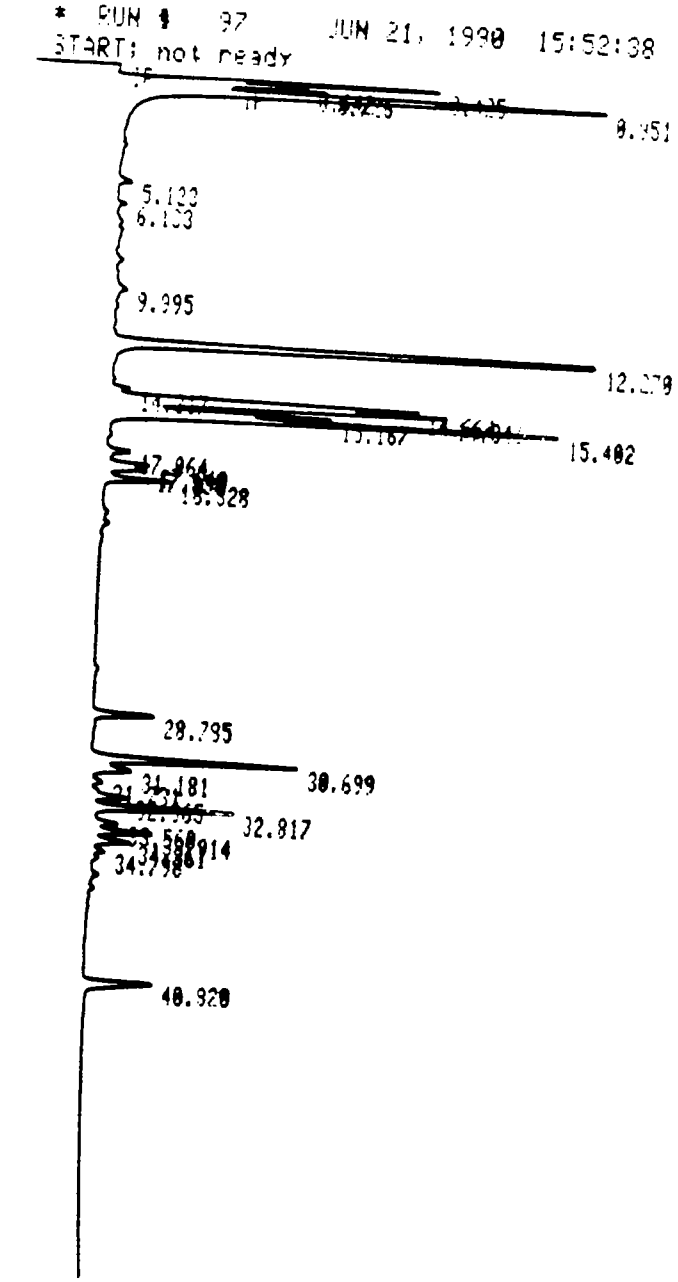
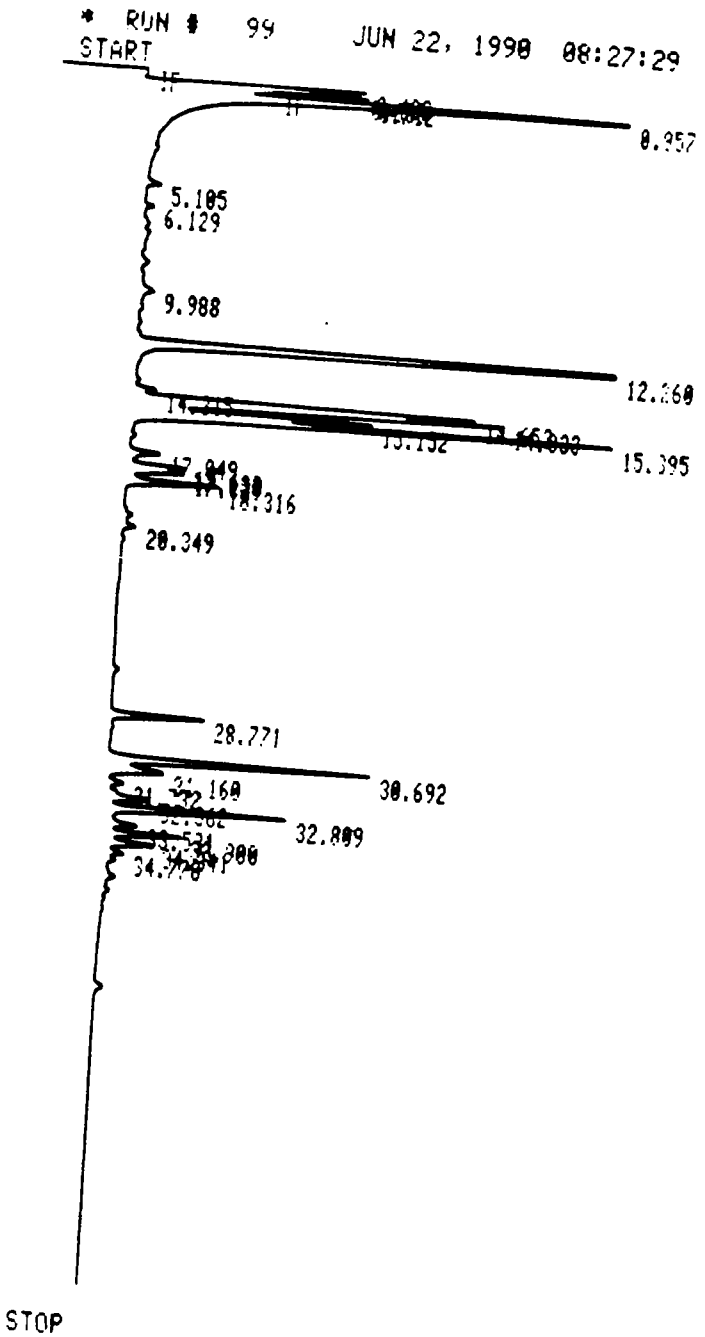


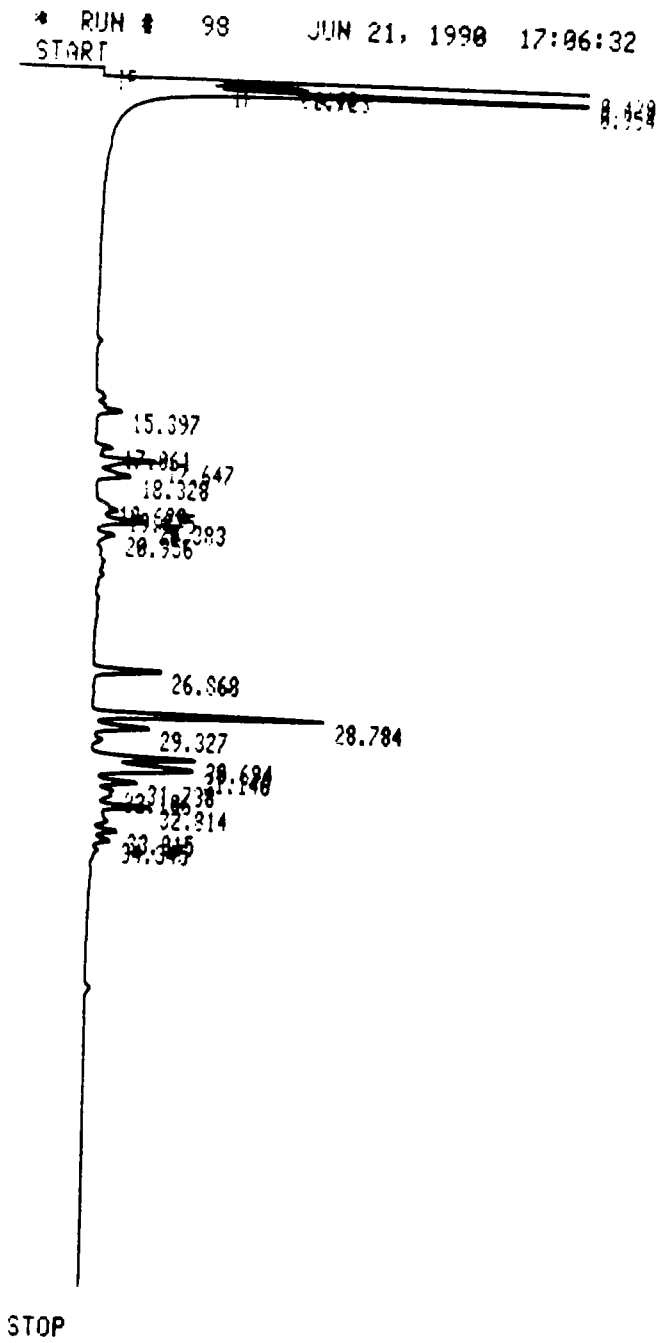
FIGURE 5-4
GC/PID CHROMATOGRAM
OF CIBRO SAMPLE



LOUIS BERGER & ASSOCIATES, INC.	
GC/FPD Chromatogram of Sample 1 - Exxon	
JUNE 1991	FIGURE 5-5



LOUIS BERGER & ASSOCIATES, INC.	
GC/FPD Chromatogram of Sample 2 - Exxon	
JUNE 1991	FIGURE 5-6



LOUIS BERGER & ASSOCIATES, INC.	
GC/FPD Chromatogram of CIBRO Sample	
JUNE 1991	FIGURE 5-7

6.0 RESULTS AND CONCLUSIONS

6.1 Extent of Spill From On-Scene Observers

A spill of approximately 13,500 barrels (567,000 gal) of No. 2 heating oil occurred on January 1-2, 1990, from an underwater Exxon pipeline in the Arthur Kill, the waterway which separates Staten Island from New Jersey. Initial overflights by the U.S. Coast Guard showed oil extending south to the southern end of Pralls Island and north into Newark Bay.

Upon assuming responsibility for the spill, Exxon set up a command center at the refinery and activated the company's spill response team. The U.S. Coast Guard's Captain of the Port, New York, was the federally designated on-scene coordinator (OSC). Using the command center as a base for cleanup operations, OSC representatives communicated with Exxon, NYSDEC, NJDEP, the NOAA Scientific Support Coordinator and New York City Department of Parks and Recreation. During the course of the cleanup, over 25 government agencies were in the command center at one time or another. OSC and many of these agencies recorded daily locations of oil, debris hazards and injured waterfowl. Some observers recorded the severity of the oil spill - high, moderate or low - in each area investigated. Other observers simply recorded the information as presence vs. absence of oil on the day and time the area was visited. LBA researched and plotted these data, and maps were reviewed by the Governments' Technical Committee. The maps were digitized in a format compatible with the Geographic Information Systems used by the states of New York and New Jersey.

The spill data thus gathered are summarized in the Oil Spill Extent Map (Figure 6-1). The data indicate that oil released from the spill affected the Arthur Kill, Kill van Kull, Newark Bay, and their tidal tributaries. The oil travelled north into Newark Bay to the mouths of the Passaic River and Hackensack River. The oil extended east in the Kill van Kull to the southern shore of Constable Hook (Bayonne). The southernmost extent of contamination observed in the Arthur Kill was to the Outerbridge Crossing.

Some tidal tributaries were affected to the head of tide. In New Jersey, secondary sources put the farthest approximate extent of oil to the US 1 and 9 viaduct in the City of Elizabeth. Piles Creek was affected as far inland as one-half mile west of the New Jersey Turnpike crossing.

On Staten Island, Old Place Creek was oiled to the I-278 (Staten Island Expressway)/NY 440 (West Shore Expressway) interchange, although some later observers recalled seeing oil the entire length of Old Place Creek. Sawmill Creek was contaminated to NY 440. Neck Creek was oiled up to Meredith Avenue. Fresh Kills was impacted to the confluence of Richmond Creek and Main Creek. Permanent booms for the Fresh Kills Landfill at this confluence prevented contamination from entering either waterway.

Most of the western and northern shores of Staten Island were found to be heavily impacted from Smoking Point to the Bayonne Bridge. The shores of Pralls Island, Shooters Island, and the Isle of Meadows were also heavily impacted.

On the New Jersey shores, zones of heavy impact were found on the southern and western shores of Bayonne, the southern portions of Elizabeth's shoreline, and intermittently along the shore in Linden. Medium oiling was observed sporadically along Bayonne's south shore and the shoreline in Linden and from the Rahway River to Tufts Point.

Isolated areas of heavy contamination were also found around piers, breakwaters, wreckage, and rip-rap.

6.2 Containment and Recovery

During the initial phases of the spill, Exxon's efforts focused on containment and equipment deployment for the removal of the heaviest concentrations of oil. As reported by OSC, the basic strategy was to provide overall general containment at the north and south ends of the Arthur Kill, and, within that area, to deploy containment boom to protect sensitive areas and take advantage of natural collection areas. Some observers reported, however, that shallow tidal wetlands were sometimes used to collect the oil, and boom was deployed to encourage collection rather than to protect the areas.

Self-propelled oil skimmers were utilized in areas where heavy concentration of free-floating oil and mousse were spotted, primarily between Howland Hook and Fresh Kills. Vacuum trucks removed oil at collection sites where shore-side accessibility permitted. Sorbent material was directly applied to affected shorelines, and sorbent boom was placed at accessible locations to capture the oil being released from the shoreline by natural flushing actions.

Active recovery of oil continued until March 15, 1990 except for the beach along the western shoreline of Pralls Island, where OSC determined that there remained subsurface oil in the intertidal region. This area was treated by bioremediation techniques during September 1990.

6.3 Field Observations

From March 15-21, 1990, LBA set up 92 transects along the shores of the Arthur Kill and its tributaries to observe the degree of residual oiling of the sediments. Sediment samples collected by hand auger at and around the high water line were inspected for evidence of petroleum residue. The results, shown on Figure 6-2, indicate that sheen was observed three months after the spill in the same areas where the spill impact was considered high. In particular, heavy residue was observed in Staten Island from the Isle of Meadows to the Bayonne Bridge, and in New Jersey, from Tufts Point to the Turnpike Bridge.

Areas outside of the primary spill area also contained sediments with oil, including the mouth of the Hackensack River to the north and areas south of Tufts Point. These observations indicate that either the extent of the Exxon spill was further than reported or that residuals from the Exxon spill are superimposed on a waterway contaminated with petroleum hydrocarbons from other anthropogenic

sources. Among these other sources was the March 6 explosion aboard the Cibro Savannah, which resulted in a spill of 127,764 gallons of No. 2 heating oil at the Citgo Terminal opposite Prall's Island. Reported by the U.S. Coast Guard as well controlled, this spill affected some of the same areas affected by the Exxon spill.

6.4 Field Sampling Programs

Field sampling was conducted during April and May 1990, at 37 stations distributed along the main stem of the Arthur Kill and its tributaries in New York and New Jersey. The majority of the stations were placed in areas that were heavily oiled by the Exxon spill (Figure 6-3). Three programs were implemented at these stations: sediment sampling via coring, sampling for two species of mussels and two species of clams, and counts of live and dead ribbed mussels. The results of these programs are summarized in Table 6-2.

6.4.1 Results of Ribbed Mussel Survey

Ribbed mussels were found in the high intertidal zone at 32 of the 37 stations. Their densities and the percentage of dead versus live mussels varied considerably. The highest densities were observed at Kreischerville, NY (403 mussels/sq. m), Smith Creek, NJ (147 mussels/ sq. m), opposite Cedar Point, NJ (113 mussels/sq. m) and near the Citgo Terminal, NJ (113 mussels/sq. m). These high density beds are all located in the southern portion of the study area.

The percent dead varied from 0 to 100 percent, with no observable correlation with density. The distribution of percent mussels dead is shown in Figure 6-4. The beds with highest percentage dead are located in and around Morses Creek (the location of the Exxon spill), upstream in Neck Creek, NY and at Tufts Point. These are all places which were heavily oiled by the Exxon spill. Conversely, the mussel beds around the site of the Cibro Savannah spill were relatively unaffected, possibly due to the quick containment of released oil following the latter spill.

6.4.2 Petroleum Chemistry of Sediments

Sediment cores from the middle of the intertidal zone were collected at 36 stations, and the top 2 cm of each core were analyzed by GC/FID and GC/PID methods (petroleum fingerprinting). The distribution of Total Petroleum Hydrocarbons (TPHC) in these samples varied between 170 ug/g and 57,000 ug/g, with the highest levels occurring at Morses Creek (57,000 ug/g), upstream at Neck Creek (7,200 ug/g), Goethals-South (6,900 ug/g) and Rahway River-West (5,300 ug/g). These stations and others where TPHC concentrations in medium intertidal zone sediments exceeded 1,000 ug/g, are generally clustered around the origin of the spill, from the Elizabeth River and Howland Hook in the north to Cedar Point in the south (Figure 6-5).

When compared to the observed spill extent, average TPHC concentrations in the medium intertidal zone were highest at the heavily oiled areas (average of 1,114 ug/g) and decreased as the level of oiling decreased (Figure 6-6).

Sediment cores were also collected at the high intertidal, low intertidal and subtidal zones at 11 "intensive sampling" stations, including 9 "affected stations" and 2 "control stations". As shown in Tables 5-1 and 6-1 and Figure 6-7, TPHC concentrations at the affected stations were highest in the high and low intertidal zones. Consequently, TPHC concentrations at many of the 25 other stations where samples were only collected from the medium intertidal zone, are probably higher in the other tidal zones. The highest TPHC concentrations at the intensive sampling sites were found in the high intertidal zones adjacent to Neck Creek, NY (120,000 ug/g), Elizabeth Port Marsh, NJ (27,000 ug/g) and Goethals-South, NY (12,000 ug/g).

6.4.3 Fingerprint Matching of Oils

Analysis of sediment samples, Exxon product and Cibro Savannah product by GC/FID methods allowed for a matching of chromatograms, both qualitatively and quantitatively. A match via the profiling, or fingerprint technique required that the sample be identified as No. 2 oil and that certain compounds (e.g., pristane and phytane) be in a ratio similar to that found in the Exxon product. The results are provided in Table 6-2 and Figure 6-8. Using these criteria, sediments with oils matching Exxon's pipeline product were found at 8 stations and a possible match at an additional 7 stations as far north as the Turnpike Bridge and as far south as Isle of Meadows.

The results correspond well with observed spill locations (see Figure 6-1). All but one of the eight matched samples occurred at stations experiencing a high spill impact. They were all located within 3 miles, north or south, of the spill point. Two of the matched samples were from stations located in tributaries to the Arthur Kill. Total petroleum hydrocarbons at these stations varied from 2,200 to 120,000 ppm, considerably above the average TPHC concentration. Most of the seven "possible" matches also occurred at high spill impact stations, but were spread up to six miles from the spill point. TPHC concentrations at stations with "possible" matched samples were in the range of 210-1,600 ppm, similar to background levels for the area.

There were important exceptions to the identification. Chromatograms at Morses Creek, the site of the spill and where TPHC concentrations were 57,000 ug/g, were vastly different from Exxon's product. Similarly, contaminants in sediments at Elizabeth River, Kill van Kull, Sawmill Creek (mouth), Pralls Island (south), and Old Place Creek (inland and upstream), all close to the spill point and which experienced high spill impact, could not be reliably identified as No. 2 oil.

6.4.4 Benthic Invertebrate Sampling and Testing

Attempts were made to collect blue mussels, ribbed mussels, hard-shelled clams and soft-shelled clams for purposes of chemical testing of their tissues. Only ribbed mussels and soft-shelled clams were encountered. The ribbed mussels were ubiquitous in the high intertidal zones of most stations, usually attached to thick root mats of *Spartina alterniflora*. The few live soft-shelled clams collected all came from substrates of sand or sandy muck, particularly in the subtidal zone in which worms, mud snails and mud whelks were also present. Except for rare instances, there was insufficient clam tissue collected for a chemical analysis, and consequently, analytical testing was primarily confined to ribbed

mussels. As shown in Table 6-2, the total petroleum hydrocarbon content of the bivalve tissues varied between 60 and 1,400 ug/g, with no correlation with TPHC content in associated sediments. The highest TPHC concentrations were at the Turnpike Bridge-North, Sawmill Creek-Inland, and Kill van Kull-West stations.

At stations where oil was heaviest, the stocks of live mussels were severely depleted. Since tissue samples could only be collected from the surviving organisms, the distribution of TPHC concentrations in tissues were heavily skewed downward (i.e., exposure to and ingestion of sediments with high TPHC concentrations may have been the primary cause of death to mussels). Thus, TPHC concentrations in surviving bivalves are not considered an estimate of the injury to the bivalve population as a whole.

6.5 Short-Term Biological Effects

6.5.1 Bird Injuries and Deaths

During the cleanup process, dead or injured birds were collected by Exxon and their contractors, NYC Department of Parks and Recreation, NYSDEC, US Fish and Wildlife and other interested parties. Data accumulated by these organizations revealed that 654 birds were found dead, 40 were treated but died and 110 were treated and survived. Waterfowl and sea gulls were the two major groups of birds killed by the spill.

6.5.2 Bird Population Effects

Bird population studies conducted by the Manomet Bird Observatory for the last five years revealed that species which feed in tidal habitats of the Arthur Kill, Kill van Kull and its tributaries experienced lowered reproductive success and disrupted foraging ecologies during the spring 1990 breeding season.

Numerous aquatic bird species at three colony sites (Isle of Meadows, Pralls Island, Shooters Island) were studied, including Great Egrets, Cattle Egrets, Snowy Egrets, Black-crowned Night Herons, Glossy Ibises and Herring Gulls. Omnivorous and upland foraging species (Black-crowned Night Heron, Cattle Egret, Herring Gull) were relatively unaffected. Waders (herons, egrets, ibises) initiated nesting later in 1990 than in previous years and tidal waders (Snowy Egrets and Glossy Ibises) fledged fewer young. Poor fledging rates were attributed primarily to starvation. Weight gain of chicks did not differ in 1990, but culmen growth, a sensitive indicator of environmental conditions, was significantly slowed for some species. Depressed flight rates also occurred for Snowy Egrets and Glossy Ibises, and owing to their poor reproductive success and high chick mortality, it is likely that adults of these species spent more time at feeding sites and less time at their nests. These species were apparently unable to compensate for degraded feeding habitats by selecting new sites or by altering their foraging behaviors (strike rate).

6.6 Conclusions

The Exxon oil spill of January 1-2, 1990 affected a large shoreline area of the Arthur Kill and its tributaries up to head-of-tide, with evidence of spill residues still existing from the New Jersey Turnpike Bridge to Woodbridge Creek

several months after the spill. The total petroleum hydrocarbon content of sediments in the area were as high as 120,000 ug/g and exceeded 1,000 ug/g in about 50% of the sediments tested. When multiple zones were tested, the highest TPHC levels at a station were usually found along the highest or lowest intertidal zones. Some of the oil in the sediments could be matched with oil released in the spill, but background contamination in the range of 300-1,000 ug/g TPHC existed at both affected and control sites, making positive identification difficult. Use of other chemical identification techniques, such as biomarkers and inorganics, may prove an excellent supplement to fingerprinting in previously contaminated areas.

Some of the effects of the spill on biota were measurable. In areas closest to Morses Creek, the site of the spill, mussel beds were heavily injured, locally experiencing up to 100% mortality. The total petroleum hydrocarbon content in tissues of surviving mussels varied from 60 to 1,400 ug/g, but there was little or no correlation of these levels with the spill impact nor the TPHC content of the sediments. Unless substantial background information is available, chemical analysis of organisms may not be a good indicator of a spill's effects nor of its origins.

Approximately 700 aquatic birds died as a direct result of the oil spill, and population studies of egrets, ibises, herons, cormorants and gulls revealed the 1990 breeding season for several species was significantly disrupted. The long-term effects on aquatic birds in the Arthur Kill still remain to be examined. Of particular interest will be recruitment to the breeding populations - a parameter unchanged in 1990 but expected to reflect current productivity in future years. Also important are long-term measures of productivity to assess the time required for affected populations to recover and for community dynamics to equilibrate. Of final concern will be monitoring possible sublethal effects resulting from accumulation of toxic petroleum constituents.

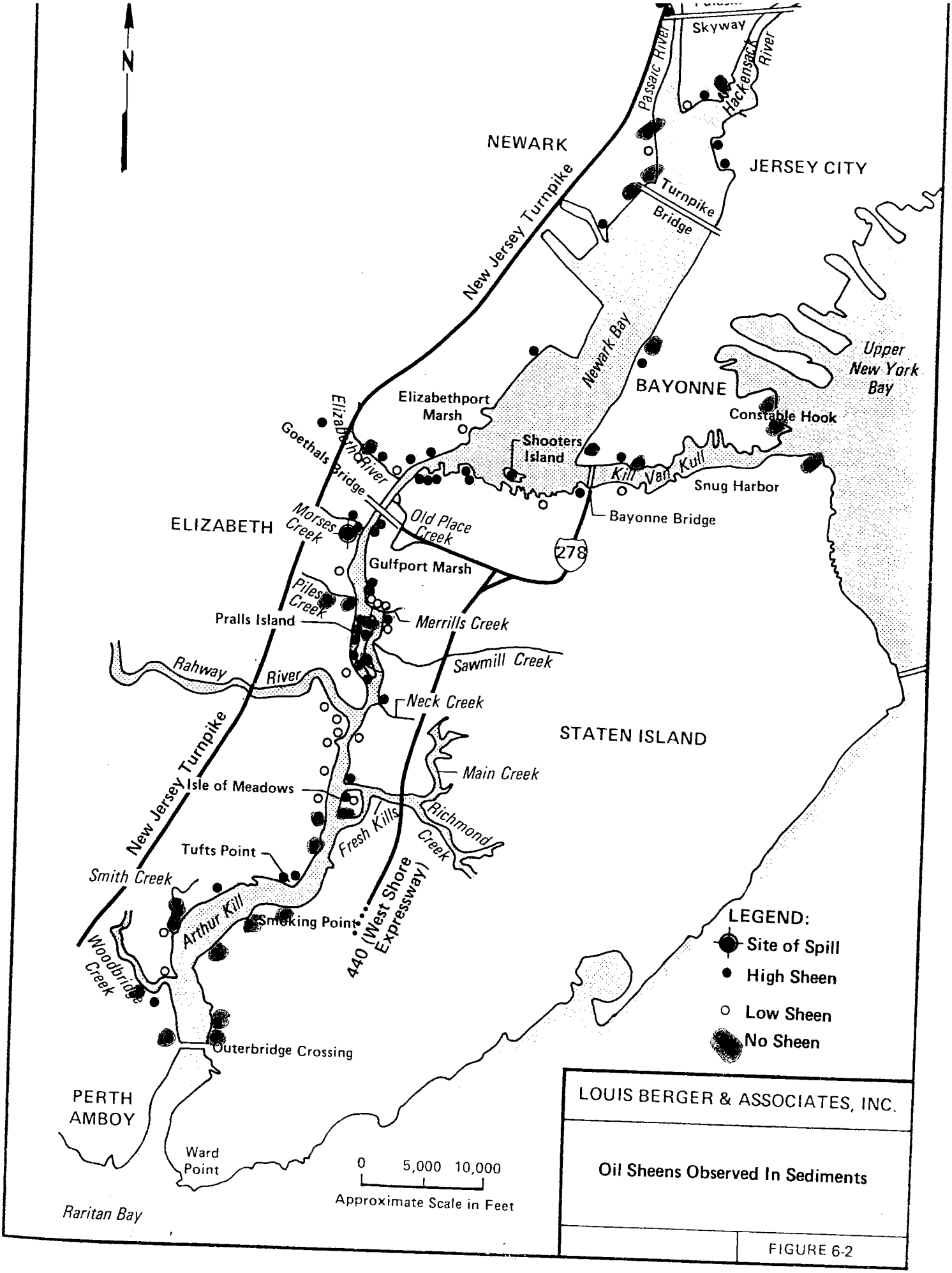
Table 6-1
Average Total Petroleum Hydrocarbon Concentrations in Sediment
All Samples (ug/g)

Tidal Zone (No. Samples)	Spill Impact			
	Heavy	Medium	Light	None
High Intertidal (11)	13,467 (3)	40,303 (3)	2,840 (3)	740 (2)
Medium Intertidal (36)	5,479 (19)	1,088 (6)	1,173 (6)	1,226 (5)
Low Intertidal (22)	1,110 (6)	1,560 (6)	1,201 (6)	798 (4)
Sub Intertidal (10)	1,787 (3)	2,050 (2)	1,830 (3)	710 (2)

Table 6-2
Summary of Findings from
the Sampling Programs

Site #	Site Name	Spill Impact	Highest TPHC (ppm)	TPHC (ppm) in Mussels	% Dead Mussels	Match to Exxon Oil
1	Goethals - s	High	12,000	150	75	Match
2	Elizabethport Marsh	High	27,000	210	80	Match
3	Pralls Island - ne	High	1,600	110	6	
4	opposite Cedar Point	Medium	5,100	160	18	
5	adjacent to Neck Creek	Medium	120,000	280	45	Match
6	Elizabethport - n	Medium	920	230	17	
7	Rahway River - w	Light	6,700	430	40	
8	adjacent to Smith Creek	Light	520	990	11	
9	Turnpike Bridge - s	Light	1,300	N/A	N/A	
10	Hackensack River	None	1,500	800	0	
11	Outerbridge - s	None	1,100	73/67	5	
12	Piles Creek - w	None	3,700	780	19	
13	Kill Van Kull - w	High	880	1,200	24	
14	Droyers Point	None	190	N/A	N/A	
15	Howland	High	2,200	290	100	Match
16	Old Place Creek - mouth	High	3,000	140	91	Match
17	Elizabeth River - up	High	1,400	N/A	N/A	
18	Morses Creek	High	57,000	N/A	100	
19	Gulfport Marsh	High	360	180	96	
20	Sawmill Creek - mouth	High	1,100	110	5	
21	Pralls Island - s	High	170	150	1	
22	Citgo	Medium	1,300	660	17	
23	Isle of Meadows	High	430	180	28	
24	Fresh Kills	High	210	330	53	
25	Tufts Point	Medium	370	N/A	74	
26	Rahway River - up	Medium	2,300	70	5	
27	Kreischerville	Light	290	60	11	
28	Ploughshare	None	450	240	N/A	
29	Sawmill Creek - up	High	3,400	86	13	Match
30	Piles Creek - up	Medium	N/A	N/A	N/A	
31	Turnpike Bridge - n	Light	600	1,400	2	
32	Old Place Creek - in	High	2,300	68	4	
33	Neck Creek - up	High	7,200	930	76	Match
34	Pralls Island - w	High	12,000	130	28	Match
35	Merrills Creek	High	1,400	740	36	
36	Old Place Creek - up	High	3,400	770	7	
37	Sawmill Creek - in	Light	180	1300	N/A	

N/A: Not Available


N
Skyway
Passaic River
Hackensack River
NEWARK
JERSEY CITY
New Jersey Turnpike
Turnpike Bridge
Newark Bay
Upper New York Bay
BAYONNE
Elizabethport Marsh
Elizabeth River
Goethals Bridge
Shooters Island
Constable Hook
Kill Van Kull
Snug Harbor
Bayonne Bridge
ELIZABETH
Morses Creek
Old Place Creek
278
Gulfport Marsh
Piles Creek
Pralls Island
Merrills Creek
Rahway River
Sawmill Creek
Neck Creek
STATEN ISLAND
New Jersey Turnpike
Main Creek
Isle of Meadows
Richmond Creek
Fresh Kills
Tufts Point
Smith Creek
Arthur Kill
Smoking Point
440 (West Shore Expressway)
Woodbridge Creek
Outerbridge Crossing
PERTH AMBOY
Ward Point
Raritan Bay
0 5,000 10,000
Approximate Scale in Feet
LEGEND:
Site of Spill
High Sheen
Low Sheen
No Sheen
LOUIS BERGER & ASSOCIATES, INC.
Oil Sheens Observed In Sediments
FIGURE 6-2

Distribution of Sampling Stations by Impact of Spill

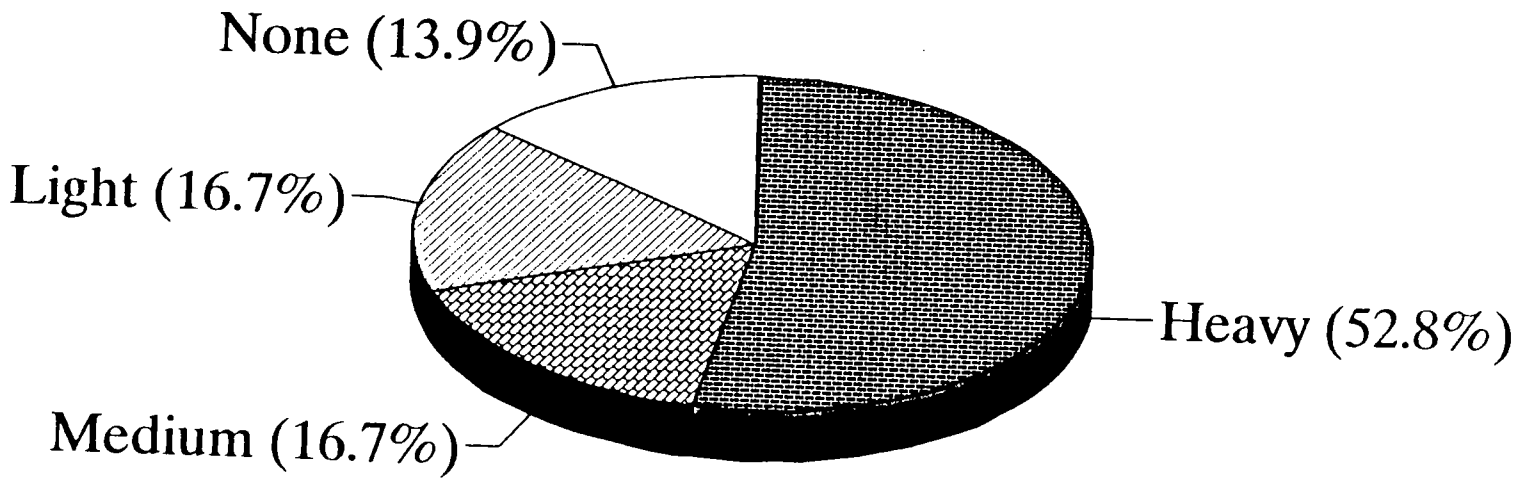
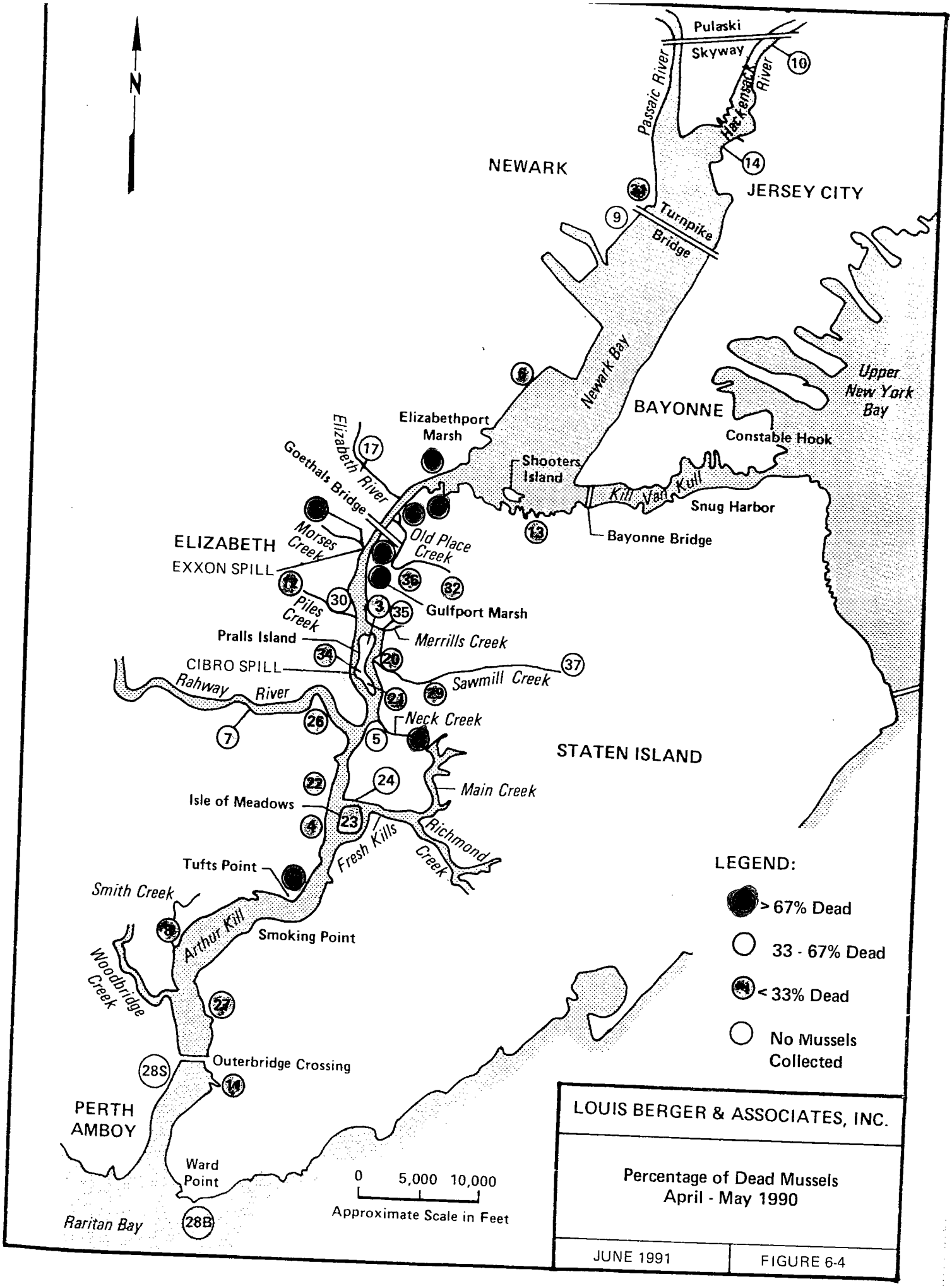
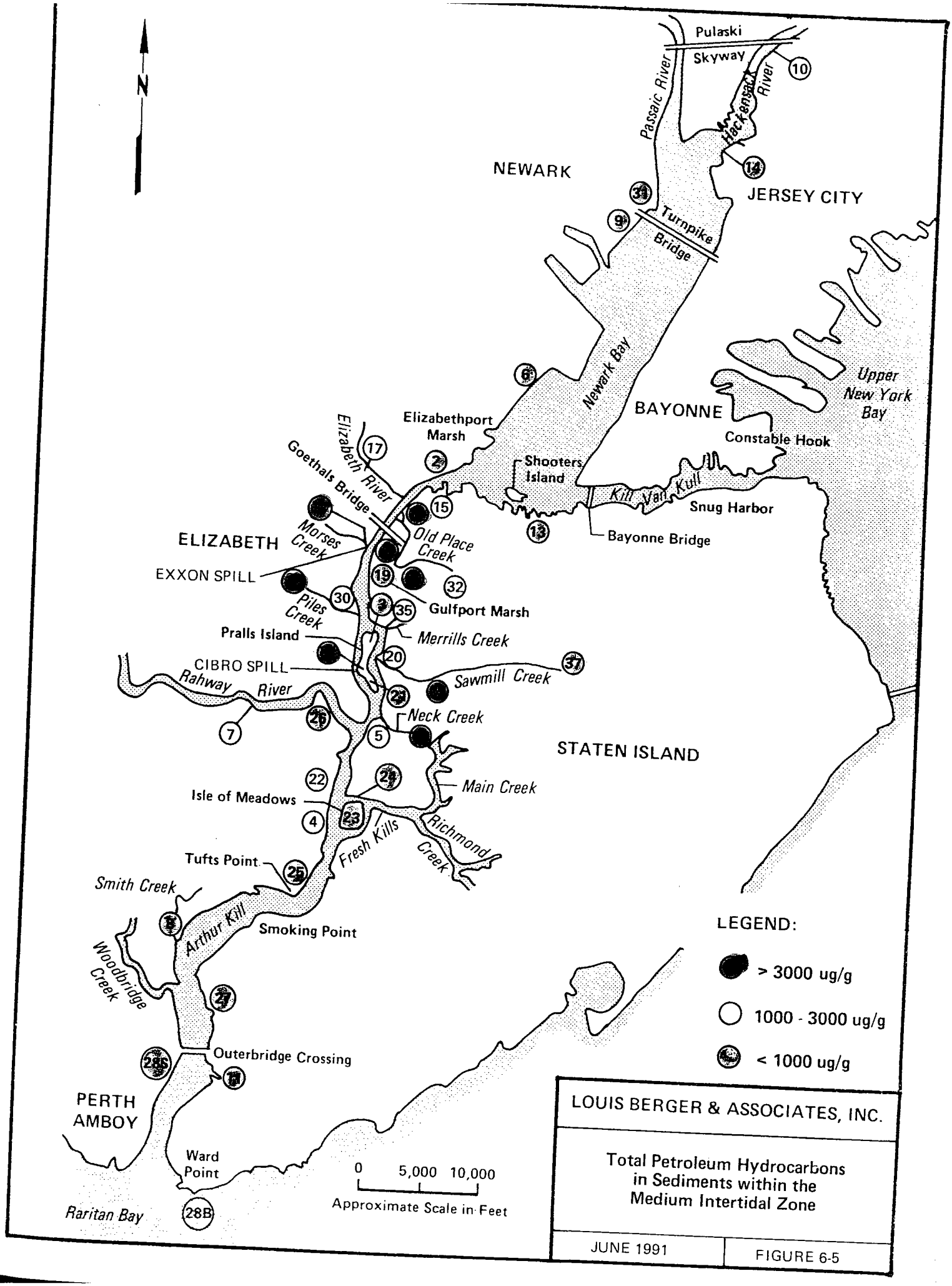
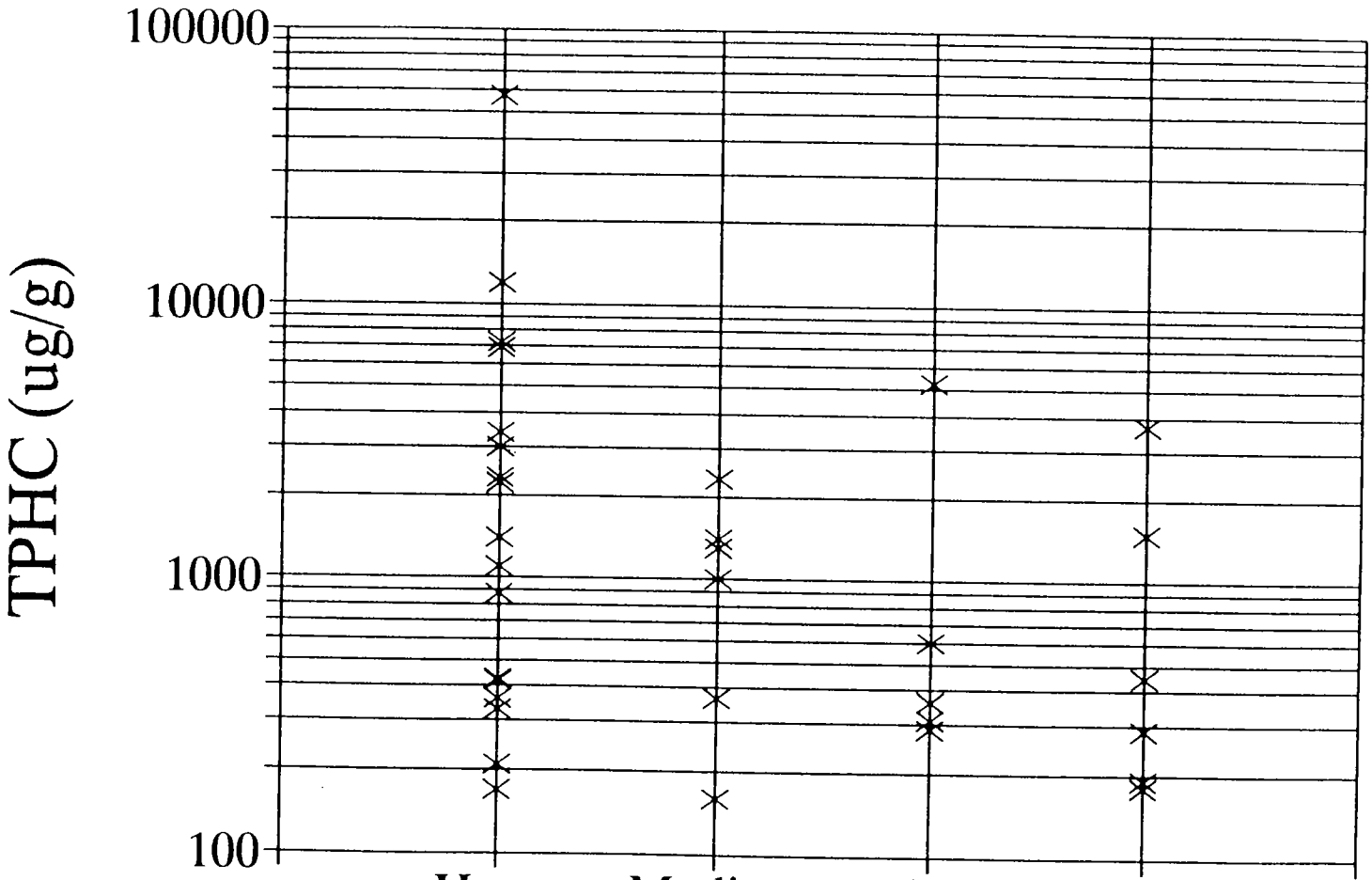


FIGURE 6-3


N
Pulaski
Skyway
Passaic River
Hackensack River
NEWARK
JERSEY CITY
Turnpike
Bridge
Newark Bay
Upper New York Bay
BAYONNE
Constable Hook
Elizabethport Marsh
Elizabeth River
Goethals Bridge
Shooters Island
Kill Van Kull
Snug Harbor
Bayonne Bridge
ELIZABETH
EXXON SPILL
Morses Creek
Old Place Creek
Piles Creek
Gulfport Marsh
Pralls Island
Merrills Creek
CIBRO SPILL
Rahway River
Sawmill Creek
Neck Creek
STATEN ISLAND
Main Creek
Isle of Meadows
Richmond Creek
Fresh Kills
Tufts Point
Smith Creek
Arthur Kill
Smoking Point
Woodbridge Creek
Outerbridge Crossing
PERTH AMBOY
Ward Point
Raritan Bay
0 5,000 10,000
Approximate Scale in Feet
LEGEND:
> 67% Dead
33 - 67% Dead
< 33% Dead
No Mussels Collected
LOUIS BERGER & ASSOCIATES, INC.
Percentage of Dead Mussels
April - May 1990
JUNE 1991
FIGURE 6-4


N
Pulaski
Skyway
Passaic River
Hackensack River
10
NEWARK
JERSEY CITY
14
31
9
Turnpike
Bridge
Newark Bay
6
BAYONNE
Upper New York Bay
Constable Hook
Elizabethport Marsh
Elizabeth River
17
2
Goethals Bridge
Shooters Island
Kill Van Kull
Snug Harbor
15
13
Bayonne Bridge
ELIZABETH
Morses Creek
Old Place Creek
EXXON SPILL
19
32
Piles Creek
30
3
35
Gulfport Marsh
Pralls Island
Merrills Creek
CIBRO SPILL
20
37
Rahway River
Sawmill Creek
21
Neck Creek
26
7
5
STATEN ISLAND
22
24
Main Creek
Isle of Meadows
4
23
Fresh Kills
Richmond Creek
Tufts Point
25
Smith Creek
1
Arthur Kill
Smoking Point
Woodbridge Creek
27
Outerbridge Crossing
28A
11
PERTH AMBOY
Ward Point
Raritan Bay
28B
0 5,000 10,000
Approximate Scale in Feet
LEGEND:
> 3000 ug/g
1000 - 3000 ug/g
< 1000 ug/g
LOUIS BERGER & ASSOCIATES, INC.
Total Petroleum Hydrocarbons in Sediments within the Medium Intertidal Zone
JUNE 1991
FIGURE 6-5

TPHC In Sediments
Medium Intertidal Zone



Mean (Geometric)	1114.01	792.54	634.60	539.91

FIGURE 6-6

Distribution of TPHC In Sediments at the Intensive Sampling Sites

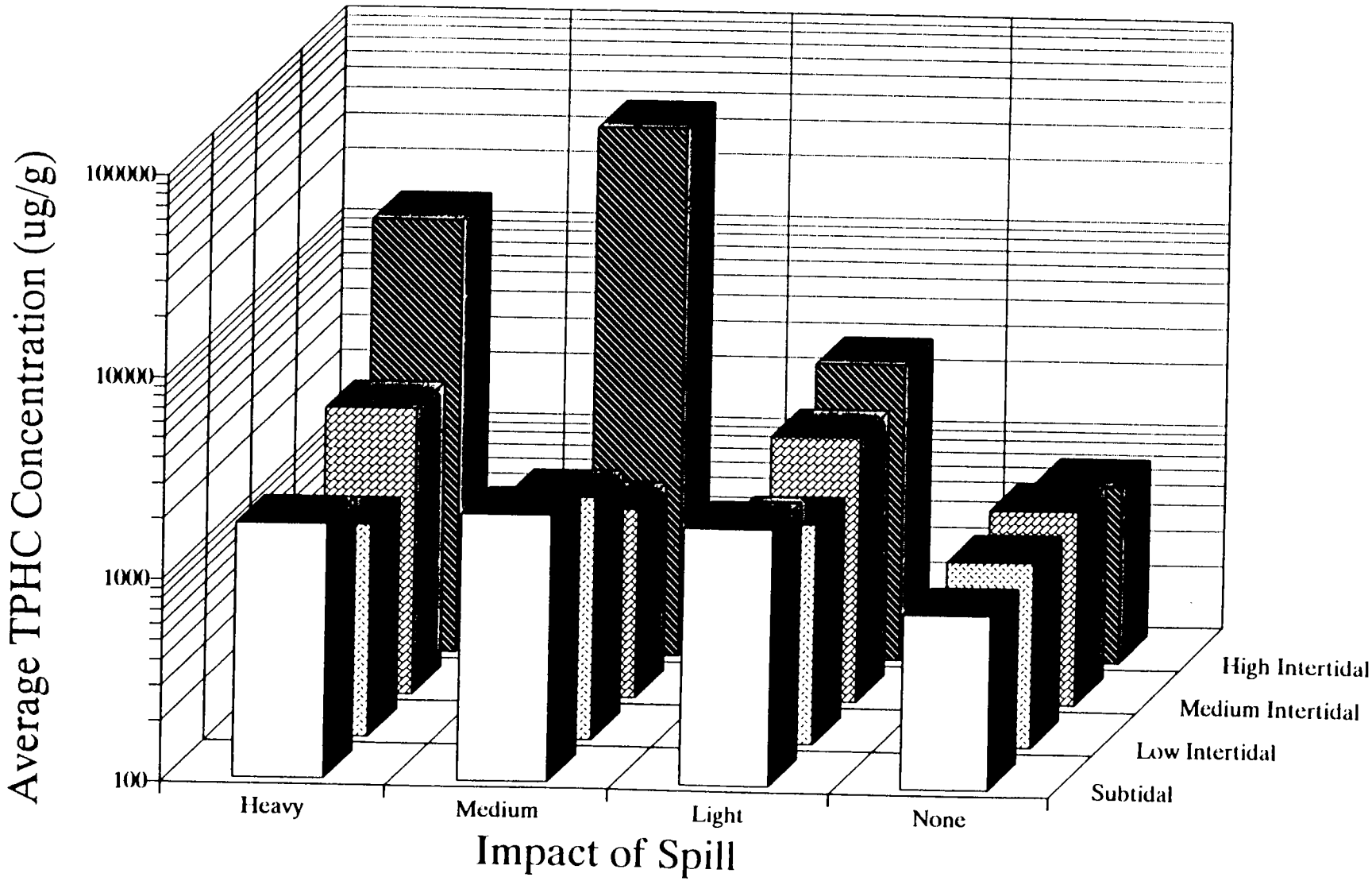


FIGURE 6-7